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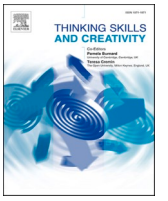

Thinking skills in transdisciplinary curriculum integration: A service-learning project in a Spanish secondary school

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ABSTRACT

Curricular integration based on a transdisciplinary approach poses a significant challenge in secondary education. This study analyses the development of creative thinking, problem-solving and decision-making, collaborative thinking and systemic thinking within a transdisciplinary service-learning project focused on sustainable development. The participants included 192 students and 17 teachers from 12 academic departments in a Spanish secondary school. A concurrent triangulation design was implemented using QUAL+QUAN data for a mixed-methods research approach with the results showing a connection between the explored thinking skills, and how problem-solving and decision-making were characterized by the development of analytical and applicative cognitive processes. Creative thinking in artistic areas was marked by originality and divergent thinking, which contrasted with the convergent and analytical nature of the thinking used in the scientific and mathematical fields. Critical thinking was cultivated through cognitive processes of analysis and evaluation across all areas, both transversally and through continuous feedback during the various activities. Collaborative thinking emerged at an integral level, influenced by the methodological approach. The transdisciplinary approach significantly contributed to the development of systemic thinking, which enabled a comprehensive understanding of complex social and ecological issues. This approach fostered: (1) a world-centered perspective in the various disciplines; (2) the application of knowledge in real-world situations through a practical and experiential focus; (3) creative expression through various forms of communication; (4) the awareness of social and environmental issues, all leading to the proposal of innovative solutions.

1. Transdisciplinary curriculum integration in secondary education

Education is facing a crossroads in responding to the multiple global transformations occurring in posthumanist societies (Braidotti, 2013), which are characterized by complexity, uncertainty and chaos as inherent elements. Curriculum integration offers an opportunity in secondary education to foster a more complex and profound understanding of reality (Burnard et al., 2022). However, the practical application thereof poses significant challenges in teaching as well as institutionally and administratively. This is an issue that has been highlighted for at least 25 years (Weilbacher, 2000). Rooted in the philosophical and pedagogical traditions of progressive

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education and constructivism, Dewey (1916) warned of the excessive compartmentalization of knowledge into separate subjects back in the early 20th century. He advocated linking educational practices to students' experiences, emphasizing the procedural and contextualized nature of education in addressing real-world problems. The application of curriculum integration in secondary education as an umbrella category has allowed a wide range of practices and possibilities from multiple angles and outlooks, depending on a) the subjects involved; b) the depth of the curriculum integration; and c) the educational practices implemented, making it a broad umbrella category (McPhail, 2019). This perspective is supported by competency-based approaches in secondary education curricula, focusing on promoting critical thinking, creativity, problem-solving and cooperative work (Anderson-Levitt & Gardinier, 2021; OECD, 2019)

Curriculum integration in secondary education has been approached through themes with varying levels of specificity, based on concepts such as "big ideas" (Chalmers et al., 2017) or thematic centers (Etim, 2005). The 21st century has seen renewed interest in integrating scientific areas (STEM: Science, Technology, Engineering and Mathematics) (Struyf et al., 2019), along with artistic areas (STEAM: Science, Technology, Engineering, Arts and Mathematics) (Ulbrich et al., 2024; Harris & de Bruin, 2018), and the humanities (STREAM: Science, Technology, Reading, Engineering, Arts and Mathematics) (Sun & Zhong, 2024). The integration of other knowledge areas, such as the arts (Bautista et al., 2016; Lage-Gómez, 2020) and the humanities (Cox et al., 2017), has been explored by various authors.

The transdisciplinary curriculum integration approach developed in the project at hand identifies a series of general principles (Lage-Gómez & Ros, 2021; Lage-Gómez & Ros, 2024). This approach offers a metadisciplinary view that blurs the boundaries between knowledge areas. In this project these include the Humanistic-Social Domain (Classical Culture, Economics and Religion), Scientific-Mathematical Domain (Biology, Mathematics, Physics and Chemistry and Technology) and Artistic Domain (Music, Visual Artes and Physical Education). It emphasizes reflection and a comprehensive understanding of real-world problems in addition to promoting a holistic view of knowledge grounded in general systems theory as an epistemological principle (Martín-Ezpeleta & Echegoyen-Sanz, 2022), which can be concretized in education through systemic thinking. This approach also examines the complexity of knowledge from a holistic angle as a foundational principle. Furthermore, it aims to cultivate committed global citizens to democratic societies (Burnard et al., 2022). From a pedagogical standpoint, curriculum integration turns students into active participants of the teaching and learning processes, addressing their interests, motivation and self-awareness (Bautista et al., 2016). Thus, pedagogical practices are developed in various physical and temporal contexts through different educational agents and methodologies (Martínez Rodríguez et al., 2018). These practices also utilize cross-cutting mediating axes, such as technology (Ulbrich et al., 2024), physical spaces (Carranza et al., 2024), and specific content knowledge (Lage-Gómez & Cremades-Andreu, 2023). For example, curriculum integration has been linked to education for sustainable development in secondary education to address real-world problems, fostering critical thinking, problem-solving, communication and collaboration skills (Carranza et al., 2024; Ulbrich et al., 2024).

In this regard, the literature identifies several learning benefits: (1) it promotes authentic learning through real-world experiences (Chappell et al., 2019); (2) it fosters creative and critical thinking through a multidimensional transfer between different learning areas, addressing both theoretical and practical perspectives of content and specific pedagogies (Harris & de Bruin, 2018); (3) it encourages the development of new learning ecologies that recognize the interconnected roles of emotions, feelings and wellbeing in the learning processes (Arrowsmith & Wood, 2015), in addition to increasing student motivation (McPhail, 2017); (4) it facilitates meaningful learning across various subjects (McPhail, 2017); and (5) it promotes satisfactory learning outcomes (Dowden, 2014). Conversely, potential drawbacks have been identified, including: (1) the need for specific institutional and administrative support to provide material, spatial and temporal resources for implementation (Weilbacher, 2001); (2) the complexity of addressing the theoretical content of the curriculum (Arrowsmith & Wood, 2015); (3) the difficulty of acquiring specific curriculum knowledge from various subjects, which poses a risk of fragmentation, decontextualization and a lack of systematization in learning (Lam et al., 2013; Naidoo, 2010); (4) challenges with regard to assessment in accordance with the standards in effect (Weilbacher, 2000); (5) tensions among teachers related to the importance of collaboration and varying degrees of involvement (Norden, 2018); as well as (6) the complicated nature of balancing the different subjects involved (Bouwmans & Béneker, 2018). McPhail (2017) suggests curriculum integration should be approached after disciplinary work is effectively applied in various contexts, emphasizing the need to provide teachers with additional time and support for implementing teaching and learning processes.

1.1. The classroom in context through service-learning and sustainable development in secondary education

Biesta (2022) emphasizes the ethical and relational dimensions of education, highlighting the importance of establishing a central axis in its meaningful relationship with the world from an existentialist view. This is done by pragmatically seeking to avoid polarization between student-centered and teacher-centered perspectives all while balancing the functions of education, described by Biesta (2022) as: qualification (the transmission of knowledge and skills); socialization (the transmission of values, norms and social practices from the past and present); and subjectification (fostering autonomy and the ability to think and act independently and consciously).

In this project, we proposed a complex approach to understanding the world by repositioning learning spaces in a natural environment near the secondary school of great environmental and historical value. The aim was to create a metaphor for the world around us through multiple landscapes with a clear purpose: care and reconstruction. This perspective was linked to service-learning (SL), which is understood as a pedagogical method that extends the scope of teaching and learning beyond the classroom (Camilli-Trujillo et al., 2022). While there is a wide variety of SL designs and projects that expand the field of action based on key components such as learning, service, needs, collaboration and reflection in real-world contexts (Deeley, 2016), the impact on secondary education remains limited (Singer, 2023). Rooted in the Deweyan tradition, SL pursues several fundamental objectives (Maguire, 2016): a)

providing some type of service to the community to improve some aspect thereof; b) linking the service to curricular objectives; c) promoting participation and social commitment; d) generating meaningful experiences connected to processes of reflection and critical thinking; and e) promoting students' voices as active subjects. From this point of view, sustainable development in education through SL is of an ethical transdisciplinary nature (Martínez-Agut, 2022).

1.2. Thinking skills through transdisciplinary curriculum integration in secondary education

Building on the classic categorizations mentioned by authors such as Bloom (1956) and Guilford (1967), who identified a series of cognitive processes—remembering, understanding, applying, evaluating and creating—, Presseisen (2001) grouped these categories and proposed four complex thinking processes applicable to educational practice: a) problem-solving; b) decision-making; c) critical thinking; and d) creative thinking. Problem-solving and decision-making are concepts that were introduced in the field of education by John Dewey and Lev Vygotsky in the late 19th and early 20th centuries. Considering the multiple meanings described in the literature (Crilly, 2024), problem-solving in secondary education settings involves situations that students must resolve using their own resources, activating their awareness of the particular situation and facilitating subsequent decision-making (Dostál, 2015). Initially, there is an understanding of the problem where the individual is able to recognize their lack of knowledge or strategies for addressing it. After this, the student analyzes the situation, mobilizing cognitive, motivational and emotional aspects that help with problem resolution (Funke, 2010; Tasgin & Dilek, 2023). Critical thinking is described as one of the most prevalent thinking skills in educational literature (Crilly, 2024), representing a cognitive process in which secondary school students devise concepts, apply, analyze, synthesize and evaluate information that has been collected (Moon, 2007). It focuses on establishing relationships between concepts and drawing conclusions by evaluating the information received (Cottrell, 2017; Elen & Verburgh, 2023). Creative thinking skills are described as the ability to generate new and original ideas, or new solutions and apply them to various contexts and situations (Saeed & Ramdane, 2022). Lubart and Thornhill-Miller (2019) describe creative thinking through the cognitive and conative dimensions of the creative thinking skills. The cognitive dimension is characterized by convergent-divergent duality, as well as analytical, associative, flexible thinking and knowledge. The conative traits include openness to new experiences, risk taking, tolerance to ambiguity, creative self-concept and intrinsic motivation. From a historically-rooted sociocultural perspective, Glăveanu, 2018 identifies three distinct routes in the development of creative action (Glăveanu & Beghetto, 2021): (1) the scientific route, characterized by convergent, analytical thinking and problem-solving; (2) the artistic route, marked by divergent, spontaneous and original thinking; and (3) the artisanal route, associated to the creation of everyday objects and the manipulation of tools. This perspective facilitates a plural approach to creativity in the curriculum, while also enabling the complex connection among the nature of the various thinking skills.

In developing these thinking skills, collaborative thinking not only enhances problem-solving thinking skills but also fosters critical and creative thinking. This aligns with the social nature of learning and its significance in cognitive development, largely emphasized by Vygotsky (1978). In this context, Dillenbourg and Fischer (2007) highlight the role of collaboration in the shared construction of knowledge, which involves a shift in participants' perspectives through dialogue. Consequently, the enhancement of deeper thinking skills, such as problem-solving and critical analysis, is supported when students engage in authentic environments and collaborate. All of the aforementioned thinking skills activate systemic thinking, conceived as a cognitive paradigm of interconnected components interactingwith one another to make up a dynamic whole (Randle & Stroink, 2018). This approach is explicitly linked to the transdisciplinary integration methodology developed in the project at hand, focused on systemic thinking for a better understanding of social and ecological problems (Bosh et al., 2007).

Based on the literature review, this article presents a transdisciplinary SL project that integrates a transdisciplinary curriculum integration approach linked to SL for sustainable development. This proposal encompasses an integrated, global and balanced perspective to various scientific-mathematical, humanistic-social and artistic areas for the purpose of gaining an in-depth understanding of the development of creative thinking, problem-solving and decision-making, critical thinking, collaborative thinking and systemic thinking, all while answering the following research questions:

- Which distinctive features of transdisciplinary integration were evidenced in the evolution of the project's teaching and learning processes?
- What was the impact of the learning spaces on the service-learning transdisciplinary project for sustainable development?
- How were the various thinking skills under analysis engaged and how did they interact throughout the project?

2. Method

The study integrates three distinct purposes of educational research from a pragmatic standpoint (Biesta, 2020): explanation, understanding and emancipation. It aims to propose a balanced approach between identifying thinking skills in the activities implemented and explaining the interrelationships thereof so as to achieve a deep understanding of curriculum integration in context and adopt a transformative social outlook through the service-learning project. We implemented a mixed-method approach based on a concurrent QUAL+QUAN design (Creswell & Creswell, 2018), involving students, teachers and researchers. The qualitative perspective, focused on the epistemological principle of practitioner research, was integrated from a complementary approach (Johnson & Onwuegbuzie, 2004), along with a quantitative perspective based on statistical descriptive analysis in order to gain profound insight into the interrelationships between the different types of thinking skills through a transdisciplinary service learning project at a secondary school in Alcalá de Henares (Madrid, Spain).

2.1. Context and participants

This research was conducted at a public secondary school in Alcalá de Henares, Spain, where compulsory secondary education (ESO, as it is known in Spanish) and baccalaureate studies are offered. The school is located near the Henares River, which forms a meandering landscape as it passes through the city. Nestled along the banks of the river is an island known as *Isla de los García*. Of major ecological value, this area is also home to significant archaeological, historical and cultural heritage. In this context, this landmark is conceptualized as an additional teaching and learning space in the city and was used as an essential educational resource for the development of the project implemented in this study.

The school caters to a highly heterogeneous population as concerns various aspects: academic, personal, socio-familial and socio-economic. It welcomes students of 19 nationalities other than Spanish, representing 21 % of the total number of students.

A total of 17 teachers (11 women, 64.7 %, and 6 men, 35.3 %) from 12 different pedagogical departments voluntarily participated in the study. Additionally, 192 students (88 girls, 45.8 %, and 104 boys, 54.2 %) from the 2nd, 3rd and 4th years of ESO and the 1st year of baccalaureate, aged 13 to 18 ($M_{Age} = 14.61$), participated as well. Two teacher-researchers and two university researchers in the field of education were also involved.

2.2. Instruments

An *ad hoc* questionnaire was designed, informed by a previously validated Service-Learning questionnaire (León-Carrascosa et al., 2020). This questionnaire was structured around three dimensions: a) curriculum integration; b) contextualized classrooms; and c) sustainable development. Each dimension included specific indicators of critical thinking (Elen & Verburgh, 2023), creative thinking (Lubart & Thornhill-Miller, 2019), and problem-solving and decision-making (Tasgin & Dilek, 2023), which have an implicit relationship with the educational practices utilized in the project and are related to the items on the questionnaire, as described by Bloom (1956) and later adapted to the field of education by Presseisen (2001). Collaborative thinking (Dillenbourg & Fischer, 2007), and systemic thinking (Fazey, 2010) were considered transversal in the project as a whole. Participants responded to the questionnaire items using a Likert scale, where 1 = almost never and 5 = almost always.

To assess construct validity, the Kaiser-Meyer-Olkin (KMO) sample adequacy test was performed, yielding a value of 0.935, indicating excellent sample adequacy for factor analysis. Additionally, Bartlett's test of sphericity proved to be statistically significant ($\chi^2 = 1909.813$, $df = 136$, $p < 0.001$), confirming the suitability of exploratory factor analysis. Regarding the total explained variance, the analysis identified three main factors which, together, explain 64.73 % of the total data variance. This indicates that the resulting factor structure represents the three theoretical dimensions established in the questionnaire. The internal reliability of the instrument was evaluated using Cronbach's alpha coefficient, which yielded a value of 0.935, reflecting excellent internal consistency and high coherence among the items. It was conducted at the end of the project, and the approximate completion time for the questionnaire was 15 min.

Throughout the transdisciplinary SL project, qualitative participant observation (Angrosino, 2012) was done by the 17 teachers during their respective class activities and was recorded in their class diaries, which were structured according to the project's dimensions.

Semi-structured interviews (Brinkman, 2012) were conducted at the end of the project with all the teachers to facilitate joint reflection based on the project's dimensions. Additionally, three semi-structured interviews were carried out with a total of 17 students at the end of the project in 2021. These students participated voluntarily in gender-balanced groups, which were diverse both academically and socio-culturally. Five of the students were from the 2nd year of ESO, seven from the 3rd year of ESO and five from the 4th year of ESO. For the curriculum integration dimension, discussions focused on the content covered across different subjects and the connection established by the students. In relation to the contextualized classrooms dimension, the students' reflective perspectives and evaluations of the project activities that took place in the *Isla de los García* natural space, along with the implications for learning were explored. Finally, the sustainable development dimension addressed how the project promoted the importance of caring for the environment near the school.

Fig. 1. The Isla de los García natural space.

2.3. The transdisciplinary service-learning project

The project represents the starting point for an integrated approach to knowledge, developed complementarily and in parallel to disciplinary work. It was designed within a multidimensional framework that encompasses both vertical development—allowing for progressive advancement within a single discipline across different levels—and horizontal development—facilitating simultaneous connections among various disciplines at the same educational level. Designed during the first term of the academic year 2020/21, it was implemented during the second and third term.

The project is structured around the objective of reclaiming and transforming the immediate environment through diverse actions, with the wealth and value of the *Isla de los García* natural space serving as a central reference point (see Fig. 1). It was used as a transversal axis to connect multiple disciplines so as to foster contextualized and meaningful learning. In view of this thematic axis, the concept of "landscape" was explored in-depth across various domains of knowledge (scientific, humanistic-literary, artistic and social) and from a global perspective (ecology and the environment, health and physical and emotional well-being).

The artistic domain (art, music and movement) was integrated with an artistic creation process through group improvisation centered on the concept of soundscape (see Fig. 2). Additionally, a sound map of the *Isla de los García* natural space was created. The abstract creation of visual landscapes inspired by the environment under exploration was the foundation for a creative embodied process focusing on the creation of music.

The humanistic and social domain was reflected in the study of landscape as a recurring theme in literature. For instance, the Spanish Language Department proposed an analysis of the works of three authors—Antonio Machado, Miguel Delibes and Claudio Rodríguez —aiming to identify areas of the *Isla de los García* natural space that might have inspired these writers. The creation and re-creation of legends associated to it provided the basis for transitioning from oral storytelling to written narratives. This also served as a starting point for working with oral sources, constructing historical knowledge through interviews conducted by students with residents connected to this space. This dimension of knowledge was integrated into the work of other departments such as Geography and History, which analyzed the landscape by distinguishing between physical and human elements. As concerns physical elements, the geographical evolution of the landscape was examined, including relief, vegetation, soil and climate. In terms of human elements, historical human activities in this space were studied, along with potential future outlooks for the landscape, including the possibilities for new uses. Linked to the analysis of uses and prospects for this area, the Economics Department incorporated content on environmental economics and sustainable development, generating proposals for critical analysis and reflection by students on the future of this exceptionally rich landscape, all while emphasizing the need for sustainable development and changes to the current consumption model (See Fig. 3). The Classical Culture Department had students identify the scientific Latin names of the fauna and flora found on *Isla de los García* and investigate the etymology of these names, linking them to the corresponding living beings.

The handling of all these topics was enriched with insights from various fields, particularly in the scientific-mathematical domain. Departments such as Biology and Geology explored aspects related to geomorphology, flora, fauna and the ecology of the island (See Fig. 4). This exploration prompted students to develop and present proposals in the form of murals, models and video presentations aimed at the sustainable revitalization of the area. A key point of intersection in the content was established with the Physics and Chemistry Department, which focused on noise pollution and its impact on health and the environment. Activities were planned to measure sound intensity levels using various tools, including sound level meters and mobile device apps, at different locations on *Isla de los García*. The Mathematics Department used this environment as a teaching resource to apply principles of similarity to height calculations. This type of work was also done in Biology. The Technology Department planned to create an audiovisual summary of the project showcasing various landscapes, including soundscapes and artistic expressions (art, music, movement, linguistic expression and literary contemplation), as well as historical, economic, environmental, social, technological and physical contexts. They also aimed to organize a multimedia repository featuring significant places and spaces on *Isla de los García*. Although the work planned by this department could not be fully completed, it nevertheless provided technical and technological support for the proposals from other departments.

The Guidance Department integrated work on proper co-existence by facilitating group dynamics and using this environment to

Fig. 2. Artistic creation in the transdisciplinary-SL project.

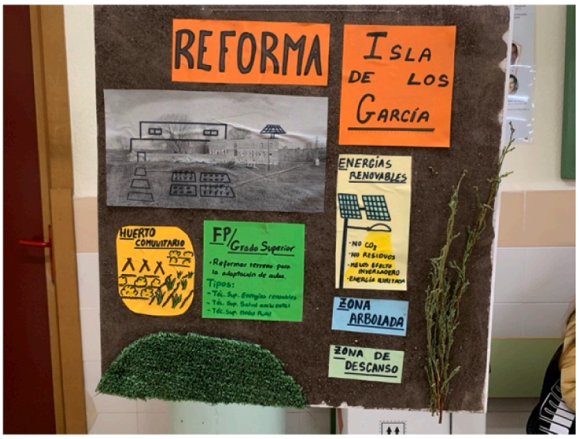

Fig. 3. Sustainable development in the transdisciplinary SL project.

Fig. 4. Flora and fauna found on the island Isla de los García.

conduct various activities and proposals that encouraged caring for it and appreciating it. Another element included was the introduction of different relaxation techniques across all grade levels, utilizing the real sounds of nature from this environment for this purpose.

2.4. Procedure

In relation to the first research question exploring how transdisciplinary integration was implemented in the SL transdisciplinary project, participant observation—as recorded in the 17 teachers' diaries during the project—was triangulated with the curricular integration dimension and the indicators (critical thinking, creative thinking, problem-solving and decision-making, collaborative thinking and systemic thinking) on the questionnaire completed at the end of the project along with a discursive analysis of the semi-structured group interviews with students and teachers. As concerns the second research question, which attempts to understand the influence of utilizing diverse environments in teaching and learning processes, participant observation was triangulated with the contextualized classrooms and sustainable development dimensions, the indicators on the questionnaire and the discursive analysis of the semi-structured group interviews with students and teachers.

In order to answer the third research question, the activities carried out in the project were categorized by authors 1 and 2 based on the cognitive processes proposed by Bloom (1956) and the relevant thinking skills, including problem-solving, decision-making, critical thinking and creative thinking. Consistent with the literature, problem-solving and decision-making were grouped into a single category. In subsequent analyses, systemic thinking and collaborative thinking were also included. Categorization was qualitatively implemented by using the participant observations recorded during the project and the design of each activity prepared by the teachers. Following discussions between the two teacher-researchers, the percentage of agreement reached 90 %.

2.5. Ethical considerations

The study was conducted with the approval of the school's administrators and all participants—including students and teachers—provided their informed consent for audio recordings and questionnaires after receiving all relevant information. Additionally, the anonymity and confidentiality of both the participants and the institution were ensured in accordance with the ethical research guidelines established by the Complutense University of Madrid.

3. Results

To address the research objectives, data coding and triangulation were performed from a deductive-inductive approach and were supported by the theoretical and pedagogical perspectives developed in the framework of the study.

3.1. Transdiscipinary curricular integration in the project

The questionnaire results for the curricular integration dimension indicate that students established a strong connection between the content in the various subjects (I1). This integrated transdisciplinary approach facilitated a deeper understanding of the content areas (I5). Additionally, students found the transdisciplinary approach motivating (I3) (See Table 1).

The average scores given by the students hover around 4 across all indicators, suggesting that they perceived consistent improvements in critical thinking (I1, I5), creative thinking (I2), and problem-solving (I3, I4). The average scores from the teachers were consistently higher than those from the students. The only exception was the critical thinking indicator in item 1, which refers to the relationship between the project content and the subjects. In this case, the teachers' scores were around 5, reflecting improvements in all the indicators and items analyzed. This contrast can be explained by the perceptions of the coherence and effectiveness of the pedagogical approaches implemented in relation to the learning objectives. These approaches foster conceptual understanding and assess the comprehensive progression of the achieved outcomes as opposed to a more experiential and hands-on approach.

Given the type of sampling, which was based on convenience, and the size of the sample obtained, the assumption of normality was not met; therefore, non-parametric tests were performed. Consequently, due to the lack of normal distribution in the data, a *Mann–Whitney U* comparison analysis was conducted between the students that were more highly involved in the project and those who were less involved. This analysis revealed statistically significant differences in all indicators and items within this dimension. In each case, the average rank scores were higher for the group of students who were more highly involved in the project development. Specifically, a small effect size was observed for item I1 related to the critical thinking indicator ($RP_{Higher\ Involvement\ Group}$= 50.28, $RP_{Lower\ Involvement\ Group}$= 38.98, U = 719.000, Z= −2.219, p= .026, r = 0.24), and item I4 related to the problem-solving indicator ($RP_{Higher\ Involvement\ Group}$= 50.79, $RP_{Lower\ Involvement\ Group}$= 38.49, U = 697.000, Z= −2.797, p= .018, r = 0.25). Conversely, a medium effect size was found for item I2, the creative thinking indicator ($RP_{Higher\ Involvement\ Group}$ = 51.90, $RP_{Lower\ Involvement\ Group}$= 37.43, U = 649.500, Z= −2.797, p= .005, r = 0.30), item I3 related to problem-solving ($RP_{Higher\ Involvement\ Group}$= 53.21, $RP_{Lower\ Involvement\ Group}$= 36.18, U = 593.000, Z= −3.311, p< .001, r = 0.35), and item I5 related to the critical thinking indicator ($RP_{Higher\ Involvement\ Group}$= 55.38, $RP_{Lower\ Involvement\ Group}$= 34.10, U = 499.500, Z= −4.064, p< .001, r = 0.43).

The collective interviews provided a forum for reflection on the project so the students could explore the connections between the content addressed across the various subjects. Given the project's focus on *La Isla de los García* and its diverse landscapes, when asked, "How have you connected the content worked on in the different subjects?" (Teacher, collective interview, 3rd-year ESO, June 2021), one student (3) requested clarification asking whether the question meant "in the subject or between the subjects". She then explained how, in Geography, "it was always about how things were before, what has changed and why it has changed". Similarly, 4th-year ESO students highlighted the connection to "sustainable development, which is why it was linked to plant care and what could be done to improve the planet" (Student 1, collective interview, 4th-year ESO, June 2021). This reflects a systemic approach to knowledge through problem-solving and decision-making, as well as the transversality of critical thinking. Regarding inter-subject connections, another student noted "the changes, in history or in sound," as a common element, demonstrating the significance of learning based on a metacognitive approach to systemic thinking. In this context, one student emphasized that "we have seen different facets of the same thing" (Student 4, collective interview, 3rd-year ESO, June 2021). The boundaries between knowledge domains became blurred with

Table 1
Descriptive statistics of the responses provided by students and teachers to the items for the Curricular Integration dimension.

INDICATOR	Items	$\bar{X}_{students}$	σ	$\bar{X}_{teachers}$	σ
Critical Thinking	I1. I have been able to establish connections between the content of different subjects.	3.68	.891	3.71	.588
Creative thinking	I2. I found it motivating to work on the project's content across various subjects.	3.63	1.045	4.47	.624
Problem Solving	I3. I have gained a better understanding of the content by approaching it from multiple subjects.	3.61	.954	4.35	.786
Problem Solving	I.4 The development of the project has allowed me to better understand the content I have learned in different subjects.	3.65	1.002	4.53	.624
Critical Thinking	I 5. The project has enabled me to delve deeper into the content covered	3.54	1.092	4.53	.800

Note: $N_{students}$=192, $N_{teachers}$= 17; 1= Hardly ever, 5= Very frecuently.

La Isla de los García used as the thematic and structural axis for various activities across subject areas. Although the questionnaire scores for the integration dimension were high and students perceived themselves as active participants, the teachers simply focused on delivering specific subject content after the project was designed.

Given the complexity of the design and implementation, the teachers highly valued the opportunity to work with an integrated and collaborative approach. They also identified areas for improvement, such as enhancing the depth of curricular integration through flexible scheduling to allow multiple teachers from different subjects to share sessions with groups. Additionally, improving the collaborative monitoring of various activities and final products was emphasized. One teacher noted, "I have tried to create projects for them to work on together, but I haven't found that cohesion. I have found many things done individually." (Teacher 1, collective interview, June 2021). Another teacher pointed out the challenge of "trying to arrange a weekly meeting or a way to coordinate what everyone else was doing to avoid overlaps and to enrich each other" (Teacher 2, collective interview, June 2021). Given this concern, once the initial design was established by the entire teaching staff, teacher coordination took place informally or within the various subject departments. The complications mentioned by the teaching staff regarding project coordination and joint implementation can be explained by the school's organizational structure and the inherent framework of the secondary education curriculum. Despite these challenges, the initiative was viewed as a positive starting point for consolidating a transdisciplinary approach to teaching and learning processes.

3.2. Sustainable development through the transdisciplinary service-learning project on La Isla de los García

The service-learning project focused on reappraising the significance of the *La Isla de los García* area. By developing a deeper understanding of this environment, the project aims to foster the future preservation thereof while simultaneously placing it at the heart of teaching and learning processes.

The activities conducted on *La Isla de los García* were highlighted as an innovative aspect of the project (A6), underscoring its capacity to foster practical, hands-on learning and connect in-classroom experiences with out-of-classroom ones (A2, A4). Furthermore, the project demonstrated its significant educational value by establishing a clear and effective connection with the formal curriculum contents (A1, A3, A5) (See Table 2).

Similar to the Curricular Integration dimension, the mean scores for the teachers' opinions were higher than those given by the students across all items for this dimension. The items under the creative thinking indicator received the highest mean scores, while the item associated with the problem-solving indicator showed the lowest mean.

The *Mann-Whitney U* comparison analysis between students who participated more in the project and those who were less involved yielded statistically significant results for the following items: A2 on problem-solving ($RP_{Higher\ Involvement\ Group}$= 49.81, $RP_{Lower\ Involvement\ Group}$= 39.42, U = 739.000, Z= −1.982, p= .047, r = 0.21); item A3 on creative thinking ($RP_{Higher\ Involvement\ Group}$= 49.73, $RP_{Lower\ Involvement\ Group}$= 39.50, U = 742.500, Z= −1.968, p= .049, r = 0.21); and item A4 on problem-solving ($RP_{Higher\ Involvement\ Group}$= 50.05, $RP_{Lower\ Involvement\ Group}$= 39.20, U = 729.000, Z= −2.078, p= .038, r = 0.22). The average rank scores in these cases were higher for the group of students more highly involved in the project, with a small effect size.

On the other hand, significant results with a medium effect size were found for the item linking project activities to course content under the critical thinking indicator ($RP_{Higher\ Involvement\ Group}$= 54.33, $RP_{Lower\ Involvement\ Group}$= 35.11, U = 545.000, Z= −3.749, p< .01, r = 0.40) and the item regarding the project originality ($RP_{Higher\ Involvement\ Group}$= 52.35, $RP_{Lower\ Involvement\ Group}$= 37.00, U = 630.000, Z= −3.024, p= .002, r = 0.32), which fall under creative thinking. In both cases, the higher scores corresponded to students who were more highly involved.

Almost unanimously, the students emphasized this was the first time they had worked on an educational project of this nature. This was explained in two ways: firstly, the visits to *La Isla de los García*, where project-specific activities were conducted for each subject; and secondly, the pedagogical approach based on more practical and collaborative methods in most subjects, as mentioned by one student during the 2nd-year ESO group interview. The development of collaborative thinking was therefore evident throughout the project, transcending all subjects. While the use of *La Isla de los García* as a pedagogical resource had a positive impact, one student and one teacher expressed a sense of fatigue due to the constant outings across different subjects during the group interviews. This reveals a need for better coordination among those involved (Teacher 1, group interview, June 2021).

Table 2
Descriptive statistics of the responses provided by students and teachers to the items for Classrooms in Context.

INDICATOR	Items	$\bar{X}_{students}$	σ	$\bar{X}_{teachers}$	σ
Critical Thinking	A1. The learning experience has been useful for my personal development.	3.40	1.073	4.76	.437
Problem Solving	A2. I have acquired practical knowledge through the project developed. the classroom.	3.49	1.039	4.71	.588
Creative Thinking	A3. I have learned in new contexts through the activities carried out on García Island.	3.60	1.059	4.88	.332
Problem Solving	A4. I have connected the activities carried out on García Island with the activities developed in the classroom.	3.65	1.058	4.41	.795
Critical Thinking	A5. The activities carried out on García Island have been related to the content of the subjects.	3.96	1.127	4.65	.862
Creative Thinking	A6. The project has been original and different from other experiences	4.18	.967	4.82	.393

Note: $N_{students}$=192, $N_{teachers}$= 17; 1= Hardly ever, 5= Very frecuently.

Additionally, the usefulness of the activities on *La Isla de los García* for understanding the content covered was noted. One student remarked, "It helped us when we had to calculate the height; later, we had a similar exam on the Pythagorean theorem, where we had to calculate the height. When we studied the Pythagorean theorem, it was about figuring out the length of a triangle." (Student 6, 2nd-year ESO group interview, June 2021). Similarly, the value of working on content "in situ" was emphasized, noting it facilitated comprehension: "Doing it up close, being able to listen without technology, in its natural state." (Student 7, 3rd-year ESO group interview, June 2021). Students highlighted the importance of context in developing problem-solving skills.

In summary, one student stated, "It has been a very interesting experience; it was super interesting to go out and learn more about that place because we had always heard about it but did not know the history behind it. Basically, super interesting." (Student 8, 3rd-year ESO group interview, June 2021).

The applied and transformative nature of the learning experience was emphasized (S1, S6), with participants acknowledging the need for environmental stewardship and improvement through direct action. Furthermore, the results reflect the development of a proactive and creative mindset toward sustainability (S2, S4), particularly in relation to transforming the school environment and fostering ecological awareness. Finally, they demonstrate a critical understanding of the relationship between the school and its surroundings (S3, S5)—specifically, the capacity to connect environmental realities with educational practices (See Table 3).

As shown in the table above, the mean scores provided by students are around 4, indicating that the statements included in the dimensions were consistently relevant to them. The highest scores were recorded for items related to raising awareness about environmental care (systemic thinking) and the project's contributions to enhancing this idea (problem-solving). Much like the previously mentioned dimensions, teachers assigned higher scores than students across all indicators, with values around 5. Notably, the highest mean scores coincided with the same items highlighted by the students.

The results obtained through the *Mann-Whitney U* test revealed that only the item related to the need to reflect upon caring for the natural environment of *La Isla de los García*, included in the problem-solving indicator showed a significant difference ($RP_{Higher\ Involvement\ Group}$= 51.08, $RP_{Lower\ Involvement\ Group}$= 38.21, $U = 684.500$, $Z = -2.475$, $p = .013$, $r = 0.26$). Although the effect size was small, the results indicate that students who participated more in the project achieved a higher average rank than those who were less involved.

Throughout the project sessions and in the group interviews conducted with students, a certain lack of knowledge about the thematic focus of the project was observed. Many students were unaware of its name or most of its defining characteristics. For example, it was common to hear statements such as, "I knew the area, but not that it was called *La Isla de los García*." (Student 8, 2nd-year ESO group interview, June 2021). Similarly, during the group interview with teachers, the project's strength in building connections with the environment—and consequently with the school—was highlighted: "I believe that it does succeed in establishing links with the area, with the territory and I think that, in the end, it has partly succeeded in making people think about the territory and about the area, which is already a way of building a connection." (Teacher 3, group interview, June 2021). This reflects a bit of a shift in the students' perspective or focus. "On the other hand, I believe we are connecting the school with the neighbors[…] I think it is a way of building bridges." (Teacher 3, group interview, June 2021). This highlights an implicit connection between the development of the project and environmental care, which 2nd-year ESO students noted had been explicitly addressed in some subjects, underpinning the idea as one of the project's pillars. Furthermore, the creation of bonds emphasized by some of the teachers fosters proper student co-existence and the development of social skills. All of this is achieved through the comprehensive connection of all participants with nature at cognitive, spiritual, physical and sensory levels. This represents the most profound level of transdisciplinary integration where knowledge, reflection and action converge toward a common purpose: the development of critical and responsible environmental awareness. The results for sustainable development confirm that the project succeeded in transcending mere curricular integration to generate processes of critical reflection and creativity as well as an ethical commitment to the environment. Within this framework, the environmental dimension works as the synthesis and practical application of the skills developed in the preceding phases.

Table 3
Descriptive statistics of the responses given by students and teachers to the items for the Sustainable Development dimension.

INDICATOR	Items	$\bar{X}_{students}$	σ	$\bar{X}_{teachers}$	σ
Problem Solving	S1. The project has made me reflect on the need to value and care for the environment of García Island.	3.98	1.107	4.59	.712
Creative Thinking	S2. The project has made me aware of the need to transform the school's surroundings.	3.92	1.025	4.47	.800
Critical Thinking	S3. I have become aware of the need to connect the reality of the environment with the school.	3.89	1.004	4.59	.618
Creative Thinking	S4. The project has increased my sensitivity toward sustainable development.	3.56	1.101	4.53	.800
Critical Thinking	S5. The project has helped me become aware of the importance of caring for the environment.	4.07	1.024	4.76	.562
Problem Solving	S6. I believe the project can contribute to improving environmental care.	4.10	.913	4.65	.493

Note: $N_{students}$=192, $N_{teachers}$= 17; 1= Hardly ever, 5= Very frecuently.

Table 4
Identification of problem-solving, critical thinking and creative thinking skills in the activities.

Area	Subject	Problem-Solving and Decision-Making	Critical Thinking	Creative Thinking
ARTISTIC	Music	Adapting group improvisation to sounds and techniques to align with visual artworks	A relationship between musical and visual elements Analyzing soundscape and its connection to music	Group improvisation based on visual images Creating a soundscape inspired by natural sounds
	Art	Exploring different visual forms to represent sounds	Reflecting upon iconicity and abstraction in visual representation	Experimenting with graphic techniques to express emotions
	Physical Education	Adapting dance to spatial and expressive parameters	Creating a choreography based on elements of *La Isla de los García*	Creating a choreography based on elements of *La Isla de los García*
HUMANISTIC-SOCIAL	Classical Culture	Identifying scientific names and their meanings	Evaluating Latin as a scientific language and its importance in taxonomy	Making connections between etymology and the characteristics of living beings
	Economics	Searching for measures to reduce environmental impact	Analyzing the impact of consumption on sustainability	Proposing innovative solutions for a sustainable consumption model
	Social Sciences	Comparing landscapes using repeat photography and environmental analysis	Assessing the human impact on the environment and the use of historical sources	Creating digital cartography using past and present images
	Spanish Language (4th-year ESO)	Organizing and structuring an audiovisual project	A literary analysis of the landscape as a symbol and its representation in literature	Creating video poems inspired by literary landscapes
	Spanish Language (2nd-year ESO)	Creating and adapting written and oral narratives	Studying the origin and evolution of oral legends	Creating and reworking local legends
	Religion	Reflecting upon specific ways to collaborate in environmental conservation Proposing individual and collective solutions for respecting and caring for nature	Developing critical awareness of the impact of human actions on the environment	Artistic expression through collage using images of nature Writing inspirational messages about nature linked to The Canticle of the Creatures by Saint Francis of Assisi
SCIENTIFIC-MATHEMATICAL	Biology 1	Identifying different species and their environmental impact	Analyzing the relationship between environmental sounds and emotions/health	Developing experimental proposals for environmental studies
	Biology 2	Drawing up proposals for the sustainable revitalization of space	Analyzing the geological evolution of the island	Creating models, murals and videos
	Mathematics	Applying mathematical principles in real-world contexts	Reflecting upon the accuracy of the methods used	Devising strategies for calculating heights using basic tools
	Physics and Chemistry	Using instruments to measure sound intensity and assess its effects	Analyzing noise pollution and its environmental impact	Devising strategies for data measurement and presentation
	Technology	Developing a geolocation-based web application	Evaluating the information provided by other activities	Designing and structuring a multimedia repository

3.3. Thinking skills in the transdisciplinary service-learning project

The activities carried out in the project are categorized below, with an indication of the relationships between them and the development of thinking skills, including problem-solving and decision-making, critical thinking and creative thinking (See Table 4).

3.3.1. Problem-solving and decision-making

As for the artistic areas, Physical Education students applied their knowledge to develop an original proposal that combined creativity and technique. This involved analyzing the fundamental elements of creative dance and making decisions regarding structure, rhythm and expressiveness, addressing both creative and technical challenges. In Music and Visual Arts, students utilized their understanding of instrumental technique and collective improvisation to develop their proposals. This required specific analyses of technical and expressive aspects for informed decision-making during the musical interpretation process.

In the humanistic-social domain, and engaging cognitive processes, students in Classical Culture analyzed linguistic and biological information to establish coherent connections. They further analyzed the etymology of scientific names and linked those names to their corresponding living beings. In Geography and History, students examined technical aspects that enabled the precise location of viewpoints and the integration of data into a digital platform. In Spanish Language, they adapted written and oral narratives in addition to organizing and structuring an audiovisual project. In Religion, they explored solutions for respecting and caring for the environment.

In the scientific-mathematical domain, they researched methods in Biology to be applied to the study of flora and fauna in addition to analyzing the interactions between these elements within the ecosystem. In Physics and Chemistry, practical knowledge of noise pollution and sound measurement was applied using specific tools. In Mathematics, the concept of triangle similarity was used to calculate the heights of trees, buildings and streetlights as well as to analyze the relationship between the results and visual estimates obtained to verify their coherence. The Technology Department applied acquired knowledge to select appropriate technological tools.

In all subjects, problem-solving and decision-making focused on the practical application of acquired knowledge for domain-based analysis. In the artistic domain, this entailed embodied practices linked to divergent creative action involving constant decision-making. In contrast, in the scientific, technological, and humanities areas, it involved reflective application with convergent analysis.

3.3.2. Critical thinking

In the artistic domain, the coherence of choreography was evaluated in Physical Education to enhance performance. Similarly, improvisations in Music were assessed from a critical perspective to facilitate improvement.

In the humanistic-social domain, the significance of contributions made by prominent botanists and zoologists was assessed within the context of Classical Culture, highlighting their role in the evolution of science and the importance of Latin as a universal language of culture. In Geography and History, changes in the landscape were analyzed to identify their causes and consequences, while also reflecting on their broader significance. In English, students' haikus were evaluated. In Spanish Language, the role of orality in legends and their evolution into modern written forms was examined. The activities organized by the Religion Department emphasized the importance of valuing nature from an ethical and Christian perspective.

In the scientific-mathematical domain, critical thinking in Biology focused on evaluating how environmental stimuli impact human well-being from various scientific and social perspectives. Environmental issues were assessed from multiple viewpoints, with an emphasis on designing viable solutions. In Economics, the limits of economic growth and the environmental impact of the current model were analyzed, requiring the interpretation of data and the development of a well-founded stance on sustainable development. In Physics and Chemistry, the critical evaluation of collected data was emphasized, particularly regarding the interpretation of results and their relationship to auditory health. There was also a strong focus on reflecting on the causes and consequences of noise pollution and strategies to mitigate the effects thereof. In Mathematics, students identified and assessed potential errors in measurements in addition to proposing possible improvements.

The project developed addressed critical thinking transversally across all departments within the context of the *La Isla de los García* natural space, fostering reflection on the importance of environmental care. Additionally, critical thinking was consistently integrated as a form of feedback throughout the creative process.

3.3.3. Creative thinking

In the artistic domain, Physical Education involved the creation of choreographies while Music classes explored the sonification of soundscapes or paintings through collective improvisation.

In the humanistic-social domain, specifically in Geography and History, a digital cartography project was created merging history, geography and technology to visualize the evolution of the landscape. In Religion, collage-style cards were developed; in English, the composition of haikus was emphasized; and in Spanish Language, the creation of new legends was highlighted.

In the scientific-mathematical domain, Biology linked creative thinking to the representation of flora through ecological narratives with students preparing presentations and exhibitions. In Economics, a proposal for sustainable transformation was designed. In Physics and Chemistry, creative efforts concentrated on developing materials to present results visually and orally. In Technology, results were presented on the platform. In Mathematics, designing result presentations was prioritized.

Artistic areas required constant decision-making, as was evident in the embodied creative actions characterized by originality and divergent thinking. One the other hand, scientific-mathematical areas focused on generating ideas. In both areas, creative thinking with a strong domain-based perspective was directly involved so such thinking could be developed not just for the cognitive potential, but as a creative experience.

3.4. Transversal and emerging skills in the project

Collaborative thinking and systemic thinking were identified as transversal and convergent skills throughout the project. These thinking skills are categorized below across the various areas.

3.4.1. Collaborative thinking

The interdisciplinary SL project focused on developing various thinking skills that foster deeper and more meaningful learning. Among these, collaborative thinking is essential as it enables the co-construction of knowledge through interaction and the exchange of ideas among students. The project involved activities on *La Isla de los García*, where students worked in groups to investigate, analyze and create content across multiple disciplines, including science, art, music, physical education and technology. Additionally, learning experiences outside the classroom promoted proper co-existence among students. Specifically, the Guidance Department organized activities centered on proper co-existence and cooperative work which contributed to the development of the thinking skills initially identified, particularly collaborative thinking skills. This generated positive synergies in the practical application of group work across subjects and improved the classroom climate. This was exemplified by both the nature of the activities proposed by the departments and their implementation. Not only does teamwork encourage collaboration, but the process of developing critical thinking, problem-solving and decision-making skills also integrates and aligns with collaborative thinking skills.

3.4.2. Systemic thinking

The cognitive processes developed in each activity across the various areas facilitated a complex approach to knowledge, synthesized through the practical application of all cognitive processes and thinking skills. Each area approached the phenomenon from a distinct perspective, encompassing both the content taught and the different cognitive frameworks used for comprehensive understanding. This integration allowed students to naturally confront and incorporate knowledge, reflecting the real interconnections among concepts. A global and contextualized vision of reality was thus promoted, oriented toward the functionality of learning, as illustrated in the figure below. The development of two levels of systemic thinking is evident. On one hand, there is the level inherent to the activities conducted in each specific area, as shown in Table 5. On the other hand, there is the level related to the connections established among the various areas through shared themes and common spaces.

The inter-related nature of the thinking skills analyzed became evident during the development of the SL transdisciplinary project (See Fig. 5). There was a change in mindset from the domain-based and interconnected perspective of creative thinking and problem-

Table 5
Collaborative thinking and systemic thinking in the transdisciplinary SL project activities.

Area	Subject	Collaborative Thinking	Systemic Thinking
ARTISTIC	Music	Cooperatively creating musical pieces Collaborating to record and edit the soundscape	Integrating different artistic languages (music and painting) Making connections between auditory perception, the environment and musical expression
	Art	Creating music-visual scores for interaction with other artistic departments	Analyzing relationships between visual arts and musical interpretation
	Physical Education	Group work to develop a collective dance	Analyzing relationships between movement, music and the natural environment
HUMANISTIC-SOCIAL	Classical Culture	Doing joint research into taxonomy and the biographies of scientists	Analyzing relationships between culture, science and universal communication
	Economics	Debates and teamwork to evaluate sustainability alternatives	Looking into global perspectives on the economy, environment and human development
	Social Science	Collaborating with municipal experts and conducting community interviews	Making connections between geography, history and the environment
	Spanish Language (4th-year ESO)	Group work to plan, record and edit a video-poem	Relationships among literature, nature and human perception of the landscape
	Spanish Language (2nd-year ESO)	Collecting testimonies and teamwork to record them	Making connections between oral tradition, cultural identity and literature
	Religion	Joint reflection on caring for the "common home" and on shared responsibility in conserving the natural environment. Classwork involving the creation of cards to foster cooperation in appreciating nature.	Understanding the relationship between spirituality, ethics and the environment Identifying the natural environment as an interconnected system requiring care and collective responsibility
SCIENTIFIC-MATHEMATICAL	Biology 1	Classwork involving the creation of cards to foster cooperation in appreciating nature	Analyzing relationships among biodiversity, ecosystems and geology
	Biology 2	Group work to investigate the island's flora, fauna and geology	Making connections between geomorphology, biodiversity and sustainability
	Mathematics	Collaborative efforts in creating herbariums and exhibitions	Analyzing relationships between mathematical concepts and the natural environment
	Physics and Chemistry	Group work to apply principles of similarity to height calculations	Making connections between sound, health and the environment
	Technology	Teamwork for noise measurement and presentation of results	Analyzing relationships between technology, geolocation and access to information

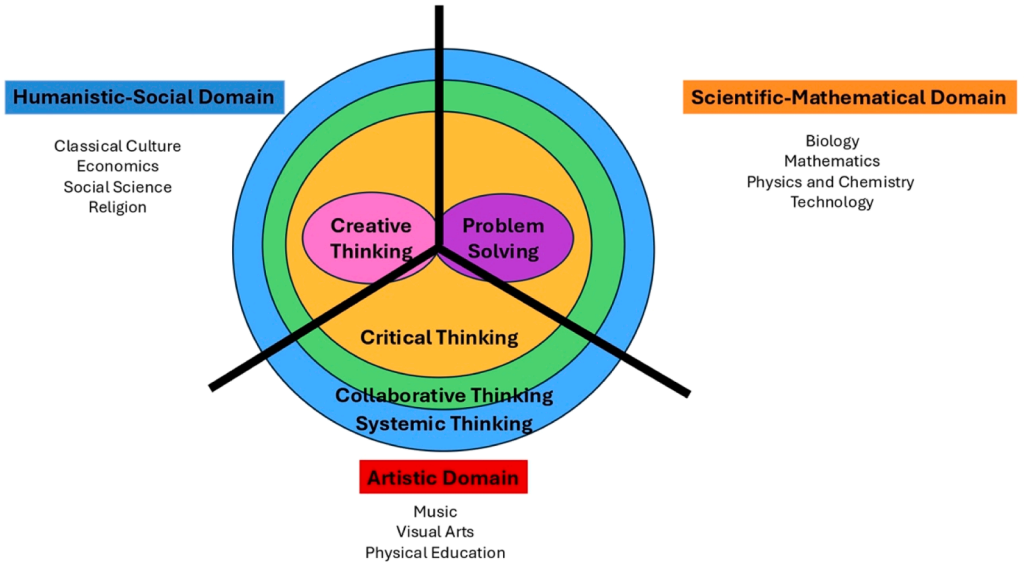

Fig. 5. Thinking skills in the transdisciplinary service-learning project.

solving to a more general approach to critical thinking. Collaborative thinking developed transversally and integrally, while systemic thinking connected the various domains.

4. Discussion

Drawing on the multiple possibilities and perspectives offered by curriculum integration and grounded in a solid and long-standing pedagogical foundation, the transdisciplinary approach has enabled us to merge scientific and technological areas with the humanities and arts in a balanced, integrative and holistic manner (Chappell et al., 2019). The transdisciplinary approach developed in our study centers around the concept of *La Isla de los García* as the integrating axis, in line with Carranza et al. (2024), with a thematic focus on landscapes, which was addressed in various secondary education activities (author & author). This spatial context facilitated the blurring of boundaries between subjects, allowing for a comprehensive understanding of specific real-world problems through a holistic, ethical and relational pedagogical approach (Biesta, 2022). This approach operated within the framework of a service-learning project aimed at sustainable development (Singer, 2023; Ulbrich et al., 2024). We took a complex approach to knowledge (Norden, 2018), focusing on the development of global and engaged citizens in democratic societies (Burnard et al., 2022).

In accordance with Carranza et al. (2024) and Ulbrich et al. (2024), we observed the development of critical thinking, problem-solving anddecision-making and creative thinking skills. Both students and teachers emphasized the importance of these skills and the relevance of active student engagement. We identified specific developments across different areas, with a predominance of intermediate and higher-order cognitive processes such as applying, analyzing, evaluating and creating. However, the characteristics of these skills varied depending on the disciplinary domain: scientific-technological, humanistic or artistic. For instance, problem-solving and decision-making were characterized by the development of analytical and applicative cognitive processes in scientific-mathematical and humanistic areas due to their convergent and analytical nature. In contrast, artistic areas demonstrated constant decision-making as evident in embodied creative actions characterized by originality and divergent thinking, directly involving creative thinking, conceived not just for the cognitive potential but as a creative experience (Glăveanu & Beghetto, 2021). According to Glăveanu, 2018, these perspectives can be framed within the concept of creativities where problem-solving is a hallmark of scientific creativity, while artistic creativity is defined by originality from a divergent perspective. Both perspectives were implemented with a balanced approach, fostering an integrated approach across diverse areas. Critical thinking was developed through evaluative cognitive processes across various areas in a general perspective, incorporating environmental awareness and continuous feedback during diverse activities. Collaborative thinking, which is linked to the development of social skills, emerged in a transversal and integral way, rooted in a methodological approach that promotes integrative and collaborative work. Consequently, the epistemological conception derived from general systems theory within a transdisciplinary framework significantly advanced systemic thinking, allowing for a comprehensive understanding of complex social and ecological issues (Bosh et al., 2007). This advancement was facilitated by connecting various fields with a complex and meaningful approach to knowledge, along with the service-learning framework for sustainable development, which fosters real-world connections in the search for solutions to genuine problems.

We also identified challenges in the implementation of the project, particularly a need for coordination among participating teachers. This requires institutional support to allocate schedules and spaces for collaboration (Davis, 1999; Norden, 2018). To effectively blur the boundaries of knowledge between subjects in secondary education, flexibility in scheduling and resource allocation is essential as it would enhance transdisciplinary integration.

5. Limitations

The study was conducted at a single secondary school with specific organizational, cultural and pedagogical features in Spain. This limits the transferability of the findings to other international contexts as the implementation of a transdisciplinary approach may vary substantially depending on institutional conditions, available resources and teacher training. Implementing a transdisciplinary model in secondary education involves considerable organizational and methodological complexity. Nevertheless, the study presents an approach that could be adapted and applied to various secondary education contexts.

Coordination challenges among departments, timetables and curricular objectives may have influenced the consistency of the experience, leading to variations in the degree of integration achieved across disciplines. The project was implemented within a single cycle and over one academic year, which constrains the assessment of its long-term effects. A longitudinal follow-up would be advisable to examine potential changes in the school's pedagogical culture. Although data collection took place in 2021, the results remain valid as the principles of transdisciplinarity, service-learning and sustainable development continue to be key elements of current curricular frameworks. Furthermore, no substantial curricular or legislative changes have been made since 2021, either in the broader educational context or within the school where the study was carried out. The project has maintained continuity through ongoing work related to La Isla de los García, which continues to be used as a pedagogical framework for promoting transdisciplinary learning and community engagement. Principio del formulario

6. Conclusions

The objectives outlined in this study have been addressed and we can summarize the outcomes as follows: the project implemented fostered (1) an understanding of the world around students through various disciplines; (2) the application of knowledge in real-world situations based on a practical and experiential approach; (3) creative expression through narratives, audiovisual productions and technological solutions; and (4) awareness of social and environmental issues, leading to the proposal of innovative solutions.

Systemic thinking played a key role in promoting the understanding of interconnections as a fundamental 21st-century competency, enabling students to analyze the complexity of the real world and its multiple interrelationships. In this project, students developed systemic thinking through: (1) Interconnections between disciplines: instilling a global vision where literature, science, economics and ethics converge in the analysis of the environment. Students discovered that environmental, social and cultural problems are interrelated rather than isolated phenomena; (2) The analysis of cause-effect relationships: reflections across scientific areas regarding sustainability; (3) Modeling real systems: allowing students to model reality using geometric principles; (4) Organizing and structuring data in an accessible system; (5) Awareness of the impact of human actions: understanding how culture and identity are linked to the environment. The analysis of unsustainable growth encouraged reflection on the consequences of human decisions for the planet; (6) Abstraction through art: developing a synthesis of some of the content explored in various areas, promoting a broader and more connected understanding and fostering a more analytical, reflective and sustainable mindset.

In summary, from a complementary perspective to disciplinary development, this approach made it possible for students to not only reflect upon their natural environment but also establish a deeper connection with caring for the planet. It promoted creative thinking, ethical and critical reasoning and transdisciplinary service-learning proposals for sustainable development. This integrated, integrative and holistic approach can be extrapolated to other secondary education contexts so as to foster a meaningful and complex understanding of the world we live in.

7. Implications for teaching practices

The findings of this study highlight the importance of stable and sustained structures for teacher coordination that extend beyond initial planning stages when implementing transdisciplinary approaches. Effective transdisciplinary teaching demands collaborative workspaces for the different departments, flexible scheduling and shared time for joint planning, monitoring and assessment. Such conditions enhance coherence in curricular content, teaching methodologies and evaluation processes across disciplines.

The results indicate the development of complex skills—such as critical, creative, collaborative and systemic thinking—particularly when projects connect learning experiences to real-world or context-based situations. Authentic task design, aligned with the Sustainable Development Goals and SL principles, is therefore essential when linking disciplinary learning with social and environmental challenges. Thinking skills are reinforced when students establish meaningful connections between diverse areas of knowledge.

Consequently, teaching practices should foster interrelated learning experiences in which knowledge is addressed as part of a broader system rather than as isolated fragments. This integrative approach stimulates the targeted thinking skills and enables students to better understand the complexity of real problems. The balance observed between convergent and divergent thinking in both scientific and artistic domains underscores the need to diversify instructional strategies. Learning tasks should alternate between phases of analysis, evaluation and application—typical of critical thinking and problem-solving—and stages of creative exploration and design—characteristic of creative thinking. This alternation enhances students' cognitive flexibility and innovative capacity.

The development of critical thinking requires learners to reflect upon their own cognitive processes, identify errors, evaluate alternatives and make evidence-based decisions. Teaching practices should therefore include systematic metacognitive strategies—such as learning journals, guided self-assessments and reflective rubrics—that make thinking processes explicit. Moreover, peer collaboration was found to have not only social but also cognitive benefits: it fosters argumentation, negotiation of meaning and shared decision-making. Accordingly, teaching should promote structured spaces for interaction and co-creation, where individual thinking is amplified through dialogue and interdisciplinary collaboration.

The relationship observed between systemic thinking and environmental engagement—central to the sustainability project—suggests that authentic, complex contexts (e.g., environmental or social issues) can serve as powerful platforms for teaching students to analyze interdependencies and consequences. This approach not only deepens conceptual understanding but also cultivates critical, socially engaged citizens capable of addressing global challenges.

Finally, the methodological implications point to the need for continuous, process-oriented assessment of thinking skills. Teaching practices should incorporate qualitative observation tools, portfolios and analytical rubrics that assess students' progress in reasoning, creativity and problem-solving, rather than focusing exclusively on final outcomes.

CRediT authorship contribution statement

Carlos Lage-Gómez: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Ruth González-Pizarro:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization. **Arantza Campollo-Urkiza:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis. **Roberto Cremades-Andreu:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

Do not exist any conflict of Interest or Competing Interest.

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Data availability

The data that has been used is confidential.

References

Anderson-Levitt, K., & Gardinier, M. P. (2021). Introduction contextualising global flows of competency-based education: Polysemy, hybridity and silences. *Comparative Education, 57*(1), 1–18. https://doi.org/10.1080/03050068.2020.1852719

Angrosino, M. (2012). *Etnografía y observación participante en investigación cualitativa.* Morata.

Arrowsmith, S., & Wood, B. (2015). Curriculum integration in New Zealand secondary schools. *SET: Research Information for Teachers, 1*, 58–66.

Bautista, A., Tan, L. S., Ponnusamy, L. D., & Yau, X. (2016). Curriculum integration in arts education: Connecting multiple art forms through the idea of 'space. *Journal of Curriculum Studies, 48*(5), 610–629. https://doi.org/10.1080/00220272.2015.1089940

Biesta, G. (2020). *Educational research: An unorthodox introduction.* Bloomsbury.

Biesta, G. (2022). *World-centred education. a view for the present.* Routledge.

Bloom, S. (1956). *Taxonomy of educational objetives. handbook,1: Cognitive domain.* David Mckay.

Bosh, O. J. H., King, C. A., Herbohn, J. L., Russel, I. W., & Smith, C. S (2007). Getting the big picture in naturalresource management—Systems thinking as"method" for scientists, policy makers, and other stakeholders. *Systems Research and Behavioral Sci-ence, 24*, 217–232. https://doi.org/10.1002/sres.818

Bouwmans, M., & Béneker, T. (2018). Identifying powerful geographical knowledge in integrated curricula in Dutch schools. *London Review of Education, 16*(3), 445–459. https://doi.org/10.18546/LRE.16.3.07.

Braidotti, R. (2013). *The Posthuman.* Wiley.

Brinkman, S. (2012). *Qualitative interviewing.* New York: Oxford University Press.

Burnard, P., Colucci-Gray, L., & Cooke, C. (2022). Transdisciplinarity: Re-visioning how sciences and arts together can enact democratizing creative educational. Experiences. *Review of Research in Education, 46*(1), 166–197. https://doi.org/10.3102/0091732X221084323

Camilli-Trujillo, C., Cuervo-Calvo, L., García-Gil, D., & Bonastre-Valles, C. (2022). Mixed methods research in service-learning: An integrative systematic review. *Qualitative & Quantitative, 56*, 2361–2386. https://doi.org/10.1007/s11135-021-01218-3

Carranza, P., Kanobel, M. C., Tejera, M., & Lavicza, Z. (2024). Linking sustainability and STEAM education in Argentine Patagonia: A solar energy irrigation system project for secondary school students. *Research in Integrated STEM Education, 2*(1), 1–30. https://doi.org/10.1163/27726673-bja00020

Chalmers, C., Carter, M. L., Cooper, T., & Nason, R. (2017). Implementing "big ideas" to advance the teaching and learning of science. Technology. Engineering. And mathematics (STEM). *International Journal of Science and Mathematics Education, 15*(1), 25–43. https://doi.org/10.1007/s10763-017-9799-1

Chappell, K., Hetherington, L., Keene, H. R., Wren, H., Alexopoulos, A., Ben-Horin, O., Nikolopoulos, K., Robberstad, J., Sotiriou, S., & Bogner, F. X. (2019). Dialogue and materiality/embodiment in science|arts creative pedagogy: Their role and manifestation. *Thinking Skills and Creativity, 31*, 296–322. https://doi.org/10.1016/j.tsc.2018.12.008

Cottrell, S. (2017). *Critical thinking skills: Effective analysis, argument and reflection.* Macmillan.

Cox, M., Elen, J., & Steegen, A. (2017). Systems thinking in geography: Can high school students do it? *International Research in Geographical and Environmental Education, 28*(1), 37–52. https://doi.org/10.1080/10382046.2017.1386413

Creswell, J. W., & Creswell, D. J. (2018). Research design. Qualitative, quantitative, and mixed methods approaches. *SAGE.*

Crilly, N. (2024). *Design thinking and other approaches: How different disciplines see, think and act.* Cambridge University Press. https://doi.org/10.1017/9781009498685

Deeley, S. (2016). *El aprendizaje- servicio en educación superior: Teoría, práctica y perspectiva crítica.* Narcea.

Dewey, J. (1916). *Democracy and education.* Macmillan.

Dillenbourg, P., & Fischer, F. (2007). Basics of computer-supported collaborative learning. *Zeitschrift Für Berufs- Und Wirtschaftspädagogik, 21*, 111–130.

Dostál, J. (2015). Theory of problem solving. *Procedia-Social and Behavorial Sciences, 174*, 2798–2805. https://doi.org/10.1016/j.sbspro.2015.01.970

Dowden, T. (2014). Challengign, integrated, negociated and exploratory curriculum in the middle years of schooling: Designing and implementing high quality curriculum integration. *Australian Journal of Middle Schooling, 14*(1), 1–27. http://www.adolescentsuccess.org.au/journal-nov-2011-current/.

Elen, J., & Verburgh, A. (2023). Fostering critical thinking: Features of powerful learning enviroments. *European Journal of Education, 58*(3). https://doi.org/10.1111/ejed.12568.

Etim, J. S. (Ed.). (2005). *Curriculum integration K-12: Theory and practice*. University Press of America.
Funke, J. (2010). Complex problem so ling: A case for complexión cognition? *Cognitive Processing, 11*, 133–142. https://doi.org/10.1007/s10339-009-0345-0
Glăveanu, V. P., & Beghetto, R. A. (2021). Creative Experience: A Non-Standard Definition of Creativity. *Creativity Research Journal, 33*(2), 75–80. https://doi.org/10.1080/10400419.2020.1827606.
Glăveanu, V. P. (2018). Educating which creativity? *Thinking Skills and Creativity, 27*, 25–32. https://doi.org/10.1016/j.tsc.2017.11.006
Guilford, J. P. (1967). *The nature of human intelligence*. McGraw-Hill.
Harris, A., & de Bruin, L. R. (2018). Secondary school creativity, teacher practice and STEAM education: An international study. *Journal of Educational Change, 19*(2), 153–179. https://doi.org/10.1007/s10833-017-9311-2.
Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher, 33*(7), 14–26. https://doi.org/10.3102/0013189X033007014
Lage-Gómez, C., & Ros, G. (2024). *On the interrelationships between diverse creativities in primary education STEAM projects. Thinking Skills and Creativity*, 51. https://doi.org/10.1016/j.tsc.2023.101456.
Lage-Gómez, C., & Cremades-Andreu, R. (2023). Creative ruptures through a transdisciplinary project in secondary education. In Adolf Murillo, Jesús Tejada, Mª Elena Riaño, Clarissa Foletto, Sara Carvalho, Lluís Solé (Eds). EXPLORING CREATIVITIES. Creation as a strategy for learning music and the arts. València: EdictOràlia. ISBN: 978-84-126371-3-7.
Lage-Gómez, C. & Ros, G. (2021) Transdisciplinary integration and its implementation in primary education through two STEAM projects (La integración transdisciplinar y su aplicación en Educación Primaria a través de dos proyectos STEAM), *Journal for the Study of Education and Development*, 44:4, 801-837, https://doi.org/10.1080/02103702.2021.1925474.
Lage-Gómez, C. (2020). Aproximación transdisciplinar a la Música Popular Urbana. *Estudios Pedagógicos, 46*(2), 159–176. https://doi.org/10.4067/S0718-07052020000200159.
Lam, C., Alviar-Martin, C., T. Adler, S. A., & Sim, J. B (2013). Curriculum integration in Singapore: Teachers' perspectives and practice. *Teaching and Teacher Education, 31*, 23–34. https://doi.org/10.1016/j.tate.2012.11.004
León-Carrascosa, V., Sánchez-Serrano, S., & Belando-Montoro, M. R. (2020). Diseño y validación de un cuestionario para evaluar la metodología aprendizaje-servicio. *Estudios Sobre Educación, 39*, 247–266. https://doi.org/10.15581/004.39.247-266
Lubart, T., & Thornhill-Miller, B. (2019). Creativity: An overview of the 7C's of creative thought. *Psychology of Human Thought*, 279–306. https://doi.org/10.17885/heiup.470.c6678
Maguire, L. (2016). *TeachersExperiences Using Service-Learning in the High School Classroom*. Unpublished Thesis.
Martín-Ezpeleta, A., & Echegoyen-Sanz, Y. (2022). *El giro transdisciplinar: Integración de contenidos en torno a fenómenos y ámbitos* ([1ª edición]). Tirant humanidades.
Martínez Rodríguez, & Fernández Rodríguez, E. (2018). *Ecologías del aprendizaje : educación expandida en contextos múltiples*. Ediciones Morata, S.L.
Martínez-Agut, M. P. (2022). El concepto de transdisciplinariedad y su relación con las metodologías contextualizadoras desde los objetivos de desarrollo sostenible. Eds.. In En A. Martín-Ezpeleta, & Y. Echegoyen-Sanz (Eds.), *El giro transdisciplinar: Integración de contenidos en torno a fenómenos y ámbitos* ((1ª ed.)). Tirant Humanidades
McPhail, G. (2017). Curriculum integration in the senior secondary school: A case study in a national assessment context. *Journal of Curriculum Studies, 50*(1), 56–76. https://doi.org/10.1080/00220272.2017.1386234
McPhail, G. (2019). Curriculum integration in flexible learning environments, challenges for teachers, and teacher education. eds. In M. Peters (Ed.), *Encyclopedia of teacher education*. Singapore: Springer. https://doi.org/10.1007/978-981-13-1179-6_369-1.
Moon, J. (2007). *Critical thinking: An exploration of theory and practice*. Routledge.
Naidoo, D. (2010). Losing the "purity" of subjects? Understanding teachers' perceptions of integrating subjects into learning areas. *Education as Change, 14*(2), 137–153. https://doi.org/10.1080/16823206.2010.518001
Nordén, B. (2018). Transdisciplinary teaching for sustainable development in a whole school project. *Environmental Education Research, 24*(5), 663–677. https://doi.org/10.1080/13504622.2016.1266302
OECD. (2019). *The future of education and skills: Education 2030*. OECD.
Presseisen, B. Z. (2001). Thinking skills: Meanings and models revisited. Ed.. In En A. L. Costa (Ed.), *Developing minds: A resource book for teaching thinking* (3.ª ed., pp. 47–53). Association for Supervision and Curriculum Development
Randle, J. M., & Stroink, M. L. (2018). The development and initial validation of the paradigm of systems thinking. *Systems Research and Behavioral Science, 35*(6), 645–657. https://doi.org/10.1002/sres.2508.
Saeed, B., & Ramdane, T. M. (2022). The effect of implementation of a creative thinking model on the development of creative thinking skills in high school students: A systematic review. *Review of Education, 10*(3). https://doi.org/10.1002/rev3.3379.
Singer, S. S. (2023). *How Students define their roles and responsibilities as members of a community through critical service-learning pedagogy*. Unpublished Thesis.
Struyf, A., De Loof, H., Boeve-de Pauw, J., & Van Petegem, P. (2019). Students' engagement in different STEM learning environments: Integrated STEM education as promising practice? *International Journal of Science Education, 41*(10), 1387–1407. https://doi.org/10.1080/09500693.2019.1607983
Sun, W., & Zhong, B. (2024). Integrating reading and writing with STEAM/STEM: A systematic review on STREAM education. *Journal of Engineering Education, 113*(4), 939–958. https://doi.org/10.1002/jee.20569
Tasgin, A., & Dilek, C. (2023). The mediating role of critical thinking dispositions between secondary shool studentś self-efficacy and problem-solving skills. *Thinking Skills and Creativity, 50*, 1–11. https://doi.org/10.1016/j.tsc.2023.101400
Ulbrich, E., Da Cruz, M., Anđić, B., Tejera, M., Dana-Picard, N. T., & Lavicza, Z. (2024). Cross-cultural examination of 3D modelling and 3D printing in STEAM education: Comparing results from teachers in Montenegro and Austria. *London Review of Education, 22*(1), 12. https://doi.org/10.14324/LRE.22.1.12
Vygotsky, L. S. (1978). *Mind in society: The development of higher mental processes*. Cambridge, MA: Harvard University Press.
Weilbacher, G. (2000). *Why teachers decide to use, then not use, curriculum integration as their curriculum planning philosophy*. Unpublished doctoral dissertation. University of Wisconsin-Madison.
Weilbacher, G. (2001). Is curriculum integration an endangered species? *Middle Schhool Journal, 33*(2), 28-27.