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Research Article

Promoting Transdisciplinary and Competency-based Learning Using Web GIS in the Spanish Secondary School Classroom

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Abstract: In today´s world, education systems must adapt to stay connected with the real world. Three key elements meet these demands: the interaction between disciplines and their varying levels of complexity, the competency-based approach of the Spanish education system, and the use of web-based GIS tools for teaching and learning with a transdisciplinary approach. In this context, Spain offers a promising context to explore the integration of these elements, given its educational reforms and digital strategy. However, there are no studies in secondary schools in Spain integrating these elements. The objective of this research is to demonstrate that web GIS serves as a valuable resource for engagement in the real world, representing information on maps for teaching and learning within a transdisciplinary competency-based framework. The methodology applied follows the action-research model mainly based on classroom observations and students' satisfaction surveys. Several stages have been considered: a) planning: identifying a relevant problem or topic to improve learning outcomes; b) action: class intervention by collecting necessary information, categorizing information, analysing the problem, formulating hypotheses and creating a layer for a collaborative map; c) results and interventions assessments. Following this methodology, three interventions are presented. The sample is a convenience sample with 187 students aged 15 to 18 (ISCED 3: 4th-year Compulsory Secondary Education -K-10, ages 15–16- and ISCED 4: 2nd-year Baccalaureate -K-12, ages 17–18-), from a Spanish educational institution. It can be stated that the collaborative use of web-based GIS in secondary education enhances engagement, representation of information, and increases interaction. All these actions improve sustainability, digital, learning to learn and citizenship competencies and promote transdisciplinarity.

Keywords: web-based GIS learning; citizenship; transdiciplinarity; competency; education for sustainability

Highlights:

- Collaborative use of web GIS improves the engagement of students in Secondary School.
- Cartography based on the use of web GIS drives the transdisciplinary approach.
- Interventions evaluate sustainability, digital, learn to learn and citizenship competencies.

1. Introduction

The world is undergoing a significant transformation in how information and knowledge are created and shared. Our globalized and hyper-connected society generates an enormous amount of information, which can be transformed into knowledge to address sustainability issues. This process is accelerating with the integration of artificial intelligence into daily life. Educational systems must adapt to this new framework, where the rapid pace of change creates an increasingly uncertain environment. Thus, today's society faces a VUCA environment—originally coined in the business world to describe volatility, uncertainty, complexity, and ambiguity—requiring professionals to continuously adapt. Consequently, all members of the educational community (teachers, students, management teams, families and other stakeholders) need greater cognitive flexibility and continuous learning to adapt educational centres to rapidly changing conditions and circumstances (Lemoine, et al., 2017; Morales, 2019; Waller et al., 2019). Hence, the traditional concept-based approach should be complemented by a framework in which knowledge, skills, and competencies are more balanced.

UNESCO (n.d.) highlights the transformative role of education in shaping a future characterized by greater equity and sustainability. It suggests starting with a series of curriculum reforms, including the design of open and common curricula without disciplinary boundaries, and introducing the perspectives of multiplicity and transversality. Although these initiatives should be undertaken within an institutional framework, which lies beyond our remit, we do see potential for their integration into daily lessons and through recommendations that deepen curricular approaches. These approaches should connect the cognitive domain with problem-solving, innovation, and creativity skills, while also incorporating the development of social and emotional learning, as well as autonomous learning—such as learning to learn (Puertas-Aguilar et al., 2021).

In this educational context, it is important to use a transdisciplinary approach which means the integration of subjects and connections with real world, address socially relevant issues, active student participation and collaboration, and review curriculum structures and teacher training (Akiri, 2021; Kubisch et al., 2021; Lage, 2020). For these aims, there are no previous studies using an approach in transdisciplinarity in secondary education using web GIS technology to achieve competences in sustainability, digital skills, learning to learn and citizenship. This study aims to address a gap in educational research by integrating three pillars for the future of education: transdisciplinaryty, technology, and the development of competencies and skills that promote education for sustainability. Therefore, the following research questions are proposed: Can the integration of transdisciplinary approaches in the educational curriculum improve the acquisition of skills and competencies in sustainability by students? Is the interaction between transdisciplinarity and competencies enhanced by the use of web GIS?

2. Literature Review

Disciplinary knowledge is the usual practice of teachers. However, the integration of competencies in sustainability and technology is fundamental to the teaching-learning processes of the 21st century. This approach encompasses the interaction between disciplines, the competency-based approach emphasizing sustainability issues promoted by Spain's educational curriculum, and the use of technologies, in our case, focused on web GIS in teaching and learning.

2.1. Interaction Between Disciplines

Interaction between disciplines is a challenge that fosters the search for alternatives to current societal problems, which are complex, multifaceted, encompassing socioeconomic, technological, and cultural dimensions. This interaction should be transferred to education (Lang et al., 2012).

Choi and Pak (2006) identify different degrees of interaction between disciplines: i) multidisciplinarity, which leverages knowledge from different disciplines but maintains the boundaries of each; ii) interdisciplinarity, which analyses, synthesizes, and harmonizes the links between disciplines into a coordinated and coherent whole; and iii) transdisciplinarity, which integrates natural, social, and health sciences within the context of the humanities, thus transcending their traditional boundaries. Therefore, transdisciplinarity is the highest form of relationship between disciplines, evolving from multidisciplinarity and interdisciplinarity. It is theoretical, critical, integrative, and restructuring, aiming to transcend, transgress, and transform complex problems to provide alternatives from a global and integrated approach. Consequently, it is also broader and more exogenous (Huutoniemi et al., 2010). Despite its relevance, it is not easy to practice transdisciplinarity (Lang et al., 2012).

On the other hand, it can be considered that disciplinarity, pluridisciplinary -also called multidisciplinarity by other authors-, interdisciplinarity, and transdisciplinarity are four steps toward the construction of knowledge (Nicolescu, 1999). Transdisciplinarity faces a variety of educational obstacles and challenges. Among them is the predominance of "single thought" associated with disciplinarity, which should be seen as a complement rather than opposition (Nicolescu, 1999). Despite these challenges, studies have explored implementing transdisciplinary approaches in different fields (Clark & Button, 2011; Daneshpour & Kwegyir-Afful, 2022; Santaella & Ruiz, 2023) (Figure 1).

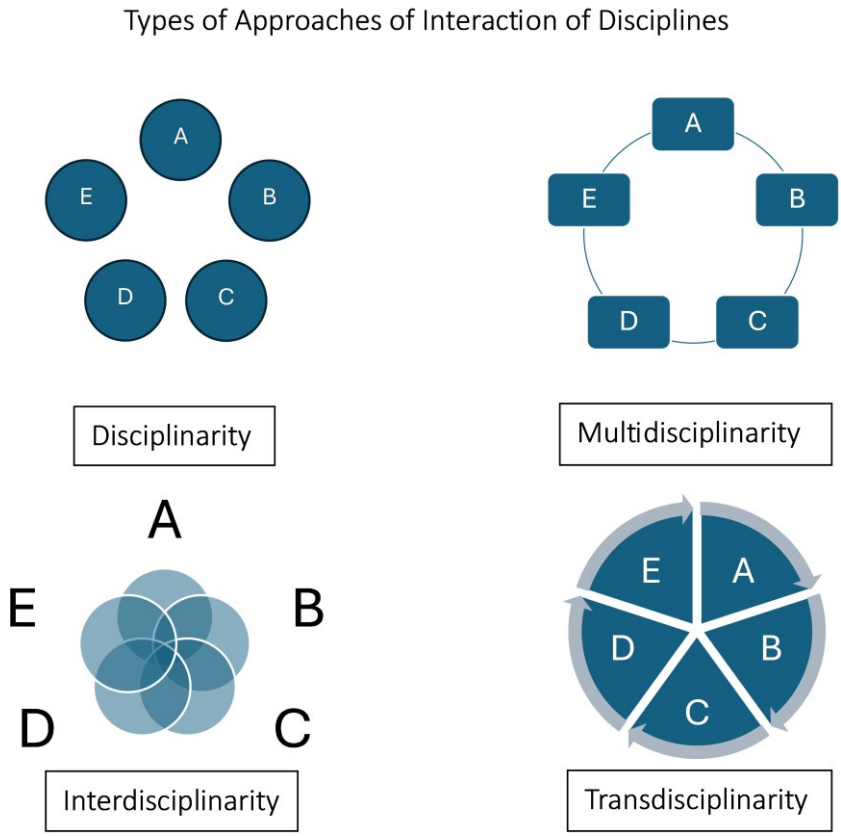

Figure 1. Types of approaches of interaction of disciplines. Source: own elaboration.

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In this context, shaping a sustainable world requires new ways of thinking and acting, making education for sustainability a proposal for change. This, therefore, implies that students must be trained in transdisciplinary competencies (Salgado-Escobar & Aguilar-Fernández, 2021) and in sustainability competencies, that is what citizens particularly need to deal with today's complex challenges (UNESCO, 2017, p. 11). Thus, this implementation is connected to the acquisition of skills and competencies within a transdisciplinary context, which necessarily implies the development of education for sustainability in the terms outlined below. This literature can be summarized in table 1.

Table 1. Interaction among disciplines.

Interaction among disciplines in education	Type of learning and teaching paradigm	Resources	Sustainability awareness
Disciplinarity or Monodisciplinarity	Subject specific teacher centered instruction. Fragmented learning.	Traditional textbooks, lectures, exams	No very strong. Low and limited scope.
Multi or Pluridisciplinarity	Parallel teaching of subjects, limited integration. Constructivism. Coexistence or perspectives. Descriptive learning.	Computer technology and multiple subject resources.	Moderate – awareness raised through multiple lenses, concepts related sustainability are explained (theoretical use).
Interdisciplinarity	Integrated teaching project-based learning centered in the student. Holistic approach. Prescriptive learning.	Interdisciplinary projects, collaborative tools	Promotes interconnected understanding of sustainability and the concept is used in the daily lessons (application).
Transdisciplinarity	Collaborative real-world problem-solving, network-centered (fluent interaction). Meaningful and powerful learning.	Community-based online resources, experiential learning	Fosters deep, action-oriented sustainability awareness (participatory and transformative)

Source: Own elaboration adapted from Koutsopoulos & Papoutsis, (2015, p.34) and De Lázaro-Torres, et al., (2023, p.140).

2.2. The Competency-Based Approach in Spanish Education

The competency-based approach in education has become a fundamental pillar of educational reforms in recent decades. The European Parliament and the Council of Europe recommended incorporating key competencies into the educational systems of member states (European Union, 2006). In Spain, the new legal framework for compulsory secondary education (Ministry of Education and Professional Training of Spain, 2022) specifies the students' competencies must acquire during their studies. Although, key competencies have been part of Spanish educational legislation since 2006 (Government of Spain, 2006), their relevance has increased in student evaluation, as their acquisition is now central to the objectives of the current law.

However, there is a controversial debate regarding the concept of competencies in education. The Organisation for Economic Cooperation and Development (OECD) introduced the concept through DeSeCo (Definition and Selection of Competencies) project, highlighting the need to for a competency-based approach in European educational systems. The OECD defines competency in education as: The ability to respond to complex demands and carry out diverse tasks adequately. It involves a combination of practical skills, knowledge, motivation, ethical values, attitudes, emotions, and other social and behavioral components that are mobilized together to achieve effective action (OECD, 2005).

Additionally, it adds that "a competency is more than just knowledge and skills, it involves the ability to meet complex demands by drawing, on and mobilizing psychosocial resources (including skills and attitudes) in a particular context"(Table 2). This includes the ability to solve problems. Therefore, "sustainable development and social cohesion depend critically on the competencies of all of our population -with competencies understood to cover knowledge, skills, attitudes, and values" (OECD, 2005, p. 3).

Table 2. Differences between skills and competencies.

Key Points	Skills	Competencies
Definition	Specific abilities to perform tasks or solve problems	Integration of skills, knowledge, attitudes, and values
Scope	Scope Narrow and task-oriented	Broad and context-oriented.
Measurement	Often measurable and observable	Includes behavioural and cognitive dimensions, harder to quantify
Main Reference	OECD 2024	Europen Union (2018)

Source: Own elaboration adapted from sources cited.

These competencies align with Sustainable Development Goal No. 4: Quality Education, specifically target 4.7, which states:

"Ensure all learners acquire knowledge and skills needed to promote sustainable development, including, among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development" (UNESCO, n.d.).

Therefore, beyond acquiring disciplinary knowledge, it is necessary to apply it to personal and professional situations and respond to sustainability challenges. This requires students to develop a set of integral and adaptive skills, enabling them to face complex and dynamic situations (Akiri, 2021; Daneshpour & Kwegyir-Afful, 2022; Fiala et al., 2018), which are difficult to acquire in traditional learning formats (Acevedo-Osorio et

al., 2020). For this reason, teaching cannot be limited to the acquisition of knowledge and cognitive intervention, since it is essential that include the exchange and improvement of practical skills along with the translation of values (Salgado-Escobar & Aguilar-Fernández, 2021; Sipos et al., 2008).

The competency-based pedagogical approach suggests that educational institutions should design interdisciplinary, flexible, and broad curricula focused on content that promotes reasoning. This approach aims to develop essential life and work competencies in students, such as creativity, entrepreneurial capacity, reflection, communication, critical thinking, problem-solving, collaboration, risk-taking, innovation, and metacognition (Scott, 2015). Four foundational competencies—sustainability, citizenship, learning to learn, and digital competence— are considered for contemporary educational, social, and professional environments. These competencies reflect a holistic approach to personal and collective development, integrating ethical awareness, civic engagement, autonomous learning, and technological literacy. Each is grounded in established European and national frameworks and contributes to the formation of responsible, adaptable, and digitally empowered individuals capable of addressing complex global challenges and participating actively in democratic societies.

2.2.1 Competencies in sustainability

Competencies related to sustainability include critical thinking, based on prior knowledge; systemic reflection, connected to a more complex and real world; collaborative decision-making, developing persuasion and negotiation skills, and a sense of responsibility toward present and future generations, being awareness and proposing possible alternatives, without compromising future generations (Murga-Menoyo, 2015; Punie & Bacigalupo, 2022; Puertas-Aguilar et al., 2022).

2.2.2 Citizenship competence

According to Spanish education law (Spain, 2020), it contributes to enabling students to exercise responsible citizenship and to participate fully in social and civic life, grounded in an understanding of social, economic, legal, and political concepts and structures, as well as in knowledge of global events and an active commitment to sustainability and the attainment of global citizenship. It encompasses civic literacy, the conscious adoption of the values inherent in a democratic culture founded on respect for human rights, critical reflection on the major ethical challenges of our time, and the development of a sustainable lifestyle aligned with the Sustainable Development Goals set out in the 2030 Agenda.

2.2.3. Learning to learn

As defined by the European Union's Council Recommendation on Key Competences for Lifelong Learning (2018) encompasses the ability to manage one's own learning effectively, both independently and collaboratively. It involves setting personal learning goals, maintaining motivation, and applying appropriate strategies to acquire, process, and evaluate information. Learners are expected to reflect critically on their learning processes, adapt to new contexts, and use digital tools and resources efficiently. This competence supports lifelong learning, personal development, and adaptability in a changing world, contributing to employability and active citizenship.

2.2.4. Digital Competence

Digital competence is recognised as one of the Key Competences for Lifelong Learning, according to the Council of the European Union Recommendation (2018). It entails the safe, critical, and responsible use of digital technologies for learning, work, and active participation in society. The framework (DigComp 2.2) is structured around five competence areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem solving. It emphasises ethical, inclusive, and sustainable digital engagement, and is designed to support policy development, educational initiatives, and lifelong learning strategies across Europe. DigComp 2.2 also aligns with accessibility standards, reinforcing the EU's commitment to inclusive digital transformation. It introduces over 250 new examples of knowledge, skills, and attitudes, reflecting the evolving digital landscape, including emerging technologies such as artificial intelligence.

Digital skills through the use of web GIS technology and digital resources (Viehrig & Siegmund, 2012; Vuorikari et al., 2022); autonomous learning to learn (Sala et al., 2020); and democratic values, respecting diverse perspectives and citizenship (Álvarez-Otero et al., 2024; Santos et al., 2023; Sebastián, 2023). These competencies equip students to respond to problem-solving and labour market demands. Furthermore, students can use the maps to study directly from layered information, viewing the maps as a natural source of knowledge.

2.3 The Use of Web GIS in Teaching and Learning

Geotechnologies, which include geolocation tools using geographic information systems (GIS), are increasingly cloud-based (García-Juan & Vallina-Rodríguez, 2019) and enhance technology. The interactive maps generated by these systems show significant potential for collaborative work and the acquisition of disciplinary competencies, such as geospatial skills (Azzari et al., 2013; Baker, 2015; Bednarz, 2004; Buzo, 2021; Buzo-Sánchez et al., 2022; Carbonell-Carrera et al., 2020; De Lázaro & Morales, 2024; De Miguel, 2024; De Miguel & De Lázaro, 2020; Fargher & Healy, 2020; Jo et al., 2016; Kerski, 2023; Lee & Bednarz, 2012; Leininger-Frézal et al., 2023; Ma et al., 2023; Martínez-Hernández, 2025; Milson, 2011; Mukherjee, 2019; Puertas-Aguilar et al., 2023; Rodán et al., 2016).

The integration of web GIS into educational systems offers pedagogical advantages in teaching and learning processes (Council of Europe, 2018) and promotes crosscutting as a useful tool across different subjects. Therefore, it has been applied to different fields related to tourism (Mínguez, 2021; Martínez-Hernández & Mínguez, 2023), architecture and urban and regional planning (Santos et al., 2021), archaeology (Pons et al., 2019; Klingman, 2021), literature (De Lázaro et al., 2023), and economics (Wilson et al., 2021), among others.

The academic studies about the potential of web GIS in education (Strachan & Mitchell, 2014) do not specifically focus on competencies and transdisciplinarity. Thus, this is an original and innovative element in this research.

3. Objectives and Hypotheses

The main objective of this research is to demonstrate that web GIS serves as a valuable resource for engagement in the real world, representing information on maps for teaching and learning within a transdisciplinary competency-based learning framework. This approach promotes active and collaborative work linking different subjects, real-world connections by developing competences in sustainability, digital, learning to learn and citizenship. To achieve this, the following specific objectives are necessary:

- Design classroom interventions with a global and transdisciplinary approach to demonstrate competency acquisition using web GIS.
- Contribute to transforming educational practice in secondary education in Spain within the current curriculum framework.
- Evaluate the impact of web GIS on students' engagement and learning outcomes across various subjects, including satisfaction questionnaires.

The hypothesis is that cloud-based geographic information system tools (web GIS) can improve learning outcomes through a transdisciplinary approach and enhance students' competencies in secondary education lessons.

4. Materials and Methods

This study has a qualitative approach, aiming to deepen the understanding of educational processes and contexts, and identify areas for improvement in teaching practices.

4.1. Method

The method followed in designing classroom experiments is action research (Lewin, 1946; Martínez-Miguélez, 2004; Pérez-Van-Leenden, 2019), which stems from the teachers' own practices and reflection on them with the aim of improving them (Blanchard & Muzás, 2024). This means direct observation and involves the following stages: a) Planning: identifying a relevant problem or topic to improve learning outcomes recognized in the classroom. In this case the lack of location knowledge and the inability to connect ideas in other to solve problems that arise during curriculum development, especially when the solutions may come from different subject areas.; b) Action: class intervention by collecting necessary information, categorizing information, analysing the problem from different subject areas, formulating hypotheses including the improvement of curriculum competencies and skills and in this case, creating a layer for a collaborative map using web GIS; c) Results: intervention assessments in the context of the competencies to be acquired from different subject which implies transdisciplinarity. This reflection will drive feedback and necessary adjustments to improve the context to achieve the objectives set. True change in teaching methodologies comes from action-reflection-action and new reflection with team analysis, facilitated by dialogue between teachers and conceptual clarification, either from a peer or an expert (Blanchard & Muzás, 2024) (Figure 2).

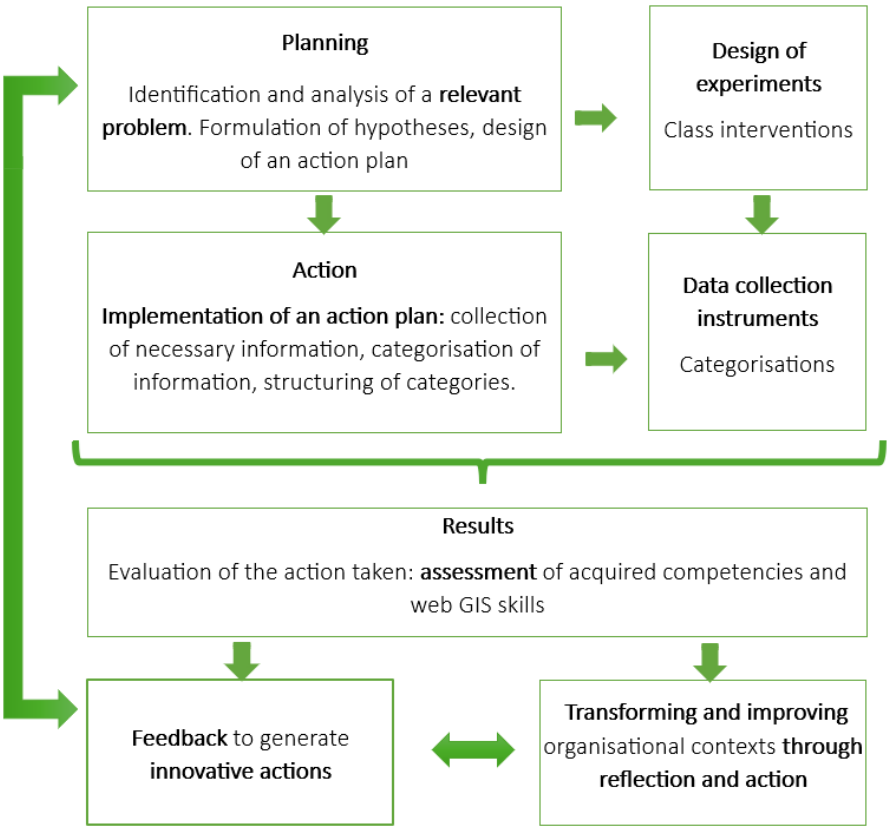

Figure 2. Action research steps own elaboration based on Lewin, 1946; Martínez-Miguélez, 2004; Pérez-Van-Leenden, 2019.

4.1.1. The Sample

The sample consists of 187 students, selected through convenience sampling. This represents the maximum number of students available in the class-groups organized for the academic year. The students' ages range from 15 to 18 years. The sample includes students from 4th year of Compulsory Secondary Education (equivalent to K-10, ages 15-16) and 2nd year of Baccalaureate (K-12, ages 17-18). With a 90% confidence level and a 3% margin of error (Cárdenas, 2018; Miles et al., 1994), this constitutes a significant sample (Argibay, 2009; Delice, 2010). No separate gender study was conducted, as previous research on technology use among young people indicated negligible differences (Puertas-Aguilar, 2023;

Rodán et al., 2016). Three classroom interventions were designed to test the hypotheses (Table 3). Therefore, data sets have been chosen based on two premises. First, the availability of teachers willing to participate in the study, along with the students they taught. Second, the inclusion of different disciplines from the Spanish curriculum, connecting them in terms of the development of competencies, the use of technology (web GIS) in the classroom and the option of thinking about sustainability. This approach follows the theoretical framework explained above.

Table 3. Classroom interventions.

Name of the intervention (academic years)	Academic year	Grade / Year	N	Subjects	Evaluation techniques to be used to obtain results
Spain in the Football World Cup	2020-2021 2023-2024	K-12 (2º Baccalaureate)	103	Geography of Spain History of Spain	Report made following a rubric introducing Survey123 data in a cartographic visualization layer. Satisfaction questionnaire
Scientists in History	2023-2024	K-10 (4º Compulsory Secondary Education)	29	Geography and History Scientific Culture	Report made following a rubric introducing Survey123 data in a cartographic visualization layer. Satisfaction questionnaire
Doing the laundry	2023-2024	K-10 (4º Compulsory Secondary Education)	55	Geography and History Biology and Geology	Accuracy in geolocation from Survey 123. Fifteen-question Google questionnaire with a rubric that measures the level of argumentation. Satisfaction questionnaire.

Source: Own elaboration.

4.1.2. The Tools Used for Data Collection and Assessment

The following tools are used for the experiments: i. Survey123 questionnaire, to collect relevant data from the students' research and geolocation; ii. Creation of a data layer based on Survey123 questionnaire results to visualize all information on ArcGIS Online web GIS; iii. Analysis of the students' arguments through a rubric (Appendix A, Table A1), and their ability to analyse and relate ideas based on Survey123 data collection (Appendix A, Table A2); iv. And an anonymous satisfaction survey for students in each experiment using a Likert scale (Appendix B)All students participating in this study had their own ArcGIS account. All of them (100%) participated by introducing data to create layers equitably. Once the collaborative layers were made, each student had to create individual maps. These maps could be customized by the students as they were intended to be tools for studying different subjects or even for taking regular exams.

4.2. Design and Implementation of Classroom Methodology: Planning and Action

The data analysis is concept-driven. The analytic method used is the logic model, and the primary coding technique is selective coding. This methodology focuses on the improvement of competencies selected (sustainability; citizenship; learning to learn and digital) when working in a transdisciplinary manner using web GIS. Below, the classroom methodology for each of the created interventions is provided.

4.2.1. Spain in the World Cup

This classroom experiment aims to integrate history and geolocation competencies by analysing the celebrations of the various men's World Cup tournaments in which the Spanish national team has participated. Its extensive temporal scope makes it particularly suitable for addressing the 20th century. The experiment was conducted during the History of Spain class in the 2nd year of Baccalaureate (K12). It is important to note that the current curriculum is compartmentalized into subjects, and Physical Education, which clearly interacts with this activity related to the history of sports, is not taught in the second year of Baccalaureate in Spain. Therefore, only the History of Spain class slot was available for this experiment.

This activity is voluntary for students and is carried out in groups of two or three. Most students have worked with web GIS in previous courses, which facilitates the technological part of the experiment.

Students must collect data on each of the football matches played by the Spanish national team in each of the World Cups they participated in, using historical sources, economic data, and academic analyses. This research must include at least the following data: stadium location, teams that played the match, identification of goal scorers, a contemporary match report from written media, a photograph of the match, and other relevant events. These elements will illustrate the analysis of the Spanish economy at the time of each World Cup.

When the group of students completes the research on the various World Cup matches assigned to them, they enter the data into a Survey123 questionnaire, creating a cartographic visualization layer. Using these data, they prepare a report relating the assigned World Cup to Spain's economic situation during that period. Finally, they observe the result on a collaborative map with all the layers generated by each group. Although some students in the class do not collaborate in creating the collaborative map because they didn't participate in the activity, they will use it to study the history lesson content. Thus, the resulting map becomes a study resource for the History of Spain subject.

4.2.2. Scientists in History

This classroom intervention aims to achieve the following objectives: to learn about the most significant inventions in human history and the male and female scientists behind them. This allows students to relate technological advances to historical processes and the territories where they occurred, and to reflect on the potential knowledge bias between inventions made by women and those made by men. It is a mandatory activity within the curriculum for Geography and History, and Scientific Culture. The activity is conducted as cooperative work in groups of three or four students.

Students must search for and provide the following data: location of the most relevant places in the invention's creation process, birthplaces or workplaces of the scientists who created them, a significant invention for humanity between the 18th and 21st centuries, and the invention's significance in its historical contexts, at the time and place of the discoveries or inventions. This aims to familiarize students with cloud-based GIS, specifically ArcGIS Online (ESRI). Students have chosen the invention and its inventor.

Finally, each group will create a report describing the invention and its relevance in history and will add the most relevant data into a Survey123 questionnaire, creating a cartographic visualization layer collaboratively. To conclude, the information, relating scientific inventions to the territory and historical processes occurring at the time of the scientific creation, is analysed based on the visualization of the created map.

4.2.3. Doing the Laundry

The classroom intervention aims to identify the manufacturing locations of the clothing commonly used by the students' families. The information collected will be useful to assess the economic and environmental impact of textile production and transportation from the place of origin to the destination.

Students must do the laundry at home for a week with the help of their families and classify the clothing based on its place of origin, using data from the labels. Once completed, they will geolocate the items using a Survey123 questionnaire. The data will be visible on a collaborative layer on a web map. They will present a well-reasoned, linguistically and grammatically correct argument on the economic and environmental impact of the textile industry, its location, manufacturing, and transportation; the gender bias in performing household chores, the socio-labour aspects in the domestic sector, and finally, on equal opportunities in democratic systems within the European Union, specifically in Spain. To do so, students will use a Google questionnaire (Appendix C). This questionnaire was chosen among others because the students are familiar with Google Space Work and items were derived deductively. Finally, the collaboratively created map will be visualized in class by the students to analyse the origin of the clothing they use at home, as well as the impact on the three dimensions of sustainability: economic, social, and environmental.

5. Results and Data Analysis

The results of each of the classroom interventions are presented below.

5.1. Spain in the World Cup

The results of this classroom intervention show that students have been able to find reliable information on the Internet, to geolocate each of the football matches of the various World Cups. All the geopoints are accurately located (Figure 3). Users have become skilled in using cloud-based GIS (web GIS) and have correctly applied copyright and Creative Commons licenses. Additionally, they have linked the achievements of the Spanish national team to the economic situation during each World Cups, as shown in the map pop-ups. Using the relational analysis rubric (Appendix A, Table A2), it is noted that the 16 reports score between level 3 (11 reports) and level 4 (5 reports). This indicates that the students have learned to analyse the context of the Spanish national team's World Cup results, their geolocation, and relate these to Spain's economic situation from 1935 to 2022, presenting their findings in a well-reasoned, justified, and accurate reports.

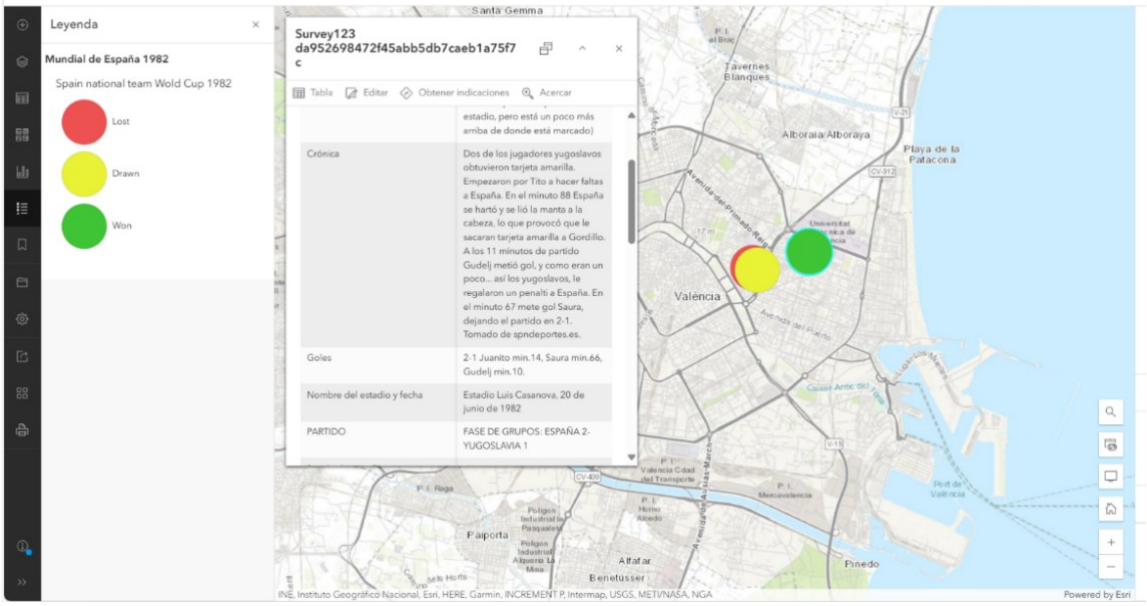

Figure 3. Spain in the Football World Cup web map. Developed collaboratively by K-12 students on ArcGIS Online ESRI Platform. Source: España en la Copa del Mundo de fútbol masculino

Part of their analysis concludes that the most successful period in Spanish football history is linked to the best economic performance in Spain's history. They associated this prosperous time with the inclusion of scientific training methods and the professionalization of football club structures, which, in their opinion, produced the best generation of footballers in Spanish history. For instance, in the 1950 World Cup, Spain ranked fourth, the best result until the first-place finish in 2010. While the Spanish economy at that time was not particularly strong, it had partially

recovered from the devastation of the Spanish Civil War, which ended in 1939. Other contenders' economies were in worse condition due to World War II. They emphasized that the 1950 World Cup was the first major international sporting event after the war, occurring two years before the Olympic Games in Helsinki.

To explain the best period in Spanish football history between 2008 and 2012, the students observed that these successful years followed the best economic period in Spanish history (2000-2008). Thus, they concluded that scientific training methods and the professionalization of football club structures were key to producing the best generation of footballers in history. This transdisciplinary activity allowed students to achieve these conclusions because they are familiar with football training methods in their school sports.

They highlighted the activity's high motivational value, as they are all football enthusiasts. They also appreciated the connection between a curricular task, such as the history of the Spanish economy, and a motivating element like the Spanish national team's World Cup journey. No areas for improvement were identified by the students.

5.2 Scientists in History

In this intervention, 24 out of 25 students correctly geolocated the points, with only one not completing it. Using the resulting map and data layer (Figure 4), students were able to perform a relational analysis of significant inventions in human history and their historical context.

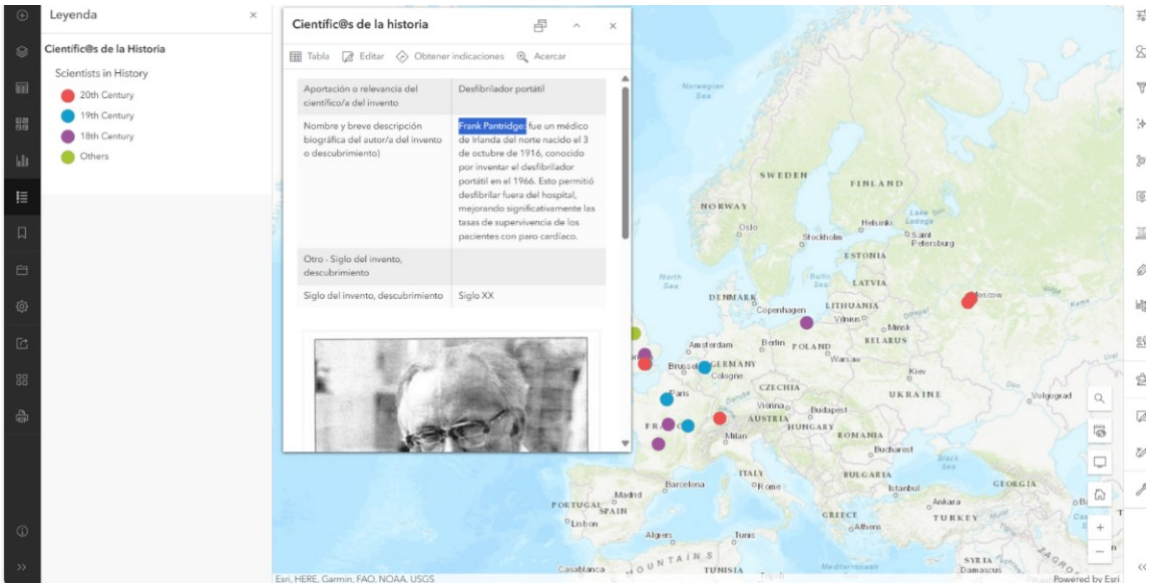

Figure 4. Scientists in History web map. Developed collaboratively by K-10 students on ArcGIS Online ESRI Platform. Source: https://bit.ly/3ZYb8ld

Twenty-five students scored in the higher levels of the rubric (Appendix A, Table A2) (level 3 and level 4), while two were in the lower levels (level 1 and level 2). The map visualization enabled a quick territorial analysis of the inventions and inventors. This activity helped students develop spatial thinking and analytical skills by searching for reliable information about inventors and their inventions online.

The experience encourages STEM students, both men and women, to pursue careers in science. The focus is on science as the driving force behind all major changes in humanity. Thus, Scientific Culture topic is enriched with geographical and historical context. Consequently, students learned the importance of scientific advancements and inventions in their respective times and places. The task outcomes are more comprehensive using the historical perspective and digital storytelling maps. Transdisciplinary arises from reflecting on the gender gap within the framework of Scientific Culture, Geography and History topics.

From a qualitative perspective, most students highlighted that relational analysis was easier with the use of the collaborative map. They also appreciated being able to choose inventions or discoveries themselves as working groups rather than having them assigned by teachers. Some students suggested that more class time should be allocated to avoid completing the activity at home.

5.3 Doing the Laundry

Of the 1057 points geolocated by the 42 students, 94.79% were correctly placed on the map (Figure 5), while 5.21% were incorrectly georeferenced.

The analysis of the argumentation of the responses to the 15 questions in the Google questionnaire shows that 30.5% were at the lowest level (level 1), 26.7% at level 2, 13.4% at level 3, and 30.4% at the highest level (level 4). Thus, 43.8% of the responses demonstrate strong argument skills.

This experimentation promoted competencies in sustainability, citizenship, critical thinking, and geospatial thinking, enhancing learning possibilities with cloud-based GIS (web GIS).

From a qualitative perspective, students appreciated being "made to think" by relating a daily activity, such as doing the laundry, to global economics, social differences, sustainability, and politics. They also enjoyed the cartographic geolocation experience. However, they disliked and expressed displeasure with the requirement to do the laundry for a week.

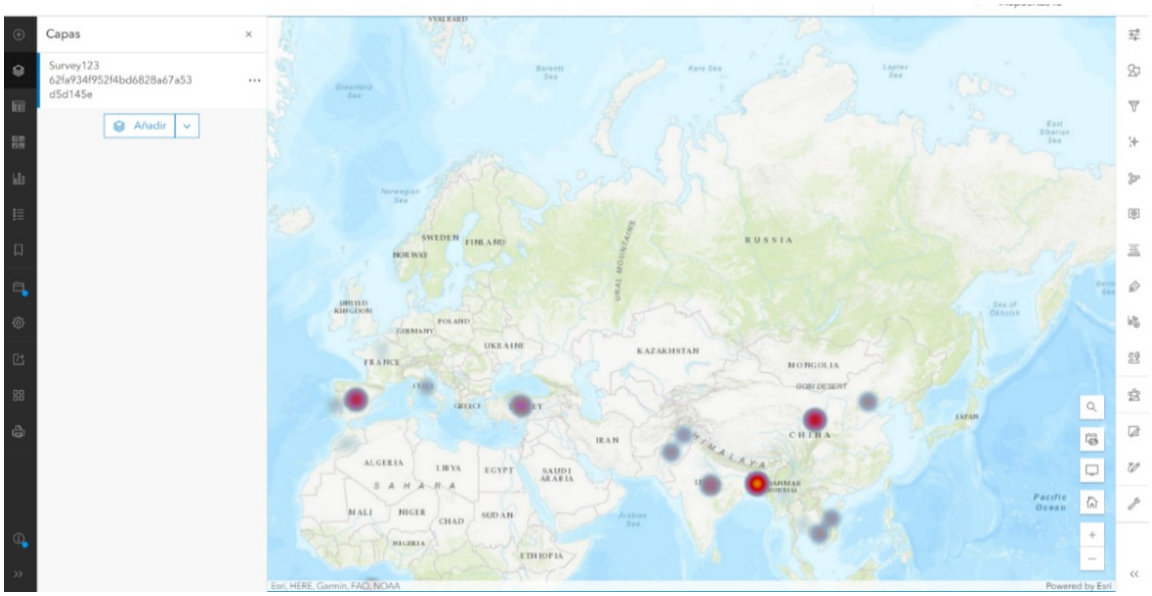

Figure 5. Doing the Laundry web map. (Heat map). Made using Surveay123 by K-10 students. Source: https://bit.ly/3Dfoxxo

5.4. Competences, Web GIS and Transdisciplinarity after the Class Experiments Interventions

The experimentation promoted competencies in sustainability, digital skills, learning to learn and citizenship using cloud-based GIS (web GIS). This promotion of competencies is reflected in table 3: Outcomes Competencies. In this context, it is proposed to work with the four competencies formulated by Murga-Menoyo, following UNESCO (2014) and OECD reports: critical analysis, systemic reflection, collaborative decision-making, and a sense of responsibility toward present and future generation. All these selected competencies for this study are included in the Spanish curriculum for each of the subjects participating in the study. They are identified as specific competencies to be developed in each subject. The following outcomes are based on the results obtained using the tools described in section 4.1.2: the Rubric for Collecting Data Related to Argumentation Skills (Appendix A, Table A1), the Rubric for Data Collection Related to the Ability to Analyse and Relate Ideas (Appendix B, Table A2), and the Google questionnaire (Appendix C). Moreover, all competencies related to the use of web GIS have been measured through direct observation of the layers and maps created by the students themselves (Table 4).

Table 4. Outcomes Competencies.

Competencies	Spain in the Football World Cup	Scientists in History	Doing the Laundry
Sustainability	• Critical thinking in searching for reliable information; be respectful with the copyrights and Creative Commons licenses. • Systemic reflection on economic issues and final winners of the World Cup. Relating the past and the present to identify trends and analogies.	• Critical thinking: searching for reliable information to conduct analysis. • Systemic reflection on scientific and technological advancement in historical and geographical contexts. • Ability to work in cooperative teams for decision-making and presentations.	• Critical thinking: searching for reliable information. • Systemic reflection integrating the dimensions of the Sustainable Development Goals (SDGs): environmental, social, and economic sustainability. • Sense of responsibility in studying environmental issues, with concern for present and future generations.
Citizenship	• Collaborative decision-making and teamwork with democratic values, respecting other students and taking turns to speak.	• Observing and reflecting on gender gaps.	• Empathy with domestic tasks. • Developing the ability to argue their own positions and respect others.
Learning to Learn	• Engagement in scientific curiosity and creating maps to study content.	• Autonomy in the learning process, following scientific methods and explaining relationships. • Ability to propose improvements to experiments.	• Using feedback to improve the argumentation of final reports.
Digital	• Familiarization with cloud-based Geographic Information Systems (web GIS), working with map layers and geolocation.	• Learning to locate scientists and becoming familiar with web GIS.	• Familiarization with digitalization processes.

Source: Own elaboration from direct observation.

5.5. Students' satisfaction about the class interventions

The satisfaction survey results for the Spain in the Football World Cup activity were very high. All students rated the activity 4 on the Likert scale, indicating complete satisfaction. Similar results were observed in the Scientist in History activity, where all students rated the activity as

satisfactory or very satisfactory, and none rated it as unsatisfactory or very unsatisfactory. Finally, 45 students rated the activity positively or very positively, while 10 students rated it negatively or very negatively (Table 5).

Table 5. Students' satisfaction survey following Likert scale.

Name of the intervention (academic years)	Academic year	Grade / Year	N	Satisfaction: positively or very positively	Satisfaction: Negatively or very negatively
Spain in the Football World Cup	2020-2021 2023-2024	K-12 (2º Baccalaureate)	103	103	0
Scientists in History	2023-2024	K-10 (4º Compulsory Secondary Education)	29	29	0
Doing the laundry	2023-2024	K-10 (4º Compulsory Secondary Education)	55	45	10 .

Source: Own elaboration.

6. Discussion

6.1. Achievements

The main objective of the research has been achieved, demonstrating that web GIS promotes transdisciplinarity and competency-based learning useful to engage in the real-world. This is evidenced by the high-performance of students in geolocation, as shown by the rubric and web maps created during the three interventions designed. The utility of web GIS with transdisciplinary approaches is confirmed by the collaborative maps created and a 95% student satisfaction rate, from anonymous surveys.

The transdisciplinary and global approach in the classroom using web GIS integrates various disciplines to enrich learning and contributes to transform educational practice. Cloud-based Geographic Information Systems (GIS) or web GIS have proven to be effective collaborative tools that facilitate education for sustainability in secondary education and promote competency acquisition in students.

There are no academic studies that have explored classroom interventions using cloud-based GIS or web GIS to integrate transdisciplinary and global approaches for improving competency acquisition. In this regard, web GIS has shown high performance in geolocation competencies with 96.16% of students achieving success. However, they have also acquired competencies in: i. Sustainability: Critical thinking and systemic reflection, using reliable information search, analytical and relational capacity, and reading comprehension to empower the capacity of collaborative decision-making and a sense of responsibility toward present and future generations (Murga-Menoyo, 2015; Álvarez-Otero & De Lázaro, 2018); ii. Digital skills: Using web GIS technology and digital resources to enhance spatial and critical spatial thinking, as students found cartographic visualization layers helpful for relational analyses (Buzo, 2021; Buzo-Sánchez et al., 2022); iii. Learning to learn: Students see how they can use different sources, including web maps to learn new things; iv. Democratic values: Developing more democratic and plural attitudes, respecting other students' thinking, arguing after hearing other opinions, and participatory citizenship (Álvarez-Otero et al., 2024; Santos et al., 2023). These competencies have been acquired in a transdisciplinary framework, which enhances the importance of transdisciplinary studies as it was thought before designing the activities that have been carried out in this work.

Besides, satisfaction surveys indicate a very positive perception among students (95.26% of cases) regarding the integration of web GIS and transdisciplinarity. Teachers share this positive view, aligning with the findings of Carlos and Moreira (2012) and Humble (2023).

The Spanish educational legislative framework allows for transdisciplinary and global approaches. However, curriculum compartmentalization by subjects and a teaching staff coming from a disciplinary university system make it difficult transdisciplinary approaches. Web GIS can mitigate these issues by serving as a collaborative and integrative resource with a global approach.

Overall, web GIS enhance geolocation competencies and a wide range of other skills and competencies (Ma et al., 2023). Nearly 70% of students achieve high performance in relational analyses and argumentation. That means that competencies have been improved using Web GIS in a transdisciplinary context activity.

All experiments can be easily replicated, also with any other topics of students' special interest or curriculum interests related to geography and history topic, and ethical and civic values. Some topic examples would be healthy eating habits, Spanish football teams to promote respect among different fans, women's football, literature to raise awareness of EU culture (De Lázaro et al., 2023), Global Change and Environmental impact (Leininger-Frézal et al., 2023), Human Rights and Social Justice among others that provide evidence to enhance critical thinking and all previously cited competencies.

6.2. Limitations, Recommendations, and Future Research Directions

The first limitation of this study is the challenge of applying transdisciplinarity within a curriculum designed for disciplinary approach and taught by teachers trained in a disciplinary university system. These factors complicate the implementation of a global and transdisciplinary approach. Consequently, the research focused on learning situations where multiple subjects shared a common program, integrating learning objectives from each discipline. The study did not address a common topic from disciplinary perspectives (multidisciplinarity), or seek convergence links between subjects (interdisciplinarity), but rather promoted transdisciplinarity.

The sample composition is done for convenience. While a random sample is more desirable, it is challenging to obtain in the school environment. However, the study is conducted with a significant sample (n = 187).

Regarding competency performance, the "Doing the Laundry" intervention, which involved many competencies, yielded less satisfactory results from the students' point of view. It is recommended to focus on a smaller number of competencies for more in-depth work.

Replicating the classroom interventions to expand the study sample, including other educational levels and different curriculum subjects would allow testing the experiment in various curriculum contexts. This could include other countries, different locations, and diverse topics.

7. Conclusion

The primary objective of the research has been achieved, demonstrating by the class experiments that web GIS fosters transdisciplinarity and competency-based learning, which is useful for engaging with real-world scenarios and promote education for sustainability. The results, such as a 95% student satisfaction rate, nearly 70% of students achieving high performance in relational analyses and argumentation, and over 96% of geolocation competencies using web GIS, indicate that competencies have been enhanced through the use of web GIS in a transdisciplinary context. The lack of academic studies exploring classroom interventions using cloud-based or web GIS to integrate transdisciplinary and global approaches for improving competency acquisition has posed a challenge due to the absence of existing references. This fact places the study at the forefront of research linking the three pillars of this work: transdisciplinarity, competencies, and the use of Web GIS in secondary education.

A limitation of this study is the challenge of applying transdisciplinarity within a curriculum designed for a disciplinary approach and taught by teachers trained in a disciplinary university system. The sample composition was done for convenience. While a random sample would be more desirable, it is challenging to obtain in the school environment. However, the study was conducted with a significant sample, making it robust.

Replicating the classroom interventions to expand the study sample, including other educational levels and different curriculum subjects, would enable the evaluation of the experiment in different curricular contexts.

This study aims to address a gap in educational research by integrating three pillars for the future of education using cloud-based GI (web GIS): transdisciplinary, technology, and the development of competencies and skills that promote education for sustainability, digital skills, learning to learn and citizenship.

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Appendix A

Table A1. Rubric for Collecting Data Related to Argumentation Skills.

Levels	Level 1	Level 2	Level 3	Level 4
Argumentation	There is no argumentation. The student presents content without order, merely reflecting vague ideas	Limited argumentation. Most of the content is reflected. There is no causal order, grammatical use is limited, and technical vocabulary is lacking.	Improved argumentation. The student can make an orderly and accurate argument. They can relate cause and effect factors but lack the required technical vocabulary.	Students can make a solid and orderly argument using complex grammatical structures and the required technical language.

Source: Own elaboration.

Table A2. Rubric for Data Collection Related to the Ability to Analyse and Relate Ideas.

Levels	Level 1	Level 2	Level 3	Level 4
Analysis	The students are not able to perform any analysis.	The students can present concepts separately, but without the ability to relate them.	Students can analyse information, relating different concepts in a partial way.	Students can perform a complete analysis relating to the different concepts studied.

Source: Own elaboration.

Appendix B

Satisfaction Survey. Questions for students:

1. Explain what you liked most about the activity.
2. Explain what you liked least about the activity.
3. What is your opinion on doing an activity shared by several subjects?

Appendix C

Google Questionnaire "Doing the Laundry"

1. Why is clothing manufactured in the locations shown on the map?
2. What are the consequences for those producing countries, which are mostly developing countries? Good, bad, or both? Explain.
3. What are the consequences for rich countries? Good, bad, or both? Explain.
4. What is the environmental cost of global clothing transportation?
5. In your family, is there a gender bias in the people who usually do the laundry? (Family members or hired help). If so, do you think it is fair or unfair? What can we do if you think it is unfair?

6. Do you like doing the laundry? Would you like to do this as a job? Explain your answer.
7. Why do you think people choose to work in domestic tasks professionally?
8. What level of education do you think people who work in households have?
9. What are the reasons for the social differences between the poor and the rich?
10. Do you think there is true equality of opportunity in Spain?
11. A state that does not guarantee equality of opportunity, is it a real democracy, or is it imperfect? Why?
12. How should a real democracy be? Is Spain one of them? Do you know any country that is?
13. What is the role of education in democratic development?
14. What can a 15/16-year-old student do for the democratic development of their country? Research who Greta Thunberg or Samantha Reed Smith are.

References

Acevedo-Osorio, Á., Hofmann-Souki, S. & Cruz Morales, J. (2020). Holistic competence orientation in sustainability-related study programmes: lessons from implementing transdisciplinary student team research in Colombia, China, Mexico and Nicaragua. *Sustainability Science, 15*, 233–246. https://doi.org/10.1007/s11625-019-00687-8

Akiri, I. (2021). Transdiciplinary as an educational paradigm of the future. *Education: Modern Discourses,* (4), 33-38. https://doi.org/10.37472/2617-3107-2021-4-04

Álvarez-Otero, J., De Miguel-González, R. & Sebastián López, M. (2024). El diseño participativo: un enfoque innovador para la educación geográfica en las aulas de Secundaria. *ENSAYOS, Revista de la Facultad de Educación de Albacete, 39*(2). https://doi.org/10.18239/ensayos

Álvarez-Otero, J. & De Lázaro y Torres, M.L. (2018). Education in Sustainable Development Goals Using the Spatial Data Infrastructures and the TPACK Model. *Education Sciences, 8*, 171. https://doi.org/10.3390/educsci8040171

Argibay, J.C. (2009). Muestra en investigación cuantitativa. *Subjetividad y Procesos Cognitivos, 13*(1), 13-29. https://www.redalyc.org/articulo.oa?id=339630252001

Azzari, M., Zamperlin, P. & Landi, F. (2013). GIS in geography teaching. *Journal of research and didactics in geography, 2*(2), 27-42. https://doi.org/10.4458/2379-03

Baker, T. R. (2015). WebGIS in education. In O. Muñiz Solari, A. Demirci, & J. Schee (Eds.), *Geospatial technologies and geography education in a changing world: Geospatial practices and lessons learned* (pp. 105-115). Springer. https://doi.org/10.1007/978-4-431-55519-3_9

Bednarz, S.W. (2004). Geographic Information Systems: A Tool to Support Geography and Environmental Education? *GeoJournal, 60*(2), 191-199. https://doi.org/10.1023/B:GEJO.0000033574.44345.c9

Blanchard Giménez, M. & Muzás Rubio, D. M. (2024). Retos y desafíos en la formación del profesorado universitario. *Revista HISTEDBR On-line Campinas, 24*, e024028-e024028. https://doi.org/10.20396/rho.v24i00.8674718

Buzo, I.J. (2021). *Aprendizaje inteligente y pensamiento espacial en Geografía*. (Doctoral Thesis, Universidad Complutense de Madrid). https://hdl.handle.net/20.500.14352/3439

Buzo-Sánchez, I.J., Mínguez, C. & De Lázaro-Torres, M.L. (2022). Expert perspectives on GIS use in Spanish geographic education. *International Journal of Digital Earth, 15*(1), 1205-1219. https://doi.org/10.1080/17538947.2022.2096131

Carbonell-Carrera, C., Saorin, J.L. & Hess-Medler, S.A. (2020). Geospatial Thinking Multiyear Study. *Sustainability, 12*, 4586. https://doi.org/10.3390/su12114586

Cárdenas, J. (2018). *Investigación cuantitativa*. Trandes. http://dx.doi.org/10.17169/refubium-216

Carlos, V., & Moreira, A. (2012, August 26-30). Contributions of transdisciplinary teaching and learning strategies supported by Geographic Information Systems to education for sustainable development – The point of view of the teacher [Conference presentation]. *32nd International Geographic Congress "Down to Earth"*, Cologne, Germany. https://www.researchgate.net/publication/322316968_Contributions_of_transdisciplinary_teaching_and_learning_strategies_supported_by_Geographic_Information_Systems_to_Education_for_Sustainable_Development_-_the_point_of_view_of_the_teacher

Choi, B.C. & Pak, A.W. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. *Clinical and investigative medicine. Medecine clinique et experimentale, 29*(6), 351–364. https://pubmed.ncbi.nlm.nih.gov/17330451/

Clark, B. & Button, C. (2011). Sustainability Transdisciplinary Education Model: Interface of Arts, Science, and Community (STEM). *International Journal of Sustainability in Higher Education, 12*(1), 41-54. https://doi.org/10.1108/14676371111098294

Council of Europe. (2018). *Reference Framework of Competences for Democratic Culture*. Council of Europe Publishing. https://www.coe.int/en/web/reference-framework-of-competences-for-democratic-culture/rfcdc-volumes

Daneshpour, H. & Kwegyir-Afful, E. (2022). Analysing Transdisciplinary Education: A Scoping Review. *Science & Education, 31*, 1047–1074. https://doi.org/10.1007/s11191-021-00277-0

De Lázaro Torres, M.L. & Morales Yago, F.J. (n.d.) *Investigación en innovación en la enseñanza de la geografía empleando tecnologías en la nube: mapas web y story maps*. https://arcg.is/1a4GXT

De Lázaro, M.L., Sánchez, I.B. & De Miguel González, R. (2023). Cartoteca digital de biografías de literatos europeos en Story Maps. *Boletín de la Real Sociedad Geográfica,* CLXI, 159-168. https://www.boletinrsg.com/index.php/boletinrsg/article/view/211

De Lázaro-Torres, ML., Puertas-Aguilar, MÁ., and Álvarez-Otero, J. (2023). Education for Sustainability Using Coud-Based Geographic Information Systems at University. In: Klonari, A., De Lázaro y Torres, M.L., Kizos, A. (eds) *Re-visioning Geography. Key Challenges in Geography. Book Series: Key Challenges in Geography* (pp.137-152). Springer, Cham. https://doi.org/10.1007/978-3-031-40747-5_8

De Miguel González, R. & De Lázaro Torres, M. L. (2020). WebGIS implementation and effectiveness in secondary education using the digital atlas for schools. *Journal of Geography, 119*(2), 74-85. https://doi.org/10.1080/00221341.2020.1726991

De Miguel González, R. (2024). Powerful geography and the future of geographic education. *Dialogues in Human Geography, 14* (1). https://doi.org/10.1177/20438206241229219

Delice, A. (2010). The Sampling Issues in Quantitative Research. *Educational Sciences Theory & Practice, 10*(4), 2001-2018. https://eric.ed.gov/?id=EJ919871

European Union. (2006). *Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning (2006/962/EC)*. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX%3A32006H0962%3AES%3AHTML

European Union (2018). *Council Recommendation on Key Competences for Lifelong Learning*. Official Journal of the European Union, C 189/01. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=oj:JOC_2018_189_R_0001

Fargher, M., & Healy, G. (2020). Empowering geography teachers and students with geographical knowledge: Epistemic access through GIS. In N. Walshe & G. Healy (Eds.), *Geography education in the digital world* (pp. 102-116). Routledge. https://doi.org/10.4324/9780429274909

Fiala, V., Freyer, B., Klimek, M. & Fahringer, A. (2018). How do you teach transdisciplinary competences for food and farming systems research? Insights from the course System Analysis and Scenario Technique. *Open Agriculture, 3*, 553-566. https://doi:10.1515/opag-2018-0059

García-Juan, L. & Vallina-Rodríguez, A. (2019). SIG y bases de datos. Oportunidades y retos en la transición de los sistemas tradicionales al Big Data; GIS and databases. Opportunities and Challenges in the Transition from Traditional Systems to Big Data. *Espacio Tiempo y Forma. Serie VI, Geografía, 12*, 135–158. https://doi-org.bibliotecauned.idm.oclc.org/10.5944/etfvi.12.2019.25124

Government of Spain. (2006). *Ley Orgánica 2/2006, de 3 de mayo, de Educación*. https://www.boe.es/eli/es/lo/2006/05/03/2/con

Humble, N. (2023). Future Paths for GIS in K-12 Education: A Review of Possibilities and Constraints. *European Journal of Geography, 14*(3), 79-88. https://doi.org/10.48088/ejg.n.hum.14.3.079.088

Huutoniemi, K., Klein, J.T., Bruun, H. & Hukkinen, J. (2010). Analyzing interdisciplinarity: Typology and indicators. *Research Policy, 39*(1), 79-88. https://doi.org/10.1016/j.respol.2009.09.011

Jo, I., Hong, J.E. & Verma, K. (2016). Facilitating spatial thinking in world geography using Web-based GIS. *Journal of Geography in Higher Education, 40*(3), 442-459. https://doi.org/10.1080/03098265.2016.1150439

Kerski, J. J. (2023). Teaching and learning geography with a web GIS approach. In: A. Klonari A, M.L. De Lázaro y Torres & A. Kizos (Eds.), *Re-visioning geography: Supporting the SDGs in the post-COVID era* (pp. 113-135). Springer. https://doi.org/10.1007/978-3-031-40747-5_7

Klingman, L.L. (2021). *Let's Get Digital! Using ESRIs ArcGIS StoryMaps as an Archaeological Education Tool.* (Doctoral dissertation, State University of New York at Binghamton). https://bit.ly/3f2RsFE

Kubisch, S., Parth, S., Deisenrieder, V., Oberauer, K., Stötter, J., & Keller, L. (2021). From transdisciplinary research to transdisciplinary education—The role of schools in contributing to community well-being and sustainable development. *Sustainability, 13*(306). https://doi.org/10.3390/su13010306

Lage Gómez, C. (2020). Aproximación transdisciplinar a la Música Popular Urbana en Enseñanza Secundaria. *Estudios pedagógicos (Valdivia), 46*(2), 159-176. http://dx.doi.org/10.4067/S0718-07052020000200159

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., & Thomas, C. J. (2012). Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustainability Science, 7*(1), 25-43. https://doi.org/10.1007/s11625-011-0149-x

Lee, J. & Bednarz, R. (2012). Components of Spatial Thinking: Evidence from a Spatial Thinking Ability Test. *Journal of Geography, 111*(1), 15-26. https://doi.org/10.1080/00221341.2011.583262

Leininger-Frézal, C., Sprenger, S., De Lázaro-Torres, M. L., Rodríguez-Domenech, M. Á., Heidari, N., Pigaki, M., Naudet, C., Lecomte, A., & Gallardo, M. (2023). Global change challenge in the higher education curriculum on the approach of blended learning. *European Journal of Geography, 14*(2), 1-14. https://doi.org/10.48088/ejg.c.lei.14.2.001.014

Lemoine, P. A., Hackett, P. T., & Richardson, M. D. (2017). Global higher education and VUCA – Volatility, uncertainty, complexity, ambiguity. In S. Mukerji & P. Tripathi (Eds.), *Handbook of research on administration, policy, and leadership in higher education* (pp. 549-568). IGI Global. https://doi.org/10.4018/978-1-5225-0672-0.ch022

Lewin, K. (1946). Action research and minority problems. *Journal of Social Issues, 2*(4), 34–46. https://doi.org/10.1111/j.1540-4560.1946.tb02295.x

Ma, Q., Duan, Y. & Yao, Z. (2023). Meta-analysis of the impact of geospatial technologies on learning outcomes. *Education and Information Technologies, 28,* 15739-15764. https://doi.org/10.1007/s10639-023-11712-w

Martínez-Hernández, C. (2025). Evaluación de competencias geográficas permitiendo el uso discente de la IA generativa. *Interdisciplinary Journal of Didactics, 2*. https://doi.org/10.14198/ijd.28999

Martínez-Hernández, C. & Mínguez, C. (2023). The Anthropocene and the sustainable development goals: key elements in geography higher education. *International Journal of Sustainability in Higher Education, 24*(7), 1648-1667. https://doi.org/10.1108/IJSHE-09-2022-0316

Martínez-Miguélez, M. (2004). *Ciencia y Arte en la metodología cualitativa*. Trillas.

Miles, M.B. & Huberman, A.M. (1994). *Qualitative data analysis: An expanded sourcebook* (4th Ed.). Sage. https://bit.ly/3SdZUG0

Milson, A. J. (2011). GIS in the cloud: Using WebGIS for teaching secondary geography. *Didáctica Geográfica, 12*, 151-153. https://didacticageografica.age-geografia.es/index.php/didacticageografica/article/view/66

Mínguez, C. (2021). Teaching tourism: urban routes design using GIS Story Map. *Investigaciones Geográficas, 75*, 25-42. http://dx.doi.org/10.14198/INGEO2020.M

Ministry of Education and Professional Training of Spain. (2022). *Real Decreto 217/2022, de 29 de marzo, por el que se establece la ordenación y las enseñanzas mínimas de la Educación Secundaria Obligatoria. Boletín Oficial del Estado*. https://www.boe.es/eli/es/rd/2022/03/29/217/con

Morales, M.P. (2019). Education in a VUCA (Volatile, Uncertain, Complex, Ambiguous) World. *The Normal Lights, 13*(2), 5-10. https://doi.org/10.56278/tnl.v13i2.2062

Mukherjee, F. (2019). Exploring cultural geography field course using story maps. *Journal of Geography in Higher Education, 43*(2), 201-223. http://dx.doi.org/10.1080/03098265.2019.1597031

Murga-Menoyo, M.Á. (2015). Competencias para el desarrollo sostenible: Las capacidades, actitudes y valores meta de la educación en el marco de la Agenda global post-2015. *Foro de Educación, 19*, 55–83. http://dx.doi.org/10.14516/fde.2015.013.019.004

Nicolescu, B. (1999). La evolución transdisciplinaria del aprendizaje. *Trans-pasando Fronteras, 4*, 39-50. https://doi:10.18046/retf.i4.1779

OECD. (2005). *Definition and Selection of Competencies (DeSeCo). Executive Summary 2005*. https://www.deseco.ch/bfs/deseco/en/index/02.parsys.43469.downloadList.2296.DownloadFile.tmp/2005.dskcexecutivesummary.en.pdf

OECD (2024), *Insights from Skills Strategies in the European Union: Lessons Learnt for Developing and Implementing Effective Skills Policies*, OECD Skills Studies, OECD Publishing, Paris, https://doi.org/10.1787/0bf9e78e-en

Pérez-Van-Leenden, M.J. (2019). La investigación acción en la práctica docente. Un análisis bibliométrico (2003-2017). *Revista Internacional de Investigación en Educación, 12*(24), 177-192. https://doi.org/10.11144/Javeriana.m12-24.ncev

Pons, J.J., Armendáriz, J. & Andreu, J. (2019). El story-map como herramienta didáctica y divulgativa en el ámbito de la Arqueología. In C. Ortega, M.Á. López-González & P. Amor Hernández (Eds.), *Innovación educativa en la era digital: libro de actas* (pp. 311-316). UNED. https://congresos.uned.es/w17905/15834

Puertas Aguilar, M. Á., Conway, B., De Lázaro-Torres, M.L., De Miguel González, R., Donert, K., Linder-Fally, M., Parkinson, A., Prodan, D., Wilson, S. & Zwartjes, L.A. (2022). Teaching Model to Raise Awareness of Sustainability Using Geoinformation: Un modelo docente para sensibilizar sobre la sostenibilidad empleando la geoinformación. *Espacio Tiempo y Forma. Serie VI, 15*, 23–42. https://doi.org/10.5944/etfvi.15.2022.33687

Puertas-Aguilar, M.-Á., Álvarez-Otero, J. & De-Lázaro-Torres, M.L. (2021). The Challenge of Teacher Training in the 2030 Agenda Framework Using Geotechnologies. *Education Sciences, 11*(8), 381. http://dx.doi.org/10.3390/educsci11080381

Puertas-Aguilar, M.Á., Sipols, A.E.G. & De Lázaro-Torres, M.L. (2023). Web GIS to learn geopolitics in secondary education: A case study from Spain. *European Journal of Geography 2023, 14*(2), 15-31. https://doi.org/10.48088/ejg.m.pue.14.2.015.031

Punie, Y. & Bacigalupo, M. (Eds.). (2022). *GreenComp. The European sustainability competence framework.* Publications Office of the European Union. https://data.europa.eu/doi/10.2760/13286

Rodán, A., Contreras, M.J., Elosúa, M.R. & Gimeno, P. (2016). Experimental but not sex differences of a mental rotation training program on adolescents. *Frontiers in Psychology, 7*, 1050. https://doi.org/10.3389/fpsyg.2016.01050

Sala, A., Punie, Y., Garkov, V. & Cabrera Giraldez, M. (2020). *LifeComp: The European Framework for Personal, Social and Learning to Learn Key Competence*. Publications Office of the European Union. https://doi.org/10.2760/922681

Salgado-Escobar, G. & Aguilar-Fernández, M. (2021). Hacia la transformación de los estudiantes: un proceso transdisciplinario para la educación superior. *Revista Iberoamericana para la Investigación y el Desarrollo Educativo, 12*(23), https://doi.org/10.23913/ride.v12i23.1057

Santaella Vallejo, A. & Ruiz Simón, E. (2023). La transdisciplinariedad educativa: análisis del marco conceptual, metodologías, contexto y medición. *Revista Iberoamericana de Educación, 92*(1), 15–28. https://doi.org/10.35362/rie9215747

Santos, B., Gonçalves, J., Martins, A.M., Pérez-Cano, M.T., Mosquera-Adell, E., Dimelli, D., Lagarias, A. & Almeida, P.G. (2021). GIS in Architectural teaching and Research: Planning and Heritage. *Education Sciences, 11*(6), 307. http://dx.doi.org/10.3390/educsci11060307

Santos, M.J.S., Carlos, V. & Moreira, A.A. (2023). Building the Bridge to a Participatory Citizenship: Curricular Integration of Communal Environmental Issues in School Projects Supported by the Internet of Things. *Sensors, 23,* 3070. https://doi.org/10.3390/s2306307

Scott, C. (2015). *El futuro del aprendizaje 2. ¿Qué tipo de aprendizaje se necesita en el siglo XXI?.* UNESCO Digital Library. https://unesdoc.unesco.org/ark:/48223/pf0000242996_spa

Sebastián López M., Kratochvíl O. & De Miguel González R. (2023). Geographic education and spatial citizenship: Collaborative mapping for learning the local environment in a global context. In: A. Klonari A, M.L. De Lázaro y Torres & A. Kizos (Eds.), *Re-visioning geography: Key challenges in geography. Springer* (pp. 177-191). Springer. https://doi.org/10.1007/978-3-031-40747-5_10

Sipos, Y., Battisti, B. & Grimm, K. (2008). Achieving transformative sustainability learning: engaging head, hands and heart. *International Journal of Sustainability in Higher Education, 9*(1), 68-86. https://doi:10.1108/14676370810842193

Spain. (2020). *Ley Orgánica 3/2020, de 29 de diciembre, por la que se modifica la Ley Orgánica 2/2006, de 3 de mayo, de Educación* [Organic Law 3/2020, of December 29, which amends Organic Law 2/2006, of May 3, on Education]. *Boletín Oficial del Estado*, núm. 340, December 30, 2020, pp. 122868–122953. https://www.boe.es/eli/es/lo/2020/12/29/3

Strachan, C. & Mitchell, J. (2014). Teachers' perceptions of Esri Story Maps as effective teaching tools. *Review of International Geographical Education Online, 4*(3), 195-220. https://dergipark.org.tr/en/pub/rigeo/issue/40895/493771#article_cite

UNESCO (n.d.). *Transforming Education Towards SDG 4: report of a global survey on country actions to transform education 2024*. Retrieved Octobre 28, 2024, from: https://www.unesco.org/en/articles/transforming-education-towards-sdg4-report-global-survey-country-actions-transform-education

UNESCO. (2014). *UNESCO roadmap for implementing the Global Action Programme on Education for Sustainable Development*. https://unesdoc.unesco.org/ark:/48223/pf0000230514

UNESCO. (2017). *Education for Sustainable Development Goals: Learning Objectives.* UNESCO Digital Library. https://unesdoc.unesco.org/ark:/48223/pf0000247444.locale=en

Vuorikari, R., Kluzer, S. & Punie, Y. (2022). *DigComp 2.2: The Digital Competence Framework for Citizens - With new examples of knowledge, skills and attitudes*. Publications Office of the European Union. https://doi.org/10.2760/490274

Viehrig, K., & Siegmund, A. (2012). Germany: Diverse GIS implementations within a diverse educational landscape. In A. Milson, A. Demirci, & J. Kerski (Eds.), *International Perspectives on Teaching and Learning with GIS in Secondary Schools* (pp. 107-115) Springer. https://doi.org/10.1007/978-94-007-2120-3_12

Waller, R.E., Lemoine, P.A., Mense, E.G., Garretson, C.J. & Richardson, M. D. (2019). Global Higher Education in a VUCA World: Concerns and Projections. *Journal of Education and Development, 3*(2), 73-83. https://doi.org/10.20849/jed.v3i2.613

Wilson, B., Wilson, N. & Sierra, M. (2021). Using GIS to Advance Social Economics Research: Geocoding, Aggregation, and Spatial Thinking. *Forum for Social Economics, 50*(4), 480-504. http://dx.doi.org/10.1080/07360932.2018.1509798