Transdisciplinary education for sustainability. Creativity and awareness in teacher training

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Teacher training is a strategic aspect to achieve quality education and, therefore, bring closer Horizon 2030 and sustainability. The aim of this work is to present the outcome of an innovative transdisciplinary educational proposal with 176 primary teachers in training with the goal of raising their sustainability awareness. It was implemented at the same time in a Social sciences subject and in an Social sciences one demonstrating both its transdisciplinary nature and the fact that sustainability is a transversal aspect in the curriculum. A mixed methods research design was used. Work products were analyzed, such as the creation of a digital story for children about sustainability and some related activities. In addition, the perceived impact of the educational experience in the teaching-learning process and sustainability attitudes were assessed using two validated questionnaires. The results show a high level of perception of the impact of the experience in the motivation of preservice teachers, the learning of concepts related to the subject, and, especially, the usefulness of this proposal for their professional future. Furthermore, their sustainability attitudes at the end of the semester were very high, with scores above 4 (out of 5) for all measured dimensions. The relevance of advocating for a transdisciplinary education for sustainability, which begins in teacher training faculties, is concluded.

KEYWORDS

preservice teachers, transdisciplinarity, sustainability, creativity, digital storytelling, teaching-learning process

1 Introduction

The need to adapt social policies and customs to achieve a more sustainable world is not a recent claim. It started in the 1972 Stockholm Conference on Human Environment and grew during the twentieth century and the beginning of the millennia. It was materialized in 2015 with the so-called Sustainable Development Goals (SDGs) of the United Nations (2015) along with the 2030 Agenda, the blueprint to achieve a better and more sustainable future for all.

The 2030 Agenda aims to eliminate extreme poverty, reduce inequalities and protecting the planet. It is universal in scope and commits all countries, rests on the interconnected and indivisible nature of its 17 SDGs and calls for the participation of all

segments of society. There are three core elements (social inclusion, economic growth, and environmental protection) and five critical dimensions: people, prosperity, planet, partnership, and peace (also known as the 5P's). The SDGs are the result of extensive political negotiations and individual consultations and are the focus areas necessary to achieve sustainable development.

During the last decades there have been many governmental projects related to Education for Sustainability as the Decade of Education for Sustainable Development (from 2005 to 2014) and the Global Action Plan (from 2015 on) from the UN. And there are also many private initiatives and projects regarding sustainability, i.e., Microsoft has pledged to achieve carbon negative status by 2030 or Starbucks has announced a reduction in its carbon emissions by 50% and a 50% of conservation or replenishing of its water withdrawal for direct operations and coffee production (Hestad, 2021).

Sustainable Development Goal 4 is the education goal and aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." Among its targets 4.7 focuses on the necessity that learners acquire both knowledge and skills to promote sustainable development, including sustainable lifestyles and behaviors. Thus, Education for Sustainable Development (ESD) is an integral part of SDG 4 and is recognized as a key catalyst for the other SDGs (United Nations, 2019). Since the greatest and most significant developments in a person's life occur during childhood and this development is considered the foundation upon which the rest of their life is constructed (Rutter, 2002), environmental/sustainability education should start from an early age.

It is known that environmental behavior is influenced by at least two types of environmental attitudes: toward the environment and toward environmental behavior (Kaiser et al., 1999). This relationship between environmental/sustainability attitudes and behavior has been the focus of various studies. For example, Levine and Strube (2012) demonstrated that knowledge about the environment and explicit attitudes influence behavior through different pathways. Interventions targeting both knowledge and explicit attitudes will be associated with behavior change: explicit attitudes predict intentions which in turn predict behavior, so interventions that change explicit attitudes impact behavior. In this sense, "promoting more favorable attitudes increases intention to act in an environmentally friendly manner and then people act on those intentions" (Levine and Strube, 2012: 321). Also, the Integrated Framework for Encouraging Pro-environmental behaviors (IFEP) (Steg et al., 2014) indicates that long-term behavioral changes can be attained by fostering pro-environmental attitudes.

In this sense, the impact of environmental education programs in the attitudes of primary school children have been long since demonstrated (Jaus, 1984). The influence of teachers in the environmental/sustainability attitudes of their students has also been described (Said et al., 2003). However, to be able to change their pupils' attitudes, future teachers should be themselves conscious of the current socio-environmental and socio-technological issues and have appropriate sustainability attitudes and beliefs. Consequently, teacher education is a key factor to achieve an effective sustainability education in the citizenship and there is a need for a more concerted effort in teacher

education to prepare future teachers adequately for their role in educating for a sustainable development (Esa, 2010).

According to Evans et al. (2017), there are four different approaches to embedding sustainability on teacher education: widely across curriculum areas, courses, and institution, through a dedicated compulsory subject, through a component of a compulsory subject, or through a dedicated elective subject. However, the authors conclude that sustainability education (SE) in initial teacher training is still an emerging area driven by individual concerned academics using a range of pedagogical approaches and strategies uncritically applied and with a small research base (generally under-theorized and descriptive). In this sense, there are many studies on early childhood and primary teachers' training focusing on different aspects of sustainability as ecological foot printing (O'Gorman and Davis, 2013), conceptions of the environment (Quinn et al., 2016), behaviors toward territory (Morote and Olcina, 2021), climate change (Hufnagel, 2015) or circular economy (Bugallo-Rodríguez and Vega-Marcote, 2020), among others.

Currently, ESD in initial teacher education is described as an emerging area of curricular activity (Evans et al., 2017). The efforts of passionate and concerned academics can embed SE at the micro-level in their own spheres of influence and within their subject area. At present there are many different areas tackling education for sustainability as English (Wright and Wright, 2010), home economics (Janhonen-Abruquah et al., 2018), chemistry (Cortes Junior and Fernandez, 2016) or the arts (Bentz, 2020), in addition to the traditional ones (science and geography). However, to achieve a change a more systemic, broad-scale approach is needed, working across diverse subjects, schools and/or disciplines, promoting more strategic or systemic approaches, as the mainstream change model, proposed by Ferreira and Ryan (2012) or a multi-level systems approach proposed by Evans et al. (2006). In this sense, there are recent studies focusing on a transdisciplinary approach in ESD, which can help understand and interpret the complex phenomenon of sustainability (Salīte et al., 2016).

Transdisciplinarity emerged as a critique of the conventional structuring of knowledge within academic disciplines and the curriculum (Bernstein, 2015). Today, transdisciplinarity is defined by its emphasis on addressing "wicked problems" that require innovative solutions, such as those related to sustainability (Max-Neef, 2005). Rocha et al. (2020) described different strategies to transition from a discipline-oriented university to inter- and transdisciplinarity. According to their model, scholars' interactions should be diversified and bidirectional, crossing the boundaries of traditional training, and focusing on learning-by-doing. This is in clear harmony with approaches such as competency learning, project-based learning or phenomenon-based learning, among others, that have highlighted the importance of transdisciplinarity as a key to explaining a new, more holistic, less ultra-specialized education.

In this sense, it is paradigmatic to advocate for a transdisciplinary education for sustainability, which brings together ecological, social and economic aspects. This is what defines the educational innovation project "Sciences and Arts," in which the didactic proposal presented and evaluated here is framed. This project was founded in 2017 at the faculty of teacher training at the University of Valencia and is currently composed of 20 teachers from different disciplines (environmental

sciences, geography, chemistry, history of art, and English, Spanish and French philology) working in Spain, Chile and USA. Its aim is to experiment with transdisciplinary education: to design, implement and analyze the outcome of educational experiences contributing to a true learning of competences through transdisciplinary learning (Padurean and Cheveresan, 2010; Clark and Button, 2011; Anastacio, 2020). Phenomenon-based learning is closely related to problem-based learning, and it involves preparing a list of important transdisciplinary phenomena for the explanation of relevant issues from the anthropological, historical and/or social point of view, in line with a holistic approach to education. A syllabus structured around these phenomena will compel not to separate related content, and especially the training of competences into different subjects. Sustainable Development Goals could be considered as a key transdisciplinary phenomenon and be the axis of the syllabus of any educational stage. Throughout the years, the "Sciences and Arts" project has promoted the design of transdisciplinary educational proposals implemented simultaneously in very diverse subjects and with great success. Several of them are presented in the recent book *The transdisciplinary turn* (Martín-Ezpeleta and Echegoyen-Sanz, 2022) and in the project website[1] innovative teaching materials are offered to the educational community. Focusing on transdisciplinary education for sustainability, several educational experiences have been monitored and their formative performance and very sensitive changes in the sustainability and environmental attitudes of future teachers have been demonstrated (Echegoyen-Sanz and Martín-Ezpeleta, 2021b,c; Martín-Ezpeleta et al., 2022).

Otherwise, it should be noted that "Sciences and Arts" mostly focuses on teachers in training and has a clear double objective: to improve their content knowledge, but also their pedagogical content knowledge (Shulman, 1987). It is known that student teachers judge interdisciplinary work as important but report little exposure during their teacher education (Biseth et al., 2022), so experiencing a new approach to learning and novel educational materials is a very valuable starting point to generate a didactic thought. This will show them the lack of necessity for separating content and competences into different subjects and the possibility of a true transdisciplinary learning. One of the tasks of these educational proposals is generally the didactic transposition (Chevallard and Bosch, 2014) with the creation of transdisciplinary educational materials for children inspired by the ones used in their own training.

Finally, the importance of another transdisciplinary aspect such as creativity should be addressed. As one of the key competencies for the 21st century society (Henriksen et al., 2016), it has been recognized by the OECD in its reports (OECD, 2019) and the focus of the last PISA tests (a creativity thinking test was included in the 2022 edition). Innovation and creation of new knowledge is demanded by companies and social organizations around the world (Soulé and Warrick, 2015). For this reason, there are references to creativity in the syllabus of many countries (Patston et al., 2021), including Spain (BOE, 2020), where this research was conducted. Creative thinking is also considered as a relevant skill in the recent European sustainability competence

framework, the greencomp (Bianchi et al., 2022). It is included in competence area 4.3 Envisioning sustainable futures (p. 23), where a reference to transdisciplinarity is also included. The greencomp also highlight that the pedagogical approaches taken in education on sustainability must encourage learners to develop abilities in creative thinking, since close links between the two have been reported (Daskolia et al., 2012). In this context, the role of teachers in developing pupils' creativity has been demonstrated (Suacamram, 2019) and it is believed that teachers must have developed their own creativity to be able to do so (Chan and Yuen, 2014; Yates and Twigg, 2017). Thus, teachers need to recognize creative thinking and understand what drives it and how they can guide their students in that direction.

In this context, there is a need to monitor educational proposals for preservice teachers with a transdisciplinary approach and a real impact in their teaching-learning process and the development of different competences. These proposals should be able to foster the sustainability attitudes of preservice teachers, while training them to prepare the materials needed for an effective education for sustainability with their future pupils. Thus, the aim of this work is to analyze the outcome of a transdisciplinary teaching unit to raise awareness about socio-environmental and socio-technological issues that was implemented at the same time in a social sciences subject and in an experimental sciences subject with preservice teachers, attending to aspects such as the products generated, the teaching-learning process, and their sustainability attitudes.

2 Materials and methods

Here we present a descriptive case study in which we employed a mixed methods research design combining quantitative and qualitative methods.

2.1 Participants

Participants were undergraduate students at their third or last year of the degree in Primary Education at a large public Spanish university. Data reported here was collected during two academic years (2020–2021 and 2021–2022) and pertain to five groups of students attending either "Science teaching: Matter, Energy and Machines" (subject taught in English) ($N = 73$) or "Social Sciences teaching: applied aspects" ($N = 103$) of the degree in Primary Education. Age of the 176 preservice teachers varied between 19 and 35 years with a mean age of 21.04, and a standard deviation of 1.64; 135 (76.7%) were female and 41 (23.3%), male, which corresponds to the typical distribution in the Spanish preservice teachers' population.

2.2 Description of the educational proposal

As explained in Morote et al. (2021), where some preliminary results with a smaller sample were analyzed, the educational experience was designed according to the pattern of socio-formative didactic sequences (Tobón et al., 2010) and the

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1   www.uv.es/ciencylet

model of complementary tasks. The use of storytelling is believed to be a good approach to addressing challenging issues regarding sustainability through holistic learning processes (Furu et al., 2021) and promoting creativity (Echegoyen-Sanz and Martín-Ezpeleta, 2021a).

The students, working collaboratively in small groups of 3 to 5 students, had to didactically transpose a cultural product (a dystopia) for adults and make it suitable for children through the elaboration of a digital story. Dystopias are those science fiction narratives drawing terrible worlds, but likely to be real on many occasions. They are a very good resource to become aware of various social and environmental problems related to sustainability, in addition to scientifically assessing the scientific-technological aspects that usually appear (not always accurate). Students attending the subject "Social Sciences Teaching: Applied Aspects" had to incorporate this digital story into a session of a larger didactic unit. Students attending "Science Teaching: Matter, Energy and Machines" had to elaborate the digital story connecting with didactic activities for primary education pupils that would enhance its formative interest and open the door to a transdisciplinary didactic education/reflection.

The sequence consisted of three phases: the first was the selection of an artistic-cultural product in which the context was a dystopian world, although not necessarily its main theme. As noted, the premise was that this cultural product (which could be a movie, a video game, a book, a comic, a television series, etc.), had to be aimed at an adult audience, that is, for themselves. Science fiction and specifically dystopias are present in books, movies, video games and, especially, television series, with great popularity among adolescents and young people. In Martín-Ezpeleta and Echegoyen-Sanz (2021) (pp. 380–382) some titles are listed as an example, and reflections are made on the so-called transmedia narratives (von Stackelberg and Jones, 2014). There are many cultural products related to climate problems presenting devastated or devastating worlds because of bad decisions in terms of caring for the environment, which are completely related to SDGs 7, 13, 14, or 15. These dystopian fictions are called ecological dystopias and are believed to be unbeatable starting points for the transformation in the classrooms and the raise of the environmental awareness demanded by the UN.

Second, the students had to select a part of their cultural product, the one most pertinent to work on the theme they had decided on and prepare a digital story for primary education pupils to take advantage of the motivational benefits of the digital format, both for the authors and for the recipients. It was essential, therefore, that they make decisions to adapt what they had understood/thought so that it would also be processed profitably by the children. The creative possibilities were enormous, since it was legitimate to base themselves as literally as they considered appropriate on the original artistic-cultural products, modify characters, introduce new plot components (characters, space, time) or even generate spin-offs with slightly different plots anchored in the original products. In addition, the format of the digital story invited to add music in the form of a soundtrack and sound effects, in such a way that it was attractive and more credible for children. Some of the software recommended for students to prepare digital stories were the very intuitive Powtoon, Toontastic, Videoscribe, Storyjumper, Storybird, Animaker, etc., which have tutorials in all cases.

Finally, the social sciences students had to integrate this story into a session of a larger didactic unit. In the case of the experimental sciences students, they had to design at least three didactic activities related to the digital story of a multi-inter-transdisciplinary nature, with the idea that the children would learn not only from the scientific subject dealt with; but also develop other basic skills that traditionally seem expelled from science classes, as literary reading or creative writing, for example.

2.3 Quantitative and qualitative analysis

The information on the effects of this educational experience was collected in an online survey during class time at the end of the semester. It included some demographic and *ad hoc* questions about the experience and two validated questionnaires. The first one was based on the one developed by Gómez-Carrasco et al. (2020), which assess the effects of educational programs on motivation, satisfaction and learning effectiveness. It uses a Likert rating scale (1–5) consisting of four thematic blocks. They addressed the perceptions of preservice teachers on how the didactic sequence including the preparation of the digital story had affected (1) their enjoyment of the subject, (2) their learning of concepts related to the subject, (3) their motivation, and (4) the usefulness for their professional future. The second one, used to assess the sustainability attitudes of preservice teachers, was the "Attitudes toward Sustainable Development scale" (Biasutti and Frate, 2017). It is composed of 20 items and uses a Likert rating scale (1–5) with four dimensions: environment, economy, society and education.

Reliability of both questionnaires was assessed via Cronbach's α. Values of 0.908 for block (1), 0.867 for block (2), 0.800 for block (3), and 0.839 for block (4) were obtained for the first questionnaire and values of 0.854 for environment, 0.837 for economy, 0.767 for society and 0.908 for education were obtained for the second questionnaire.

Qualitative analysis of digital stories and activities was carried out using Atlas.ti v8. The hermeneutical unit of analysis was composed of 39 digital stories and 39 proposals of activities prepared by the different groups. For the analysis of digital stories an iterative analysis was carried out that consisted of careful viewing, transcription of the stories, organization, interpretation and summary. Firstly, the stories were watched several times and they were transcribed. Later, after familiarization with the data, initial codes were created according to the socio-environmental aspects included, as described in a previous study (Echegoyen-Sanz and Martín-Ezpeleta, 2021a). For the analysis of the proposed activities, also an iterative analysis was carried out that consisted of a first careful reading to define the rules and the creation of initial categories according to the competences that the pupils will develop, and the subjects related to them (which will give an indication of the transdisciplinarity of the proposals), and was subsequently coded, following the process called "open coding" (Rodríguez, 1996). The final codes were exclusive with no overlapping between them. The activity proposals were coded by two coders. One week after completing the original coding, the coders recoded 10 activities again. Inter- and intra-coder agreement was greater than 85%.

2.4 Statistical analysis

Statistical analysis was done using SPSS software version 26. Particularly mean and standard deviation was calculated for each of the blocks in the questionnaire. To check the normality of the distributions Kolmogorov–Smirnov test for one sample was used. When distributions were non-normal Mann–Whitney U test for independent samples was used. For normal distributions, t-test for independent samples was used. In all cases the significance level was 0.05.

3 Results

3.1 Selected cultural products

It was surprising that many groups of students in the Social Sciences subject did not specify any cultural-artistic product acting as a reference. This may indicate, in addition to the lack of interest in the task, the limited access to the collective imagination, since even the biblical Apocalypse could be considered one. Also, very known literary, cinematographic or television fictions such as *Armageddon*, *iRobot* or *Walking Dead,* certain paintings by El Bosco or Goya or some video games like *Final Fantasy*, etc. could had been used as a dystopian cultural product. All the groups attending the social sciences subject indicated a cultural product as the basis of their digital story.

Of those that have specified artistic-cultural references, 66.7% of the groups selected a movie as their starting point, 22.2% selected a TV series and 11.1% selected a book. In the social sciences class, some selected movies were related to environmental aspects (climate change, natural disasters) like *Tomorrowland*, and other were related to social problems (depopulation, housing, etc.), like the Spanish movie *Barrio* (Neighborhood). An example for a book selected in the Social Sciences subject was *Hasta aquí llegó la riada* (Up to here the flood came), which narrates the event of one of the most important floods that occurred in the city of Valencia in 1957. No TV series were selected by any group in the social sciences class. As for the groups attending the experimental sciences class some of the selected films were *City of Ember*, in which a global catastrophe leads to mass extinction, or *The Day After Tomorrow*, which shows the consequences of climate change. As for the TV series, some were of a documentary type such as *Chernobyl*, related to the nuclear catastrophe that occurred in 1986; and others of science fiction, such as *The 100*, in which humanity has to migrate to space after a nuclear apocalypse, or *Revolution*, which fictionalizes a global energy blackout. One of the books selected was *Dry*, related to the problem of drought. They also highlight cultural products that describe the problems that could arise in overly technological societies, such as a particular episode of *Black Mirror*.

3.2 Prepared digital stories and teaching materials

In the social sciences subject, the created digital stories were mainly dystopias related to environmental problems mostly regarding water scarcity. Others were set in societies where the climate change due to anthropogenic pollution must be reversed. In the experimental sciences subject in most cases, a global disaster due to undetermined issues or unsustainable development and mistreatment of the environment (pollution, overexploitation of natural resources, use of non-renewable energies, etc.) was described, although in one case the origin of the problem was an extraterrestrial invasion. The consequences were that societies must change their way of life, either by emigrating to space, underground, under the sea or getting used to living in an Earth different than before. On other occasions dystopian societies not so related to environmental problems but those derived from an abuse of technology in society are described.

Here we show some examples of the storyline of digital stories created in both subjects (a screen capture of three of them is shown in Figure 1):

Example 1: An imaginary society is described in which the protagonists of the story are two drops of water (mother and daughter) who experience the flood of the city of Valencia (1957) in the first person. Therefore, these drops of water tell the story of the flood from the moment they are born in the clouds until they arrive and flood the city of Valencia.

Example 2: The story presents a society in which a group of people have access to a machine in which they can see the negative effects that climate change will generate in the future. Thanks to this machine, a group of people carries out an action plan to raise awareness among humanity and thus solve the problems that accelerate climate change.

Example 3: The Earth is toxic after an undetermined natural disaster, and humanity migrates to Jupiter's moon. Two people remain living on Earth, and we see their video diary in which they narrate their day-to-day life and the problems they encounter. In those videos they also talk about the need for responsible energy consumption, and the importance of a sustainable development.

Example 4: There is a great shortage of many resources on Earth due to their overexploitation. The story describes the situation when a family discovers that due to the experienced draught, the neighboring city has decided to close the dam and keep the water resource for themselves, and they have no access to that essential good.

Example 5: An extremely technological society in Madrid is presented. At a certain moment electricity is no longer available and, suddenly, they must change their way of relating to each other and of carrying out daily actions.

The socio-environmental problems dealt with in the stories designed by the groups of students were also examined. In the Social sciences subject, two types of problems have been differentiated: (1) those related to environmental issues, and (2) those linked to social issues. When focusing on social issues, the problems addressed were gentrification (poverty, urban speculation), touristification and depopulation. When focusing on environmental issues, they mainly addressed climate change and its derived effects such as natural risks (floods, droughts). Usually, the main causes of climate change are described, focusing (in a non-technical way) on pollution.
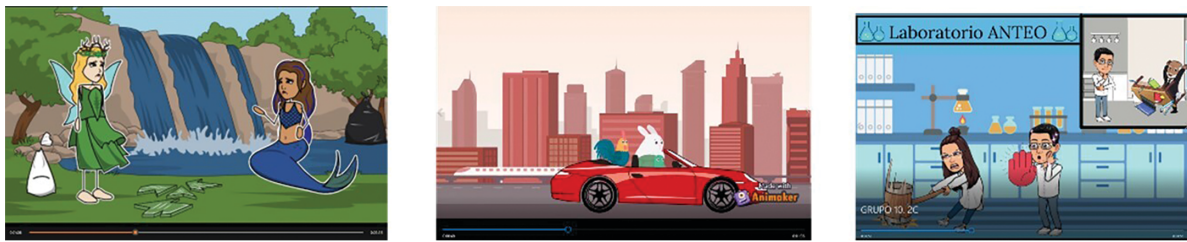
FIGURE 1
Some images of the created digital stories.

In the experimental sciences subject some groups used the digital stories to focus on conveying basic scientific questions (such as gravity, electricity, or sound) to primary education students, with the action set in a dystopic world. Others focused on recent scientific-technological advances and how these have affected our society. Most stories include scientific concepts directly related to sustainable development, either in a generic way focusing on specific problems such as water scarcity or problems related to the proliferation of waste and its possible mitigation following the 3R. However, most of the groups that relate their work to socio-environmental problems do so with the use and generation of energy, the new energy models, and the explanation of the importance of using renewable energies. They also deal with the adaptation of society to the new living conditions, after the disasters that have taken place, science being in most cases the great ally of humanity to overcome all these problems and difficulties.

The students in the experimental sciences group were also asked to prepare at least three didactic activities aimed at primary education children related to the digital story. It was suggested that these be as varied as possible and preferably inter or transdisciplinary in nature, so that they serve to develop content and skills related to different subjects and competences in the primary education curriculum. The different proposals varied between 1 and 8 subjects/competences integrated in the prepared activities, with most of the groups being able to address 4. The percentage of groups integrating each of the subjects/competences are shown in Table 1. As can be seen, the majority of the groups incorporated activities related to Spanish (either related to reading comprehension or oral/linguistic competences) or art (mainly crafts with recycled materials) in their activities. Almost one third of the groups also incorporated activities that included competences related to social sciences or that were conducted in English to promote pupils' communicative competence in that language. Other groups were also able to integrate activities related with subjects such as mathematics, music, technology, ethics, or physical education, demonstrating their ability to address sustainability issues with a transdisciplinary approach in primary education.

3.3 Impact of the experience in the teaching-learning process

The analysis of the responses to the *ad hoc* questionnaire shows how this transdisciplinary proposal that included the creation of digital stories was highly appreciated by the students. In fact, 81.71% of them affirm that they liked the assignment of preparing a digital story. They considered the study of STSE (science-technology-society-environment) relationships in primary education classrooms as very (80.55%) or quite (19.45%) important. As for the importance of integrating content using a transdisciplinary approach to different issues, they also considered it very (59.7%) or quite (35.8%) important, only 4.5% of the preservice teachers considered it of little importance.

Table 2 shows the descriptive statistics for the different blocks of the first questionnaire. It can be seen how the students considered that this transdisciplinary proposal helped them enjoy the subject more, acquire concepts related to the subject and was able to motivate them toward the subject, but most of all, they see it as a good way to practice the didactic transposition and train in methodologies that will be very useful in their professional future.

When we compare the results according to the subject that the students were attending, we can see how for all four blocks students attending the Social sciences subject considered that the transdisciplinary educational experience made them enjoy more the subject, helped them more to acquire concepts related to the subject, motivated them more toward the subject and considered it more useful for their professional future than the Social sciences subject students, although the difference was lower for the last dimension. Results of the Mann-Whitney U test show how these differences were statistically significant in all cases, as can be

TABLE 1 Subjects different than "natural sciences" included in the activities prepared by preservice teachers in the experimental sciences group.

Subject	Percentage of groups
Spanish	61,54
Art	53,85
English	34,62
Social sciences	30,77
Mathematics	23,08
Music	23,08
Technology	15,38
Ethics	7,69
Physical education	3,85

observed in Table 3. The calculated size effects were low for enjoyment ($g = 0.46$), learning ($g = 0.48$), the total impact ($g = 0.40$) and motivation ($g = 0.31$), and negligible for usefulness ($g = 0.16$).

3.4 Impact of the experience in the sustainability attitudes

As for the sustainability awareness of preservice teachers at the end of the semester in which the educational experience was implemented, the results for the different dimensions are displayed in Table 4. As can be seen, the scores are very high (above 4) for all the dimensions of the questionnaire, although somewhat lower in the environment dimension, with a mean value of 4.15. The highest scores were found for the education and society dimensions, with mean values above 4.5. No statistically significant differences were found for any of the dimensions between the students attending the social sciences and the environmental sciences subjects for any of the dimensions of the questionnaire: environment ($z = 0.777$, $p = 0.437$), society ($z = 0.069$, $p = 0.945$), economy ($z = -0.709$, $p = 0.479$), or education ($z = 0.225$, $p = 0.822$), nor for the global sustainability attitudes ($z = 0.033$, $p = 0.974$).

If we compare them with other assessments of the sustainability attitudes of preservice teachers using the same instrument, we can observe how they are higher than those reported for Spanish preservice teachers (Echegoyen-Sanz and Martín-Ezpeleta, 2021b), with statistically significant differences for the environment dimension ($z = 6.568$, $p < 0.001$), with a medium size effect ($d = 0.69$). The difference is bigger if we compare them to the

sustainability attitudes of preservice teachers in Jordan (Abu-Alruz et al., 2018), with statistically significant differences for all dimensions: environment ($z = 23.812^*$, $p < 0.001$), society ($z = 20.520$, $p < 0.001$), economy ($z = 13.672$, $p < 0.001$), and education ($z = 17.633$, $p < 0.001$), all of them with a large size effect (values of d were 2.30, 1.80, 1.57, and 1.82, respectively) or the global sustainability attitude of Pakistan (Nousheen et al., 2020) preservice teachers after an ESD course ($z = 2.568$, $p = 0.011$) with a moderate size effect ($d = 0.49$). This difference found in the sustainability attitudes of preservice teachers from different cultures could be due to the level of economic development, which is known to affect the value systems in a society (Schwartz, 2004) and, consequently, their sustainability consciousness (Berglund et al., 2020).

4 Discussion

This educational proposal had the goal to raise awareness in preservice teachers about the importance of addressing sustainability issues in educational settings. It can be considered a success since after the experience all of them considered very or quite important to address STSE relationships in the classroom and their sustainability attitudes were very high at the end of the semester, higher that those reported for preservice teachers in previous studies (Abu-Alruz et al., 2018; Nousheen et al., 2020; Echegoyen-Sanz and Martín-Ezpeleta, 2021b,c).

As explained, to achieve a true sustainable development, teachers are considered key, since a successful implementation of ESD in schools depends on the competencies and motivation of the teachers (Ferreira et al., 2007; Brandt et al., 2019). These competencies as ESD educators refer to the mixture of knowledge and awareness about sustainability issues and their ability and willingness to plan and organize learning activities. Our results show that teachers in training are aware of the importance of education to address sustainability issues. However, a review study made by Pegalajar-Palomino et al. (2021) showed that prospective teachers' attitudes toward sustainability and ESD were favorable, and they were committed to the environment, although they had a deficit in the development of professional skills needed to implement ESD. The educational proposal described above aimed at providing preservice teachers with some tools useful to address sustainability issues in their future classes. This will lead to develop pupils' capacities to understand and act for sustainability issues.

From the analysis of the cultural products for adults selected in the first phase of the educational experience it is clear that these future teachers have a much broader cinematographic than literary

TABLE 2 Descriptive statistics obtained for the different blocks of the questionnaire about the impact of the educational proposal.

Dimension	Min	Max	Mean	SD
Enjoyment	1.0	5.0	3.98	0.88
Learning	1.0	5.0	3.82	0.89
Motivation	1.0	5.0	4.00	0.87
Usefulness	1.0	5.0	4.27	0.84
Total impact	1.0	5.0	4.02	0.78

TABLE 3 Differences according to subject for the blocks of the questionnaire about the impact of the educational proposal.

Dimension	Subject	Mean	SD	Z	p
Enjoyment	Social Sciences	3.82	0.81	4.060	0.000***
	Experimental Sciences	4.22	0.94		
Learning	Social Sciences	3.65	0.83	3.923	0.000***
	Experimental Sciences	4.07	0.94		
Motivation	Social Sciences	3.89	0.83	2.740	0.006**
	Experimental Sciences	4.16	0.91		
Usefulness	Social Sciences	4.21	0.74	2.121	0.034*
	Experimental Sciences	4.34	0.95		
Total impact	Social Sciences	3.89	0.71	3.629	0.000***
	Experimental Sciences	4.20	0.85		

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

TABLE 4 Descriptive statistics obtained for the different dimensions of the "Attitudes toward sustainability" questionnaire.

Dimension	Min	Max	Mean	SD
Environment	1.2	5.0	4.15	0.71
Society	1.2	5.0	4.54	0.70
Economy	1.0	5.0	4.33	0.79
Education	1.0	5.0	4.59	0.79
Total	1.10	5.00	4.40	0.68

culture. This is logical, since the youth of today is highly influenced by globalization and advances in technology and even literature students prefer watching movies to reading books (Azizi et al., 2023). Nowadays audiovisual media play a central role in access to information in preservice teachers and the need to undertake actions to develop the training of students in the didactic use of cinema has been pointed out (Lorenzo-Lledó et al., 2022). It is also apparent that their referents are very contemporary, since there are no products prior to 2000, and that in the case of the Social sciences students were more diligent to the entrusted task. In any case, most groups were able to efficiently translate the original cultural product into a story for children in a process of didactic transposition through the creation of the digital stories. In general, the problems addressed in the stories were different for the students of both subjects: while the students in the social sciences subject focused equally on problems related to social issues and environmental issues, the students of Social sciences dealt mainly with environmental issues and problems related to an overly technical society. Regarding these environmental problems, the Social sciences students focused on climate change and natural resources (pollution, water scarcity), while the Social sciences students did on use and generation of energy and the importance of a change in the energy model toward the majority use of renewable energy (changing from an energy generation based on fossil fuels to thermal or photovoltaic solar energy).

As Barth and Michelsen (2013) stated, learning to work and reflect in transdisciplinary manners is highly strategic and at the core of collective action for sustainability. From the analysis of the proposed activities for children around the prepared digital stories, it can be seen how future teachers have been able to incorporate and merge content and skills of very different subjects, betting on a holistic and transdisciplinary education. Thus, it could be affirmed that preservice teachers have rehearsed phenomenon-based learning as students and as teachers, overcoming the curricular/disciplinary compartmentalization existing in higher education but not so much in the early childhood and primary education curricula. Currently, with a recent educational law (BOE, 2020), there is in Spain a commitment to extend learning by areas to secondary education, following the model set at primary education. Therefore, the future of compulsory education in our country will be much more transdisciplinary as happened in other countries like Portugal, with very good results (Martins Azinheiro et al., 2021).

These future teachers had no difficulty experimenting with this type of learning and did so very naturally and with a complementary dose of motivation, a critical ingredient for learning (Pintrich. 2003). The analysis of the responses to the first questionnaire indicated that their perception of the transdisciplinary educational proposal was very positive. They considered that it was able to improve their enjoyment of the subject and motivated them, as well as helped them to improve their learning and understand some of the concepts of the subject it was implemented in. These results are coherent with others that report increased motivation with the use of digital storytelling in the classroom (Hung et al., 2012; Yang and Wu, 2012; Smeda et al., 2014). In addition, they highlight this proposal as very useful for their professional future. When comparing the responses of the students attending both subjects, we can see how students attending the social sciences subject obtained higher values for all dimensions of the questionnaire than those attending the Social sciences

Subject. These differences were statistically significant for all the blocks of the questionnaire (enjoyment, learning, motivation, and usefulness) and the total impact. These results (and the fact that the selection of the cultural products was more accurate to the instructions given by the teacher in the Social sciences subject) seem to indicate that by including the transdisciplinary proposal in a more complex assignment (as was the preparation of a complete teaching unit) in the Social sciences subject the students were not so able to focus on the part related to the transdisciplinary task and did not consider it as rewarding.

As explained above, the impact generated by digital storytelling is not new. But it is worth emphasizing that the development of creativity is a transversal competence that can be trained with the preparation of digital stories, which are believed to be at the crossroads between the creative and the analytical, being both product and process able to empower students (Malita and Martin, 2010). The proposal described here was an educational opportunity to connect conceptual content (dystopias, environmental problems, etc.), procedural content (writing dialogues, managing editing software of videos, etc.), and attitudinal content (prestige of good sustainable actions, sense of usefulness of culture, etc.). Even though not all the groups worked with the same intensity (or enthusiasm), there is no doubt that the students activated very formative processes while working on the different phases of the assignments.

5 Conclusion

This study presents certain limitations derived from the sample size and the fact that it was a convenience sample. There is also the possibility of enriching the assessment process with new instruments, i.e., related to the students' reflection on their own work products or even the preparation process. In any case, it allows us to demonstrate that environmental problems do not only belong to the field of experimental sciences, and that it is more interesting to approach them in a transdisciplinary way. Specifically, this educational experience, monitored with a standardized test on sustainability attitudes, has served to stimulate different basic competencies of future teachers. It has helped them to assimilate a new way of transdisciplinary teaching-learning, bringing together aspects as important as creativity and sustainability.

In this sense, the analysis of the outcome of this educational experience confirms that the implementation of transdisciplinary teaching units is possible and desirable in teacher training. Enhancing sustainability awareness, motivation and learning can be achieved by relating real problems, technical/disciplinary issues, and artistic-cultural products. And this is not incompatible with the recreational and creative use of ICTs. The results show that this group of teachers in training successfully applied a process of didactic transposition by assimilating and adapting complex and transdisciplinary content, a work methodology and even a creative task of a narrative and digital nature, promoting their technological pedagogical content knowledge and their awareness about sustainability issues. Everything demonstrates, therefore, that these future teachers have assimilated the benefits of a transdisciplinary education for sustainability that they will soon have the opportunity to promote in their work in schools.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans in accordance with the local legislation and institutional requirements. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

YE-S: Conceptualization, Data curation, Formal analysis, Funding acquisition, Writing—original draft, Writing—review and editing. ÁM: Data curation, Formal analysis, Writing—review and editing. AM-E: Conceptualization, Funding acquisition, Investigation, Methodology, Writing—review and editing.

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

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