Digital technologies and school gardens: Possibilities for transformative pedagogies and sustainable development

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The changes brought about by the Covid-19 pandemic have compelled schools to transform their pedagogies, with two seemingly contrasting trends emerging: the growing digitalisation of schools and the increased recognition of outdoor education. Our study, based on the experience of a European project, addressed the following questions: What digital competences can be fostered through school garden-based learning activities? Which UN Sustainable Development Goals (SDGs) can be addressed by combining garden and digital activities? How do these practices align with the framework of transformative pedagogy? To answer these questions, we conducted a qualitative content analysis of 16 learning activity lesson plans designed and implemented by teachers from Slovenia, Greece, Portugal, and Spain. The findings indicate the activities contributed to exploring diverse online sources of information and integrating them into shareable digital products while developing SDG 4 (quality education), SDG 3 (health habits), and SDG 12 (sustainable consumption and production), among others. These activities align with the principles of transformative pedagogy, as they encourage students to think and interact globally while empowering them to take action at a local level. These results also emphasise the importance of enhancing students' decision-making abilities and providing opportunities for reflective questioning, less frequently identified in the activities.

Introduction

Following an increasing investment in digital equipment, infrastructures, and teaching practices in European schools (European Education and Culture Executive Agency, Eurydice, 2019), the Covid-19 pandemic crisis prompted a massive focus on digital technologies. However, with ongoing digitalisation of schools post-Covid, concerns about diminished contact with nature and well-being issues have arisen, prompting calls for increased appreciation of outdoor learning (Cowie & Myers, 2021). Reviving the importance of place and blurring the boundaries between indoor, outdoor and digital learning spaces has been sought (Činčera et al., 2023). Furthermore, the world's *Sustainable Development Agenda* calls upon pedagogical approaches that are learner-centred, action-oriented and transformative (UNESCO, 2017).

Garden-based activities are outdoor and place-based education with transformative potential towards sustainable development (Johnson, 2012). They promote student engagement with "real-world problem-solving and the design of sustainable solutions" (Zuicker & Wright, 2014, p. 557) by integrating local issues into the global perspective of *Education for Sustainable Development* (ESD) (Lochner et al., 2019) and acting on the building of more sustainable societies (Rieckmann, 2018). However, the transformative potential of

school garden-based activities in ESD has remained relatively unexplored, especially in light of the recent digitalisation of schools.

Our paper focuses on the "*esGarden: School Gardens for Future Citizens*" project (2019-2022) involving schools from Slovenia, Greece, Portugal, and Spain. This project aimed to develop schools' garden-based learning activities, using digital technologies to promote competences that support learning about sustainable development. It consisted of a strategic partnership between partners from schools, universities and industries in the education and agriculture sectors from five countries, to foster innovation in school education (Grindei, Blanc & Benlloch-Dualde, 2019). The project was supported by Erasmus+, a European program that funds 2 to 3-year projects for international strategic partnerships to support innovation actions in various social fields. Such projects require the production of a set of intellectual outputs (e.g., guides, toolkits, reports, policy briefs, prototypes) and their dissemination in seminars, multiplier events, websites and on other digital platforms to facilitate their transfer to other contexts and institutions. In the *esGarden* project the participant teachers designed, implemented and produced lesson plans for innovative learning activities that established sustained curricular connections between the physical world (garden) and the digital (virtual) and were later disseminated in multiplier events and on the project's website.

These plans were analysed under the theoretical framework of transformative pedagogy (Leite et al., 2022), which values the agency of teachers and students (Priestley et al., 2015), and stimulates initiative, individual reflection, and collective responsibility for positive social transformation based on principles and values leading to a sustainable and socially just future and aims to create conditions for transformative learning (Mezirow, 1997, 2003; Giroux, 1997).

The study was guided by the following questions:

- What digital competences can be fostered through school garden-based learning activities?
- To what extent can these activities contribute to promoting Sustainable Development Goals (SDG)?
- Which components of these practices are aligned with the transformative pedagogy approach?

Connecting garden-based activities with digital technologies in schools

Connecting school gardens with digital technologies (e.g., videos, photos, video conferences) for ESD has been explored for some time. Lochner et al. (2019) conducted a literature review on the use of digital media in school gardens since 1992. The findings highlighted various benefits, such as facilitating exchanges/partnerships, providing ESD-related information, fostering multicultural learning and language skills, garden design, promoting discussions, teaching, documentation, reflection, information provision,

monitoring, and "communicating" with plants. Lochner et al. (2019) emphasised that school gardens played a crucial role in achieving SDG 4's target of quality ESD by 2030, offering opportunities to integrate a global perspective of ESD and display interconnectedness worldwide.

Programs and projects in schools involving social and digital inclusion, environment, and sustainability issues related to the SDGs have been promoted in diverse countries in recent years. For example, Prasetiyo et al. (2020) described an "Adiwiyata Green School" program in Indonesia that featured the promotion of inclusive education for children with special needs. The program was based on the United Nations' foundations for sustainable development, showing that involvement in such activities can have positive outcomes for personal development and learning related to content, attitudes, and values outlined in ESD. The study indicated success in terms of providing literacy and skills to students with special needs as well as regular students in environmental management, achieved through the engagement and accountability of the entire community.

Another Indonesian study (Sulistyarini et al., 2022) reported on an *Adiwiyata* program aimed at pro-environmental behaviour and students' social responsibility in a senior high school. Implementing the program contributed to the development of (a) a sense of responsibility in addressing environmental issues and (b) the development of attitudes and behaviours related to the preservation of green ecology for future generations. The programs supported by Prasetiyo et al. (2020) and Sulistyarini et al., 2022) have in common the fact that they combined work on environmental issues with processes of personal and community development.

These ideas are in line with the study by Austin (2021) in Irish primary schools, which considered garden-based learning as a pedagogical strategy that used the school garden as a working tool. Garden-based learning contributed to the personal, social, and moral development of students. It can support interdisciplinary work, promote hands-on experiences, and facilitate meaningful learning through interaction and care in cultivation, especially for children and young people living in more urban areas where access to green spaces may be more limited.

An example of European projects involving school gardens is the *Domotic School Garden* project, co-funded by the Erasmus+ program of the European Union (Melián et al., 2022). It sought to use ecological school gardens to help develop common values and competencies in STEAM and linguistic competence. Another Erasmus+ example is the project *Each Act Rises The Hope, to save our planet* (E.A.R.T.H., 2020) (because small hands, small things can save the planet!)" conducted by Belgium, Cyprus, Latvia, and Slovenia, from 2020 to 2022. The project aimed to raise awareness among children in pre-primary schools about the importance of a more sustainable way of life to address climate change. The activities included climate observations, food-related activities, food production by planting it, and starting a vegetable garden.

A distinctive factor of the project focused on in our article is the relationship between digital technologies and the school garden to promote social inclusion, participation and

common values, which is in line with Erasmus+ priorities, specifically inclusion and diversity. This entails organisations considering mechanisms to ensure an inclusive and accessible approach for individuals with different characteristics and specific needs when designing project activities; digital transformation, related to contributing to the priorities of the "digital action plan" particularly in building a digital education ecosystem via the development of digital skills for individuals and improving systems, processes, and organizations; environment and the fight against climate change, aligned with the *European Green Deal* (European Commission, 2019) which involves engaging children, parents, and the general community to address the challenge of becoming climate-neutral by 2050; participation in democratic life, common values, and civic engagement, which aims to enhance understanding of the European Union and foster active engagement in local and European communities. Ideally, these priorities should be integrated as cross-cutting elements in all funded projects.

Digital education has evolved from a closed box to an open ecosystem that involves multiple components, platforms, and stakeholders (Dillenbourg, 2016). The digital education ecosystem emphasises the development of digital competence and the transformation of pedagogical practices towards learner-centred, action-oriented, and transformative approaches (Monteiro & Leite, 2021), aligned with the principles of the ESD goals set by the United Nations (2015). The integration of digital technologies in pedagogical interactions, along with access to equipment and training in ICT (information and communications technologies), has influenced the curriculum and shaped the concept of digital competence in Europe (European Education and Culture Executive Agency, Eurydice, 2019). Each European country has its national-level definition of digital competence, though all definitions focus on the need for individuals to understand digital technologies and how to use them effectively. By 2019, Eurydice reported how primary and secondary education curricula were mainly focused on integrating digital competences into existing subjects, such as mathematics or science (e.g., Spain, Slovenia), or teaching digital competences as a separate subject (e.g. Greece, Portugal). However, in countries integrating a cross-curricular approach to digital competence, there was a high level of detail in the related learning outcomes (e.g., Estonia, Greece, Malta and Finland) (European Education and Culture Executive Agency, Eurydice, 2019).

In a more standardised way, the European framework for digital competencies *Digicomp 2.0* (Carretero et al., 2017) aims to assist citizens in self-assessing their skills and identifying areas for improvement. This framework presents key competencies organised in five areas: information and data literacy; communication and collaboration; digital content creation; safety; and problem solving.

Transformative pedagogy framework

Transformative pedagogy is a teaching-learning approach that empowers students to develop agency and skills for positive community change (Leicht et al., 2018; Michel et al., 2020). It draws on critical theory principles (Apple, 1979), which advocate challenging power structures and promoting social justice in education (Priestley et al., 2015). This

approach highlights the significance of an inclusive and equitable learning environment, fostering students' critical reflection and sense of their agency (Gaard et al., 2017; Leicht et al., 2018; Michel et al., 2020; Rieckmann, 2018).

Student-centred approaches view students as active participants in the pedagogical process, engaging in discussions and activities that reflect their experiences and perspectives (Leite & Sampaio, 2020). Supporting critical reflection involves providing opportunities for students to examine their experiences, beliefs, and attitudes and question dominant narratives and power structures. This approach promotes social justice by encouraging students to challenge existing power structures and strives for a more equitable society, fostering a safe and inclusive learning environment for all students, as projected in the *Agenda 2030* (UNESCO, 2017).

Indicators of transformative pedagogy, based on Leite et al. (2022), include situations where learners engage with social issues; interact and share knowledge; reflect and question; express opinions; analyse and discuss everyday life or the environment; make justified decisions; access and analyse diverse information sources; identify problems and plan actions/interventions; analyse and discuss actions for sustainable development; see themselves as agents of positive change; embrace integrated visions based on social, ecological, economic, and cultural principles and values; and cultivate strategies for self-assessment and personal/social value development.

An example of transformative pedagogy adoption involving pre-service teachers in South Africa has been given by Barnett and Botes (2022). This educational approach revolves around the idea that learning is not just about acquiring knowledge but entails a deliberate and collaborative effort to critically assess one's beliefs, values, and assumptions. Transformative pedagogy develops transversal competences, including reflective learning that promotes personal development and a deeper understanding of oneself, including the beliefs, values, and assumptions that underlie pedagogical thinking and action; collaborative learning between teachers and students through teamwork and the sharing of ideas; and awareness and critical thinking, achieved through questioning prior conceptions and prevailing norms, and challenging critical thought in the pursuit of social change, drawing on Freire's (1970) ideas about the emancipatory role of education.

From a theoretical standpoint, Barnett and Botes (2022) relied on the concept of transformative learning by Mezirow (1997, 2003), which includes four learning processes: elaborating on an existing point of view; establishing new points of view; transforming the point of view by reflecting on misconceptions of a particular group; and developing awareness and critical reflection regarding bias towards various groups. The notion of transcending physical, cultural, and social boundaries was also advocated by Giroux (1997), who stated that students should operate as "border-crossers," moving across boundaries stemming from the Eurocentric tradition prevalent in society and mirrored in the classroom.

Although the terms 'transformative pedagogy' and 'transformative learning' are related and both involve the idea of change and personal and social development in students, there

are some differences between them. Transformative learning focuses mainly on the process of changing students' beliefs and attitudes. In contrast, transformative pedagogy is linked to the teaching and learning processes that promote transformative learning experiences.

Methods

The paper draws upon a qualitative analysis of plans produced in the design, implementation and monitoring of learning activities related to school gardens, for students between 8 and 15 years old, from schools in four European countries – Greece, Portugal, Slovenia and Spain – participating in an international interchange project.

Participants

The project's consortium consisted of teachers and students from four schools in different countries, with support from academic experts in education, engineering, educational technology, and agriculture.

A public school from northern Portugal and a private school from the Autonomous Community of Valencia, in Spain, were participating schools connected to large educational organisations offering pre-school to upper secondary level education. The school from northern Portugal engaged one cohort of upper primary students and all of its teachers, whilst the school from Spain engaged three cohorts of students from upper primary to lower secondary. Two smaller public schools in central Slovenia and western Greece participated solely with primary education teachers and students. All schools reported having adequate hardware for implementing digital resources in school and classroom activities. Only the school in Spain had prior experience with installing and using a school garden, while the other three schools developed their gardens during the project. Several learning activities were specifically designed to install and manage the school garden, with active student participation.

Table 1 summarises data on the participating students per school/country, including year of schooling, age range and number of students enrolled in each school/country.

Design, implementation and analysis of the learning activities

The learning activities focused on fostering students' skills in cultural diversity, sustainable development, and citizenship through integrating digital technologies in real-life school garden experiences. Teachers developed the lesson plans for the learning activities, which were reviewed by experts in agriculture and gardening, educational technology, curriculum, and environmental education involved in the project. The design process started in late 2019, following a workshop on school gardening and extensive interactions with these experts. Their support and feedback encompassed gardening, technology usage, curriculum, pedagogy, and inclusion.

Table 1: Data on participants in the learning activities per school/country

School/ country	Year of schooling	Age range of students	Participating students	Teachers involved in implementing the learning activities
Greece	4	10; 11; 12	27	2
	6	12	39	1
Portugal	6	11; 12	21	10
Slovenia	4	9; 10	26	4
	8; 9	13; 14; 15	42	2
Spain	5	10; 11; 12	59	1
(ACV)	7	12;13	30	5
	9	14;15	87	15

Despite facing challenges posed by the Covid-19 pandemic and subsequent school closures, implementing school activities occurred between mid-2020 and late 2021. Schools in Slovenia were fully closed for 21 weeks, Greece for 18 weeks, Portugal for 12 weeks, and Spain for 10 weeks (UNESCO, 2022). Distance learning, mainly using online tools, was adopted during these closures. However, some schools remained open for exceptional cases, including children of essential workers, those from disadvantaged households, and students requiring specialised support. Despite the closures, the involved schools and teachers found innovative solutions to maintain their gardens. They engaged other school staff and students' relatives while adjusting their crops to align with periods when schools reopened, and classes resumed their regular routines.

The final versions of the plans for each learning activity were published for dissemination on the projects' website (https://esgarden.webs.upv.es/) after being implemented in the participating schools. The plans included information regarding the age range of participating students, curricular subjects involved, contents, pedagogical approaches, competences, relation to the garden, inclusion issues, materials, and description of activities (steps). Figure 1 presents illustrations of parts of these plans.

In total, 16 learning activities were designed, implemented, and their plans were created and shared, with each country having a unique approach to the school subjects and the use of digital technologies. The structure of each learning activity plan included: title; introduction; age range of participant students; curricular subjects involved; duration; timing of the activity phases; contents; pedagogical approaches; competences; relation with the garden; inclusion; impact; progress and future goals; relation with society; previous knowledge; multimedia links; materials; phases and steps description.

Different approaches to digital technologies were observed among the countries involved. Slovenia focused on intensive use of open-source digital tools and coding, with the project being driven by the subject of ICT. Greece had a low-intensive approach to open-source digital tools without coding. They emphasised SDGs and manual projects with medium digital use. Language subjects drove the project. Portugal adopted a medium-intensive approach to open-source digital tools, with coding being less prominent. The learning activities were not integrated into a single project, though an independent gardening

subject was an important driver of the garden-based activities. Technology was driven mostly by English and mathematics. Spain took a medium-intensive approach to open-source digital tools with varied cohorts. Each cohort focused on a different learning activity within a distinct project. One cohort experienced a high-intensity use of technology, while the other three had medium or low usage. Each learning activity was driven by a topic rather than a specific subject.

Figure 1: Illustrations of parts of one set of lesson plans for one learning activity, "Eating a healthy Mediterranean diet". Use web or PDF reader 'zoom in' function to view. Alternatively, the plans may be viewed at https://esgarden.webs.upv.es/la.html

Furthermore, being a project developed within a European strategic partnership to foster collaboration and inclusion, collaborative approaches were promoted not only between the participating teachers and experts but also between students from different country schools. For instance, when traveling was possible, some groups of older students travelled to schools from other countries. Other groups of students engaged in remote communication in English and native languages through various digital platforms. Moreover, two learning activities were jointly designed and implemented by teachers from different schools.

To address the research questions, we conducted a document analysis (Patton, 2015) of the learning activities' lesson plans created by teachers. A similar procedure was used by Barnett and Botes (2022) and by Leite et al. (2022). Barnett and Botes (2022) highlighted the importance of lesson plans in teachers' activities, as they anticipated the material resources to be used, lesson objectives, teaching methods, and learning and evaluation processes. The authors analysed three lesson plans with the goal of understanding whether pre-service teachers of natural science could integrate the principles of transformative pedagogy into their lesson plans, and the content was examined by means of document analysis. Leite et al. (2022) analysed 13 pedagogical/curricular plans from teachers in six countries involving children from the fifth to the ninth year of schooling and different subjects, e.g. mathematics, science and biology, supplemented by responses to an evaluation questionnaire. The aim of the analysis was to identify the characteristics of the pedagogical/curricular activities that were aligned with transformative pedagogy. The plans were for activities aimed at developing 21st-century skills through topics related to a chosen SDG. They comprised objectives, activity details, tips for the teacher, debriefing, and follow-up/inspiration and the contents were analysed through content analysis, supported by the same indicators of transformative pedagogy considered in our article.

Initially, we examined the 16 lesson plans to better understand the subject areas and their relevance to our research questions. Subsequently, we conducted a content analysis (Bardin, 2011) using predefined coding frames, as summarised in Table 2.

To code the competences anticipated in the plans, we used a coding frame that incorporated learners' competences, from the *DigCompEdu* framework (Redecker, 2017), including both transversal and subject-specific competences. Moreover, to identify transformative pedagogy features in the learning activities and their connection with the use of digital technologies in school garden-based environmental education, we employed a coding frame based on the transformative pedagogy indicators proposed by Leite et al. (2022), which have previously been applied to other curricular and pedagogical practices.

After coding, we calculated the number of references and their proportion in the overall learning activities, which was then visualised in frequency histograms.

Table 2: Dimensions and categories of content analysis of learning activities' lesson plans

Dimensions	Categories	Coded fields
Learners' competences to be developed	- information and media literacy - digital communication and collaboration - digital content creation - responsible use - digital problem solving - transversal competences - subject-specific competences	- contents - competencies - inclusion - impact - progress and future goals - relation with society
Relationship with the promotion of SDGs	- the 17 SDGs (UN, 2015; UNESCO, 2017)	- introduction - contents - competencies - relation with the garden - progress and future goals
Twelve features of transformat-ive pedagogies	- engaging with social issues - interaction and sharing - reflection-inducing questioning - expressing opinions - discussing everyday issues - making decisions and justifying them - accessing diverse sources of information - identifying problems and conceiving plans of action/intervention - analysing and discussing actions toward sustainable development - students as agents of positive change - embracing integrated visions based on social, ecological, economic, and cultural principles and values - developing self-assessment and personal/social values	- methodology - description of the activities

Findings and discussion

The analysis conducted in this study sought to contribute to the discussion on how the combination of garden and digital-based learning, designed towards the SDG, can lead to changes in practices aligned with the transformative pedagogy framework.

Competences promoted with the integration of digital technologies in school garden-based learning

To discuss the competences in the digital domain that can be promoted with school garden-based learning activities, we identified the competences that were favoured by teachers in the plans, namely how they incorporated digital and informatics development skills. Figure 2 summarises the learning activities' coverage of competences foreseen in the *DigComp 2.1* framework (Carretero et al., 2017), to which we added categories of other transversal and subject-specific competences.

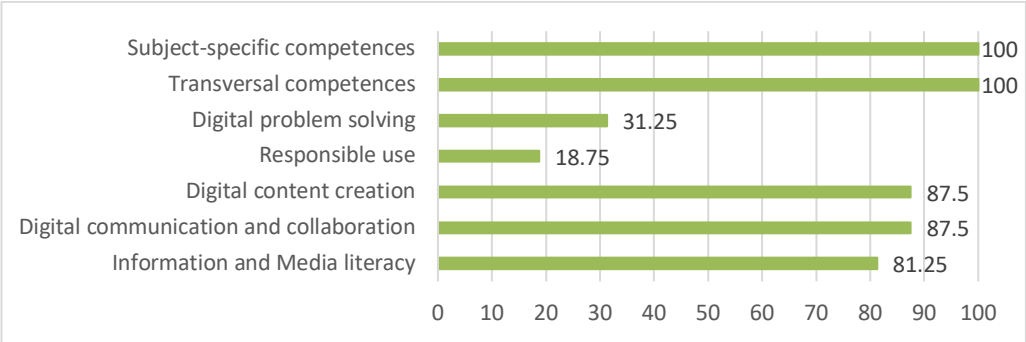

Figure 2: Proportion (%) of learning activities (n=16) that foresee the development of learners' competences in the *DigComp2.1* and transversal and subject-specific competences

Figure 2 shows the learning activities' plans covered all competence domains but had a limited focus on digital responsible use and problem-solving.

In the domain of information and media literacy, most learning activities focused on developing critical thinking skills (n=13), while many specifically targeted information search skills (n=6). One activity for older students aimed at developing data exploration, computational thinking, and programming skills to understand hardware and software and apply that knowledge in a coding project (n=1). In addition, five learning activities involved the promotion of digital problem-solving competences, using *Arduino, Scratch*, and *Tinkercad*. These activities targeted mainly secondary school students (n=4), but also primary school students (n=1). Teachers highlighted the aim of developing problem-solving skills (n=3), critical thinking (n=5), and creativity (n=4) concerning digital environments during these coding tasks.

In the digital communication and collaboration domain, teachers prioritised the development of collaboration (n=10), mutual respect (n=8), and teamwork (n=4) skills. They also emphasised immersing students in real-life scenarios to practice English communication, which would enhance their comprehension of texts (n=6), oral interaction (n=5), and written text production with specialised vocabulary (n=4), mostly concerning planting, gardening, agriculture, and local traditions related to nutrition.

Most learning activities require students to produce digital content, highlighting the need to develop this competency (n=6). Furthermore, teachers consistently prioritised fostering creativity as a broader skill across almost all activities (n=13). Among the activities, four focused on coding (n=5), web and digital design (n=4), and 3D printing (n=4) competences, with one aimed at younger students and the rest targeting older students.

Responsible use was minimally emphasised, mentioned briefly in only three digital environment safety activities. Problem-solving encompassed the explicit goals of fostering critical thinking skills (n=13), creativity (n=12), and the specific development of problem-solving (n=9).

The prominent transversal competences as learning outcomes were social skills (n=14), critical thinking (n=14), creativity (n=13), participation (n=10), sustainable production and consumption skills (n=9), and health literacy (n=8). Social skills encompassed collaboration, mutual respect, teamwork, empathy, active listening, and appreciation of diversity. Critical thinking and creativity focused on searching, selecting, and utilising information in various tasks and learning materials (e.g., recipes, podcasts, videos, and infographics). Participation primarily referred to civic and democratic engagement to empower students in their communities. Sustainability and health competences revolved around food production, consumption, nutrition, water management, and waste reduction.

In response to the first question, "What competences in the digital domain can be promoted through school garden-based learning activities?", our findings indicate that teachers utilised digital technologies in conjunction with garden-based activities, preferably to engage students in exploring diverse sources of information and integrating it into shareable digital products. These findings align with Lochner et al. (2019) who emphasised the significance of digital technologies in gathering and disseminating information, which, according to Bergdahl et al. (2020), promotes students' engagement with the global world.

Teachers expressed a strong interest in using digital technologies to enhance students' collaboration and communication skills, especially in an exchange project that enabled communication with students from different countries. They also emphasised the importance of nurturing students' creativity and critical thinking abilities. However, upon analysing the learning activities, it became clear that the emphasis on fostering creativity revolved mainly around visual and discursive communication in tasks such as creating infographics, posters, or videos. The application of creativity in real-life problem-solving received relatively less attention. This reflects how challenging it is for teachers to use digital technologies in rethinking transformative practices. On the contrary, teachers end up using digital technologies "mostly as augmentations to conventional practice" (Burbules et al., 2020, p. 94).

Although acknowledged as a skill to cultivate, problem-solving was predominantly confined to a few digital learning activities, aligning with the Leite et al. (2022) findings. These activities centred on students engaging in design and coding processes linked to technology-related matters. Examples included planning and designing the garden installation and creating simple codes for sensors of meteorological parameters.

Contributions to promoting the sustainable development goals

The eSGarden project aimed to support attaining the SDG. We identified the specific SDG targeted by teachers in their learning activity plans. Quality education (SDG4) was explicitly addressed in all activities, while most activities targeted 2 to 3 SDGs from the Agenda 2030. Through content analysis, we determined the SDGs most directly linked to garden-based activities and the distribution of activities across different SDGs, as shown in Figure 3.

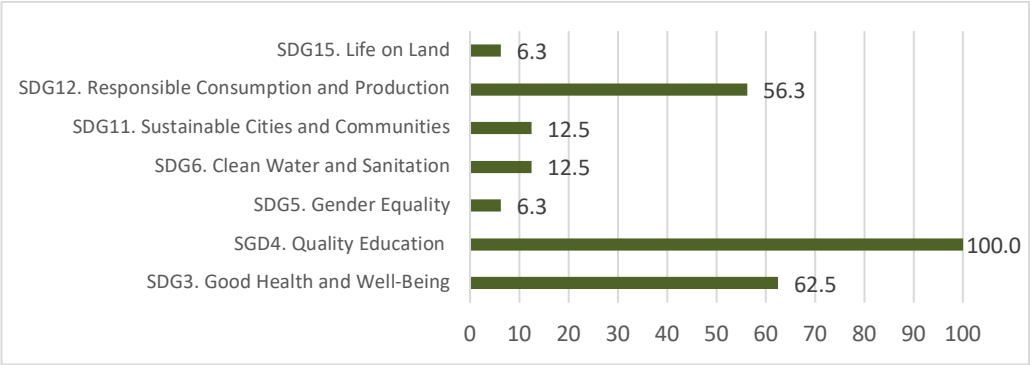

Figure 3: Proportion (%) of learning activities (n=16) that targeted different SDGs

Achieving quality education (SDG4) was targeted by enhancing students' learning experiences, intercultural understanding and dialogue, and acquiring subject-specific knowledge and skills related to sustainable development. Garden-based activities were frequently used to address nutrition and promote healthy eating among younger students (SDG3). Teachers incorporated digital tools to combine gardening with specialised content searches and the production and sharing of materials with peers from different countries. For instance, students shared digital research products on Mediterranean diet traditions and foods. Responsible production and consumption (SDG12) were emphasised through activities focused on recycling, composting, circular economy, water management, and selecting local, seasonal, and high-quality food for the garden.

The importance of water sustainability was addressed in two activities, specifically targeting SDG6. Furthermore, the connection between local garden planning, installation, and economic activities was explored in two other activities, aligning with SDG11.

Regarding the question "Which SDG can be addressed through the combination of garden and digital-based learning activities?" our findings indicate a preference for activities aligned with SDG3, SDG12, and SDG4. However, there were relatively fewer activities associated with SDG6 (Clean water and sanitation) and SDG11 (Sustainable cities and communities). This could be attributed to the stronger connections established by teachers with curricular themes such as nutrition and agriculture, as well as the existing limitations in addressing the diverse and complex aspects of sustainability in curricula across different countries (Suárez-López & Eugenio-Gozalbo, 2022).

Similarly, SDG 4 was among the most targeted objectives in the plans in the Leite et al. (2022) study, perhaps due to the cross-cutting nature of the theme, along with SDG 11 and SDG 13, which are not represented in the study presented here. The least mentioned in the plans were SDG 12 (climate action) and SDG 5 (gender equality). The differences between the framing projects of planned activities can justify these differences in the focus on SDGs.

Promoting transformative pedagogies with the use of digital technologies in school garden-based learning activities

We also wanted to examine the possibilities of promoting transformative pedagogies using digital technologies in school garden-based learning activities. For this, we coded the indicators of transformative pedagogies (Leite et al., 2022) in the learning activities' text items, which resulted in the findings summarised in Figure 4.

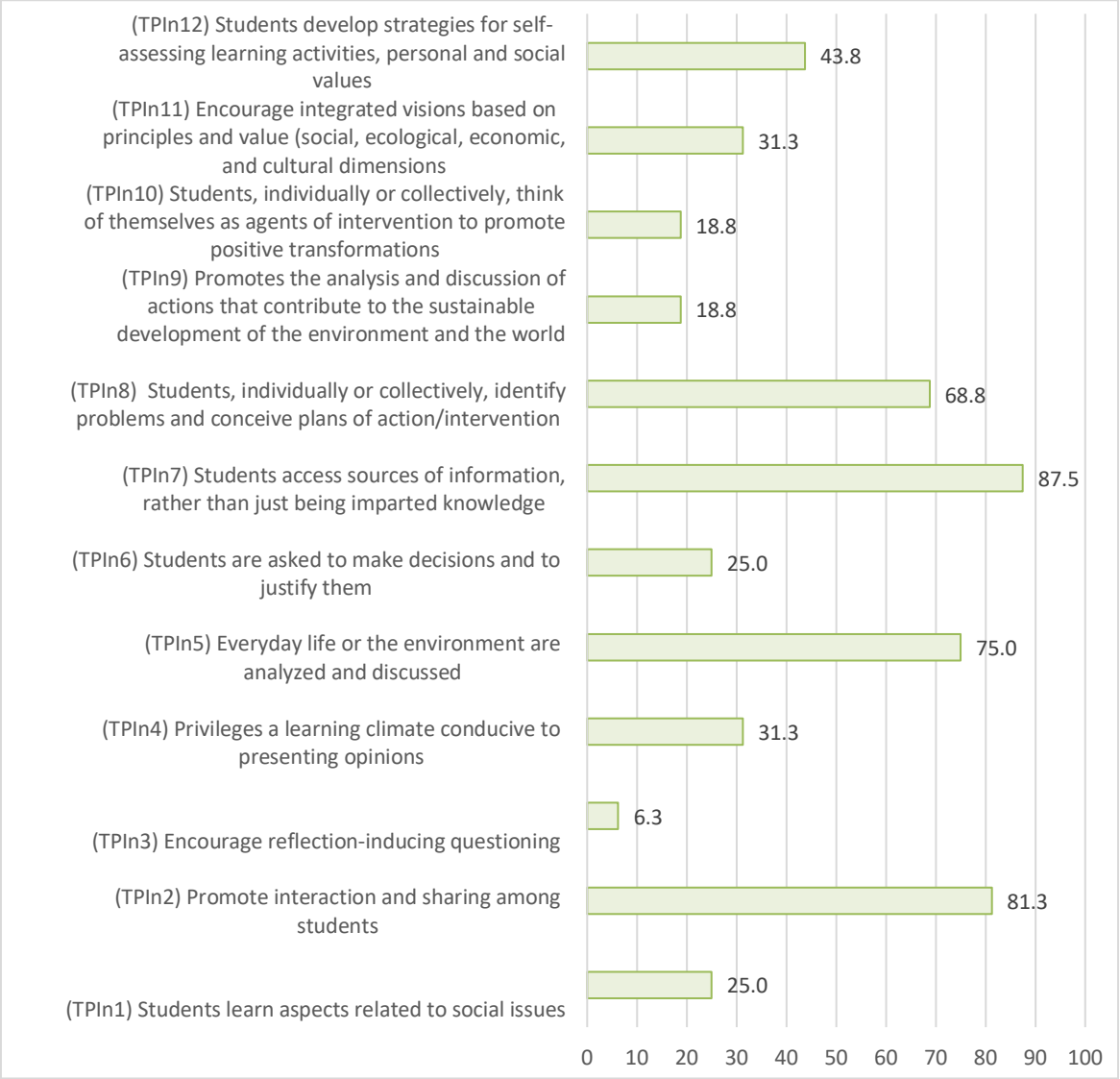

Figure 4: Proportion (%) of learning activities (n=16) that foresee the development of specific indicators of transformative pedagogies

In Figure 4, our analysis revealed features in the learning activities aligned with the 12 indicators proposed by Leite et al. (2022). Notably, teachers emphasised students accessing information sources (TPIn7; n=13), promoting interaction and collaboration (TPIn2; n=12), and addressing everyday life and environmental concerns (TPIn5; n=12).

Integrating everyday life and environmental discussions (TPIn5) in the learning activities was facilitated by connecting them to observing plant growth in the garden, analysing crops and watering requirements, and exploring their connection to local and seasonal dietary and agricultural traditions. The diversification of information sources (TPIn7) was achieved through onsite observations in the schools' gardens to collect information about plants, nutrition, gardens and agriculture tradition, mainly associated with sciences subjects. Other learning activities involved visits to supermarkets and family engagement in collecting information.

Interactions and sharing among students (TPIn2) were primarily facilitated through group work, where students collaborated on projects, conducted information searches, and created posters, videos, or podcasts based on their findings. Three additional strategies were employed to promote specific types of interactions. Firstly, intercultural interaction was encouraged, as the learning activities were part of an Erasmus+ project, allowing students from different countries to practise English and learn a few words in other languages related to gardening, local recipes, and traditions surrounding edible plants (vegetables, fruits, and aromatic plants). Secondly, interactions and communication among students of different ages were fostered. Finally, sharing content produced within group work was commonly done through online platforms, enabling collaboration with classmates, families, and other community members.

Encouraging students to reflect and question (TPIn3) and make independent decisions with justifications (TPIn6) proved challenging for teachers to integrate into the learning activities. These aspects were seldom explicitly mentioned. In one activity involving 7-year-old students, they were prompted to question and reflect on recipes and cooking practices in their peers' families, fostering critical analysis of sociocultural circumstances and differences. Although some learning activities involved problem-solving and project development, only two activities explicitly instructed students to justify their choices.

Interestingly, the results differ concerning the most and least identified indicators in the Leite et al. (2022) study. This study presented TP1, "students learning aspects related to social issues," and TP3, "encourage reflection-inducing questioning," as the most represented in the analysed plans, which are among the least identified in the plans of the present study. The least identified TP in that study was TP8, related to problem identification and intervention planning, which, once again, was not observed in the present study. Once again, we can attribute the differences to the nature of the projects and the diversity of situations and people involved. It is also worth mentioning that the two least mentioned aspects in the plans analysed in this study, "enhancing students' decision-making abilities" and "providing opportunities for reflective questioning" are fundamental elements in transformative learning (Mezirow, 1997, 2003), which could be considered a natural outcome of transformative pedagogy.

To answer the question "How do these practices align with the framework of transformative pedagogy approach?" we designed Figures 5 and 6 that showcase specific examples of actions and cognitive processes outlined in the learning activity plans, identified through content analysis and connected to indicators of transformative pedagogy. Arrows depict the relationship between TPIn, anticipated actions, and implementation elements, while the colour scheme indicates whether the activity primarily focuses on digital competence development, SDGs, or both dimensions.

Figure 5: Transformative pedagogy indicators TPI 1 to TPI 6 identified in learning activities (use web or PDF reader 'zoom in' function to assist reading)

Figure 6: Transformative pedagogy indicators TPI 7 to TPI 12 identified in learning activities (use web or PDF reader 'zoom in' function to assist reading)

Figures 5 and 6 reveal that most activities classified with transformative pedagogy indicators effectively integrate SDGs with digital competences/tools. This integration emphasises the importance of using digital technologies in garden-based activities to promote and support sustainable development objectives, addressing global challenges (Lochner et al., 2019).

An alternative interpretation is that indicators classified as both SDG and digital competence can also be seen as contributing to SDG4, as they encompass the foundations of quality education and inclusion through ESD (e.g., interacting, reflecting, discussing, creating, questioning, sharing, and assessing), as supported by Gaard et al. (2017) and

Leicht et al. (2018). In addition to SDG4, other SDGs classified about transformative pedagogy indicators highlight their significance, particularly SDG3 and SDG12, in which the potential of pedagogical work within garden-based learning is especially high (Johnson, 2012).

The presence of all the indicators of transformative pedagogy in the activity plans is aligned with the findings of Leitie et al. (2022) and Barnett and Botes (2022). Although the indicators used here may not be exactly the same as those employed in their study, the authors identified three concepts of transformative pedagogy in the analysed plans, namely: critical consciousness, active engagement, and cultivating autonomy.

Conclusions

The analysis of the learning activity plans designed and implemented by teachers allowed us to investigate the possibilities of developing learners' competences in the digital domain in school garden-based learning activities and to identify the contributions to promoting Sustainable Development Goals in the framework of the transformative pedagogy approach. These findings have implications for teacher professional development in digital education and garden-based education. Further studies should be conducted to explore teachers' perceptions and practices of digital problem-solving and responsible use of technologies. However, we believe that teachers would benefit from investment in training and support to enhance the use of digital technologies in developing higher-order critical thinking and digital problem-solving skills. Moreover, some support should aim to strengthen the connections between creativity development and encouraging students to generate innovative solutions to real-world problems, whether they are digital in nature or specific to their everyday contexts and lives.

Schools and teachers increasingly use international exchange initiatives to offer students opportunities to explore diverse realities, cultural scenarios, and traditions. Although this garden-based learning activities project has primarily focused on exploring these exchanges in connection with food and agricultural traditions, particularly related to SDG3, there is immense potential to promote intercultural dialogue and understanding about achieving SDGs related to biodiversity (e.g., SDG14 - Life below water, and SDG15 - Life on land), urban management (e.g., SDG11 - Sustainable cities and communities), and even social issues such as inequalities and decent work (e.g., SDG8 - Decent work, and SDG10 - Reduced inequalities).

Regarding the limitations, this qualitative study focused on learning activity lesson plans within a specific project. It is important to note that while these plans do not capture all of the learning experiences in the participating schools, further studies could include other teaching and learning resources and more in-depth explanations from the teachers themselves. Nevertheless, the learning activity plans serve as valuable dissemination tools, enabling other schools to replicate these proposals. Therefore, conducting and disseminating critical analysis of such documents is crucial for developing meaningful insights into teaching practices

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