Study on Learning for Sustainability and Digital Education in Primary and Secondary Schools: Synergies, Challenges, Opportunities

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Executive summary

About this study

The European Union seeks to accelerate the adoption of digital technologies to advance its vision for a sustainable future and has called for the green and digital transitions to be attained jointly. The EU Commission's report 'Towards a Green and Digital Future' (2022) examined how the 'twin' transitions can be mutually reinforcing and identifies stepping stones that can help to align pathways. However, the report also recognises that these two priorities are not entirely complementary. Tensions add a layer of complexity to twinning efforts and are increasingly visible within schools and colleges that are seeking to advance green and digital agendas.

This study investigates the relationship between learning for sustainability and digital education in formal education settings, seeking to identify synergies, challenges, and opportunities for practitioners and policy makers. It proposes pathways for harnessing digital technologies in support of learning for sustainability and in ways that can contribute to improving learner outcomes in schools. Specifically, it seeks to offer insights into how best to combine educational policy, action and investment in these areas.

The report reviews the limited number of authoritative documents that exist on the twin transitions in education but that have nevertheless set a course for the sector. It identifies policy goals and priorities as well as ways to combine these agendas in schools. It also looks at the growing body of evidence that considers the value, opportunities and issues arising from the practice of sustainability and digital education in schools. Further insights were gathered from case studies as well as from the engagement of education experts. Together, these inputs help provide a deeper and more nuanced understanding of the emerging relationship between digital and sustainability education.

Understanding the terms

Digital education seeks to make education fit for the digital age. It does so by adopting a whole-school approach that seeks to improve learning environments and learning experiences through the use of digital tools, systems and devices. Digital education seeks to build the knowledge and competences of learners through interactive, collaborative, accessible, flexible, inquiry-based and networked learning. Digital innovations such as online games, multimedia and mobile technology, the Internet of Things, Geographic Information Systems (GIS), augmented reality, robotics and Artificial Intelligence (AI) are changing how students access, interpret, and co-create knowledge. These have the potential to innovate learning as well as enable the building of digital competences.

Learning for sustainability is about creating opportunities to *experience* as well as *learn* about sustainability. It relies on participatory approaches to learning that challenge the traditional teacher-student dynamic and support the development of sustainability competences. Essentially, learning for sustainability seeks opportunities for collaborative, participatory, inquiry-based, future-facing and action-oriented learning. This educational agenda also adopts a whole-school approach to sustainability that requires extending learning beyond the classroom walls by involving students in schools' decisions, community projects and global initiatives.

The twin transitions refer to the digital and green transformations that are central to Europe's future. While distinct, these processes are interconnected and unfolding simultaneously. The green transition, guided by the European Green Deal, aims to achieve

climate neutrality by 2050, promoting sustainability, reducing carbon emissions, and advancing a circular economy. The digital transition focuses on leveraging technologies, including Artificial Intelligence, data, and digital infrastructure, to drive innovation and competitiveness. In education, these transitions provide platforms and processes that engage learners with real-world challenges, helping them build competences for a more sustainable future. Schools play a crucial role in equipping students with the knowledge, skills, and attitudes needed to succeed in an increasingly digital and green society and economy.

Key findings

The emergent relationship between digital and sustainability education

In schools, the twin transitions can be **mutually supportive** as they are both change agendas. However, they also present shared challenges when it comes to teaching and learning. Both agendas seek to engage learners actively and build competences in a way which often requires a shift in pedagogical practices. The interdisciplinary nature of learning for sustainability and digital education also poses obstacles as there is a tendency towards a subject-driven organisation of national and school-level curricula. These make cross-curricular and/or joint teaching difficult to implement.

The **twin transitions are aligned in their quest for innovation** as they seek to drive changes in society but also within schools. They challenge practices and particularly *who* is involved in teaching and learning as well as *how* and *where* learning takes place. This is done by:

- *extending learning* and involving all members of the school as well as communities of practice that exist in the local to global community. They also go beyond single subject approaches crossing boundaries to help present a more nuanced understanding of issues.
- *creating new spaces for education* taking learning outside the classroom to include school buildings, grounds and green areas as well as into local areas, parks and cultural institutions. The case studies in this report illustrate how these new spaces for learning may take the form of extracurricular activities, learning in non-formal contexts and online platforms, networks and communities.
- *promoting participatory pedagogies* that enable the active engagement of the learner in real life issues or scenarios and build learner competences. These learning approaches challenge the traditionally dominant role of the teacher in the classroom and give focus to critical thinking, problem-solving and ethical considerations.

Those seeking to jointly embed the green and digital transitions in a school have increasingly found that there are also **contradictions and trade-offs** between the two agendas. Tensions and concerns arise in a number of areas:

The *environmental impact of technologies* is a core issue for those wanting to progress the twin agendas. The production, use, and disposal of digital hardware, tools and technologies carry a carbon burden and Artificial Intelligence consumes energy intensively. Increasing the use of technology therefore has implications for the environmental footprint of education.

There are significant *inequalities* when it comes to accessing technologies, particularly for schools and students in disadvantaged areas. Similar issues arise in relation to learning for sustainability with schools from districts or regions not having access to green or natural areas in their neighbourhoods or the resources to visit field centres or parks.

Research shows how the intense use of digital technologies may result in *social disengagement* and have negative effects on the *well-being of the learner.* Those who have easy access to digital and mobile technologies can become increasingly reliant on them. In these cases, finding a balanced, 'mindful' use of digital technologies and avoiding an excess of passive screen-based activities is also a challenge.

Educators and learners may experience a generational digital divide between them, with teachers lacking similar levels of knowledge and experience with digital tools and social media as their learners. At the same time, the overestimation of learners' digital competences and readiness to use technologies can also create difficulties.

Safeguarding concerns arise from issues relating to data protection and the security of the digital systems. Schools have responsibilities associated with the storage, retrieval and use of data as well as with establishing the trustworthiness, completeness and impartiality of information accessed by administrators, teachers and students.

Additionally, more evidence is needed on the impact of digital technologies, including generative AI tools, on learner outcomes. Rigorous and comprehensive research is required to provide compelling and nuanced evidence into their educational impact and effectiveness.

Value to education

The adoption of digital technologies in education has at times been driven by general advancements in computing power, data storage capacity, algorithms and visualisation, rather than by identified educational needs. Equally, the integration of environmental themes and practices into school has been motivated by concerns about the health of the planet and the future of its people. It is therefore important to articulate **the value of the twin transitions to education and learning more broadly** rather than assume that teachers, learners, librarians, administrators and others working in schools recognise the educational needs these can address. This has implications for policy and quality frameworks as well as in teacher professional development.

Policy environments

The EU has prioritised the twin transitions, yet **few countries have integrated their policy or investment efforts across the two agendas**. Policy implementation at a national level is often dealt with by more than one ministerial unit or government department, with few synergies and interactions taking place. National or institutional frameworks for schools on how to advance the twin transitions are therefore mostly absent. Some examples of integrated policies and approaches can be found in Finland, Germany and Spain; in these cases, the transitions have been jointly addressed through coordinated financial support, training, educational research and/or curriculum development.

Opportunities for joining forces

The twin agendas could be advanced by building on emerging synergies, identifying complementary pathways but also by coming together to address common challenges.

Literacy and competence are terms often associated with both digital education and learning for sustainability. The twin transitions seek to build knowledge, skills and attitudes to be able to effectively engage with these transitions. Also, digital technologies can make knowledge generation a more dynamic and exciting process whilst learning for sustainability can bring a more socially critical and relevant edge to learning.

Both agendas adopt a *whole-school approach*, or a systems view of education. They share a vision of a connected school where everyone in the school community plays a part in the delivery. This vision also includes learning environments where students actively engage with choices around digital technologies and sustainability. The involvement of the wider

local community as well as regional institutions and spaces also form part of their vision of a connected school.

Through years of experience, schools have learnt that embedding these agendas requires building a critical mass of engaged and motivated staff to grow beyond the small, localised efforts of just a few people. They have understood that advancing the digital or green transitions in education is a complex challenge that cannot be tackled by individual teachers, administrators, or school leaders alone; efforts must go beyond mobilising champions. Joining forces to build a whole-school vision and approach is advantageous to both agendas.

The twin transition faces challenges which include a lack of national guidelines or frameworks for schools; the rigidity of existing curricular frameworks; insufficient digital infrastructure and technical support and the lack of robust evidence and examples of effective practice. Perhaps most significantly, are the missed opportunities in initial teacher education and limited opportunities for professional development for leaders, administrators, support staff and educators. The lack of guidance, confidence and capacity of educators is a key issue for both agendas and thus could be tackled jointly.

Concluding remarks and recommendations

The study shows how green and digital agendas are not always natural allies. Nevertheless, examples exist of how education authorities, teacher education institutes and schools can engage with the twin agendas effectively. There is still much to be done so that they can be mutually reinforcing and empower learners, teachers and schools to make changes for a green and digital future. The study makes the following recommendations:

National level policies and strategies

Creating value and a strategic vision: Policies should aim to raise awareness of the interconnectedness of sustainability and digital agendas and the value they bring to education. This could help frame a strategic vision for addressing these transitions jointly in education processes and systems. Document and collect case studies that illustrate how the transitions can be combined and feature these prominently in policy frameworks and strategies to illustrate possibilities.

Overcome policy silos: Promote collaboration across existing policies to effectively address the twin transitions in education and training, e.g. by establishing mechanisms for cross-sectoral coordination and cooperation between relevant government departments, agencies, and stakeholders responsible for education, environment, technology, and innovation.

Support whole-school development: Develop national-level policies and strategies that allocate time and space for schools to integrate sustainability and digital themes into their culture and teaching processes effectively. Provide support for the development of digital infrastructure and equitable access to technology and resources.

Promote the cultivation of a digital mindset among educators and learners: Emphasise that digital technology is not just a set of tools but also a mindset to successfully navigate through an increasingly technology-driven world.

Balance benefits and environmental impacts: Develop policies and strategies that aim for a balance between the benefits of technology and its ecological footprint, emphasising sustainable education practices and mitigating the digital divide to ensure equitable access to resources and opportunities for all learners. Support schools to adopt energy-efficient devices, implement responsible e-waste recycling programmes and encourage sustainable digital practices among students and staff.

Teaching and learning in an era of green and digital transitions

Promote transformative pedagogical approaches: Support the integration of pedagogical approaches that are transformative and promote critical thinking, problem-solving, and creativity in addressing sustainability and digital themes. Provide guidelines on curriculum implementation following these methods, enabling educators to design learning experiences that encourage active engagement with real-world issues and promote sustainable practices. Allow adequate flexibility in curricula for educators and learners to jointly address green and digital agendas effectively.

Advance innovation in assessment: Encourage the development of new approaches to assessment that align with competence-based learning and reflect the integration of sustainability and digital themes. Establish assessment criteria and methods that measure not only knowledge acquisition but also the development of critical skills, attitudes, and behaviours towards sustainability and responsible digital citizenship.

Support school leadership in learning for sustainability and digital education

Support school leadership: Provide strategic guidance and technical support to school leadership teams to better link learning for sustainability and digital education, towards establishing a school culture in their institutions that meaningfully embeds sustainability and digital themes in education and training. This process can be helpfully supported by such EU tools as the Digital Competence Framework for Educators (DigCompEdu), the Digital Competence Framework for Organisations (DigCompOrg), the European Sustainability Competence Framework (GreenComp), and the SELFIE self-reflection tools for schools and teachers that support digital capacity building.

Community and school networks

Promote collaboration: Strengthen community connections and networks for professional collaboration, providing opportunities for sharing good practices, experiences, and funding for networking activities and collaboration (e.g. Erasmus+ Teacher Academies).

Improve schools' possibilities to engage in partnerships: Support schools in opening up and strengthening links with their surrounding communities. This can include partnerships between schools, with families, municipalities, providers of non-formal learning or research partners.

Encourage participation in established networks: Encourage schools to actively participate in established networks and initiatives focused on sustainability and digital education. The availability of a structured framework to adhere to, paired with resources and peer support can help schools demonstrate their long-term commitment and progress towards sustainability and digital education goals.

Teacher education and teacher support

Build capacity in initial training and continuing professional development for educators: Support educators in addressing sustainability and digital themes, and in putting transformative learning processes into practice. Support the development of both pedagogical and technical digital skills.

Emphasise the added value: Demonstrate with practical examples the added value of learning through digital technologies for practitioners. Provide guidance and resources that demonstrate how digital tools and technologies can enrich learning experiences, enhance student engagement, facilitate personalised learning pathways, and promote a deeper understanding and application of sustainability concepts.

Professional development opportunities: Develop in-person and technology-based education offerings as well as digital teaching materials and learning resources. Support teachers to network and share good practice approaches through digital platforms. Aligning

policy commitments in these areas ensures the more efficient use of resources and enables this joint approach.

Digital tools and technologies to support learning for sustainability

Ensure equitable access: Ensure equitable access to digital technologies and resources to mitigate the digital divide.

Strengthen pedagogical use: Strengthen the pedagogical use of technology in learning for sustainability. Provide support for the selection of digital tools, e.g. based on a set of established quality criteria. Support schools to reflect on and improve their digital capacity and teachers to reflect on and improve their digital skills.

EU level policies and action

Generate robust evidence through further research: Invest in research to generate evidence on effective approaches to jointly address sustainability and digital themes in education. This includes promoting studies on teaching and learning processes, whole-school approaches, and the impact of technology on sustainability competences.

Encourage dialogue and partnerships: Facilitate networking, exchange and joint projects involving educators, schools, communities, and external partners, including through the Erasmus+ programme. This can play a key role in facilitating knowledge sharing and collaboration in addressing sustainability and digital education goals, and to disseminate examples of good practice.

1 Introduction

The European Commission has underlined that an environmentally sustainable, circular, and climate-neutral economy cannot be achieved without harnessing new technologies (Muench et al. 2022). For this reason, in 2021, EU Member States committed to jointly advancing the green and digital transitions, accelerating the adoption of digital technologies for a sustainable planet (EC 2021). Leading up to this commitment, the EU also adopted conclusions on the 'Digitalisation for the Benefit of the Environment' establishing the European Green Digital Coalition and bringing together technology business and enterprises in support of this venture (European Green Digital Coalition 2020; 2023).

Rapid and profound social changes are needed to develop green and sustainable societies requiring us to transform the way we presently live, learn and work as well as how we imagine our future (Tilbury 2023). Recognising this necessity as well as challenge, the European Commission has initiated a number of reports on the twin transitions and the potential for EU Member States to combine efforts in these areas (see Muench et al. 2022); EC 2022 Strategic Foresight Report). Its recent study 'Towards a Green and Digital Future' (Muench et al. 2022) examined how these transitions can be mutually reinforcing and identifies stepping stones that can help to align the two agendas. The research also recognises that these two priorities are not entirely complementary. Tensions add a layer of complexity to twinning efforts and are already visible within schools and colleges that are seeking to advance green and digital agendas (Tilbury 2023).

The term 'twin transitions' has been adopted to refer to these priority agendas given that they are concurrent transformational agendas that are increasingly influencing how we live our lives. In education, they offer platforms, processes and contexts that can help learners engage with contemporary issues, build competences and aspire to a more sustainable future.

This study investigates the relationship between learning for sustainability and digital education in formal education settings. It aims to explore synergies, opportunities, and challenges between the two agendas from the perspective of primary and secondary education across Europe. It does so by reviewing the limited number of authoritative documents that exist on the twin transitions. It identifies policy goals and priorities as well as ways to combine these two agendas, examples of which are beginning to emerge in schools. The report is rooted in a small but growing body of evidence that considers the value, opportunities and issues arising from aligned practices of green and digital education in schools. Further insights were gathered from case studies as well as from the engagement of education experts. Together, this data provides a deeper and more nuanced understanding of the emerging relationship between digital and green education.

Chapter 1 of this report introduces the key ideas and terminology often used in conjuction with digital education and learning for sustainability. It outlines the methodology and briefly explains the research considerations that shaped this report. Chapter 2 presents the main findings of the study and unpacks the issues that underpin as well as undermine progress in schools for the twin transitions. Chapter 3 provides insights and examples to help construct an understanding of how the twin transitions progress in schools. Chapter 4 presents the conclusions and offers policy recommendations based on emerging practice and lessons learnt.

1.1 Understanding the transitions

1.1.1 Learning for the digital transition

Digital technologies continue to extend their influence and importance across society and take on increasingly significant roles in education. They have advanced more rapidly than

any innovation in our history by enhancing connectivity and extending access and trade, reforming our financial and security institutions as well as public services (UN 2020). Whilst they bring social benefits, they also extend socio-economic inequalities and raise concerns relating to privacy and security (Muench et al. 2022).

When we refer to digital technologies we mean *electronic tools, systems, devices and resources that generate, store, process or communicate data or physical information.* Examples include social media, online games, multimedia and mobile technology, the Internet of Things, Geographic and Information Systems (GIS), Artifical Intelligence (AI), augmented reality, robotics and automated mobility (Tilbury 2023).

In education, digital education refers to both the use of digital technology in teaching and learning and the acquisition of digital competences. Notable, however, are the differences between 'digitalisation' which refers to the adoption of technological developments and 'digitality' which is concerned with changing social and cultural practices in the context of digitalisation. The European Commission's Digital Education Action Plan 2021-2027 focuses on supporting and scaling up the innovative use of digital tools and technologies in teaching and learning and building digital competences and capacity (EC 2020).

This report documents how digital education in schools is underpinned by a quest to develop not only digital literacy but also the capability of learners to use technologies for the benefit of society. Digital education can offer platforms, processes and contexts that can help learners engage with contemporary issues and develop capabilities. Specifically, it seeks to build learners' competences through interactive, collaborative, accessible, flexible, inquiry-based and networked learning. Of significance to this study are: i) how digital innovations such as online games, multimedia and mobile technology, augmented reality, Artificial Intelligence (AI) and robotics are changing how students access, interpret and co-create knowledge and (ii) how digital education aspires for a whole-school approach that improves learning environments as well as learning experiences (Tilbury 2023).

1.1.2 Learning for a sustainable future

Climate change and the decarbonisation of the economy are seen as the greatest challenges facing contemporary societies. The burning of fossil fuels and rampant deforestation is increasing greenhouse gas emissions and resulting in rising global temperatures (IPCC 2023). Changing weather patterns are threatening the quality of life as well as the life chances of many across the globe. However, sustainability is concerned with much more than climate change, it is about health and wellbeing, economic and social transitions, governance and education (UN 2015).

Learning for sustainability creates opportunities to *experience* as well as *learn* about sustainability. It immerses the learner in sustainability issues and seeks to build their ability to make descisions in support of sustainability now, and in the future.

In schools, it relies on participatory approaches to learning that challenge the traditional teacher-student dynamic and support the development of sustainability competences. Essentially, learning for sustainability seeks opportunities for collaborative, participatory, inquiry-based, future-facing and action-oriented pedagogies (Tilbury 2023). This educational agenda also adopts a whole-school approach to sustainability that requires extending learning beyond the classroom walls by involving students in schools decisions, community projects and global initiatives (Gonçalves and Tilbury 2024).

1.2   Study scope and approach

1.2.1   Methodological framework

The study that informed this report consisted of four separate phases and was designed to weave various investigative activities together, including a literature review, case study research and two expert workshops (see Figure 1).

Figure 1. The research components of the study

1.2.2   Phase 1

The initial phase of the research involved a literature review with preliminary findings feeding into the first expert workshop held virtually in July 2023.

The expert workshop brought together 55 attendees from 16 countries and provided opportunities to reflect on the conceptual links between learning for sustainability and digital education from the perspective of practitioners. The key discussion questions were as follows:

- What are the existing tensions and complementarities between the green and digital education agendas? Are these concepts understood as complementary or indeed competing priorities?

- How is the increasing demand for digital and sustainability competences affecting curricular design and implementation? What have been the policy responses so far?

- Are there school-level practices we can identify that show promise in building both types of competences - either jointly or in complementary ways?

- What specific support do educators and school leaders need to promote the green and digital agendas in efficient and effective ways?

The experts provided insights and identified pathways for the better integration of digital education and learning for sustainability in schools, and for the joint fostering of the two agendas. Parallel to the workshop meeting, a short survey was circulated among participants and wider education networks to identify potential case studies.

1.2.3 Phase 2

Eleven case studies, grouped into six different themes, were then selected as examples that can be considered successful and innovative. The initial desk research offered information on the overall aims, approaches, target groups and key milestones associated with the case studies. Interviews were then conducted regarding success factors, transferability to other contexts, barriers encountered, and lessons learnt. Through the case studies, patterns and clusters emerged which then informed the study's thematic structure (see below for the six themes under which the various examples are grouped).

Figure 2. Case study themes and featured examples

Connecting **data literacy** with learning for sustainability through digital tools	**Supporting teachers** in building competences for sustainability and digital education	**Game-based approaches** to jointly foster sustainability and digital skills	**Creating digital narratives** on sustainability and the environment	Promoting a joint focus on sustainability & digital through **established school networks**	Combining sustainability and digital focus in a **whole-school planning approach**
KlimaDatenSchule project ('Climate Data School') & app [Germany]	**Office for Climate Education** digital platform [u/a UNESCO]	**Earth Cubs** digital platform & app [United Kingdom]	**You & CO2** project [United Kingdom]	**ÖKOLOG school network** [Austria, national level]	**Kinsale Community School** [Ireland]
GLOBE (Observer) programme & app [United States]	Teacher Academy for Sustainable Future Educators (**EduSTA**) digital badges [Erasmus+]	**QuestaGame** digital platform & app [Australia]	**Young Reporters for the Environment** programme [FEE]		
	'**Digistainable teacher**' initiative [Slovenia, national level]				

1.2.4 Phase 3

The key findings and policy recommendations were derived from the literature review, the case studies, and the insights gathered during the first expert workshop. These findings were then presented at a second expert workshop (December 2023) attended by 33 participants from across Europe. In addition to seeking practitioners' feedback on the study's findings and initial policy recommendations, the workshop offered experts a forum for exchanging views on possible future directions and critical aspects to consider when fostering the two agendas, individually or jointly. It focused on the following key questions:

- What do existing research and case study findings tell us about the complementarities and synergies between learning for sustainability and digital education?

- What are the main practical challenges when integrating both agendas in education delivery? What are good practices in tackling those challenges?

- How could policy makers support the development of sustainability competences and digital skills jointly? Are there any policy levers identified that could foster the implementation of both agendas?

This final report documents the key research findings and practices as well as identifies patterns of opportunities, challenges, barriers and facilitators for progressing the twin transitions.

1.2.5 The limitations of the study

The limitations of this study are twofold. Firstly, the intersection between green and digital in school education is largely an unexplored field. Research literature is mainly divided into publications related to learning for sustainability, on the one hand, and to digital education on the other. Little research evidence exists to date to guide strategies or actions in support of the green and digital transitions.

Secondly, policies relating to digital education and learning for sustainability are emergent and practices relating to these areas are evolving. To date, few projects or approaches explicitly combine digital education and learning for sustainability. Perhaps, this is due to the multiple organisational and sectoral challenges to scaling up activities in this area. Most of the examples found in the study are therefore limited to individual schools and school networks rather than regional or national initiatives. The study did not fully map all the possible actions in place. However, the case studies provided can serve as examples and provide ideas for further action at the level of the school and system.

2 Findings

2.1 The value of digital technologies and sustainability to education

Digital technologies can bring value to education in a number of ways and at a number of levels. Tilbury (2023) identifies these as:

- extending learner participation and involvement by offering personalised learning experiences, enabling access to diverse resources, and facilitating collaboration among students and teachers;

- reshaping the teaching and learning dynamic through extending the source of 'all knowledge' and supporting more creative and interactive learning environments;

- new opportunities for networking with experts, other communities and schools as virtual connections extend the reach of resources and expertise available;

- informing teaching practices through providing and easing access to large, global repositories of knowledge, but also through utilising digital games, simulation, and gamification approaches in pedagogical practice.

- more efficient monitoring of student performance and/or attendance as well as key trends across the school. This is possible through the use of data capture and processing tools.

- improvements in educational management and administration, including the monitoring and management of school buildings and infrastructure through electronic devices and new communication technologies.

When embedded effectively and purposefully into schools systems, digital technologies can improve many aspects of school life. To take advantage of these innovations, it is important to not only consider the platforms, tools or devices independently but also how they collectively bring new relationships, spaces and opportunities for learning (Tilbury 2023).

A recent report from the World Economic Forum (2024) explores the potential for Artificial Intelligence (AI) to benefit educators, students and teachers. Case studies show how AI can personalise learning experiences, support innovative pedagogical approaches and streamline administrative tasks. The report stresses the need for "responsible deployment", addressing issues including data privacy and equitable access: "by leveraging this technology judiciously, we can enhance learning outcomes, empower educators and equip students with the requisite skills for success in the dynamic landscape of the future".

The ability of the new digital technologies to *extend learner participation and involvement in local to global issues* (Tilbury 2023) is of great interest to this study. New pedagogical approaches arise when teachers are no longer the source of knowledge or focal point of learning. Digital technologies have the potential to change this dynamic making information, resources and external experts more accessible to learners. Tilbury (2023) points to how they can reframe what can be done in classrooms but also how the *school buildings and grounds become key learning resources*. This is seen as an exciting innovation for some teachers who look for ways of bringing the school and its environment to the core of the curriculum. This practice serves to change our understanding and relationship with buildings. It is important to recognise, however, that some teachers may also feel ill-equipped to extend learning in this way.

It has been argued that sustainability brings value to education in several similar ways to the introduction of new technologies[1]. Researchers have made the case for how learning for sustainability refreshes the purpose, focus and outcomes of education and makes education systems *future-fit* (Sterling 2024; Tilbury 2011; Wals 2011). From a learner's perspective, it helps students develop the skills and knowledge necessary to make informed decisions about their own lives and the impact they have on their communities and the world (EC 2022b).

Learning for sustainability differs from much of the established subject-based school curricula in that it ultimately seeks to create learning opportunities to empower the learner (Wals 2011). It recognises that young voices hold a unique perspective on issues that affect them and that they can make a valuable contribution to more sustainable futures (EC 2022b). It therefore seeks to consider the views and expectations of young people as they strive to actively participate in society, but also aims to equip them with the skills and experience needed to effectively engage in changing society (Tilbury 2023). Similar to digital education, learning for sustainability can potentially support current curriculum goals while challenging types of student assessment that hinder the introduction of innovative educational practices and the development of new competences. It questions and refreshes established approaches to knowledge generation, learner outcomes and attainment (Tilbury 2022b).

There are also important contextual factors, relevant to both digital education and learning for sustainability. The adoption of digital technologies in education has been driven in part by general advancements in computing power, data storage capacity, algorithms and visualisation, rather than by identified educational needs. Equally, the integration of environmental themes and practices into school has often been driven by external concern about the health of people and planet. To date, both agendas have often been led by champion teachers committed to these agendas rather than by educational policy or the professional development of teachers. This means that teachers, learners, librarians, administrators and other users working in schools may need to be persuaded of the value and potential of these agendas to enhance teaching and learning. This has implications for how the twin agendas are introduced or enhanced in a school environment and addressed by policy and quality frameworks as well as teacher development.

2.2   Policy environments

The research highlights how few European countries have joined policy or investment efforts across the two agendas. Examples of integrated policies and approaches can be found in Germany, Finland and Spain and relate to coordinated financial support, training, educational research and/or curriculum development.

Germany and its National Platform on Education for Sustainable Development, coordinated by the Ministry of Education, offers an example of how to combine policy frameworks in support of the twin transitions. It has promoted the twinning of these agendas by authorities, schools and educators through a series of position papers specifically addressing the link between sustainability and digitalisation (BNE 2021; BNE 2022). These papers underscore the need for a comprehensive approach that combines digital competences with those required for sustainable development. They recognise the value of digital competences in support of decision-making and responsible actions towards environmental protection, economic stability and social equity.

Notably, the papers support the engagement of stakeholders at various levels of the education and training system, the adoption of a whole-institution approach and leveraging digital media for the purposes of learning for sustainability. They advocate for the

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[1] Findings from the expert workshops.

integration of ESD as a guiding framework for reorienting school learning, emphasising digital learning and sustainable digitalisation. This includes equipping all students with digital competences and ensuring access to digital infrastructure, and calling for collaboration among educational policy makers, administrators, and scientific communities to promote the development of systemic thinking and actionable learning in a digitalised, sustainable education system. They also stress the importance of further training for educators as well as research and monitoring.

In 2016, Finland developed curriculum frameworks that embedded ICT into the school curriculum (UNESCO 2023). These frameworks also give importance to nature studies, outdoor education and more recently to the Sustainable Development Goals (SDGs). In 2023, the education ministry published the '*Policies for the Digitalisation of Education and Training until 2027'* seeking to make Finland the world's leading developer and user of sustainable digitalisation in teaching, education and training. It has developed transversal competences that map sustainability and digital competences in schools.

Spain has recently launched numerous programmes at the national level bridging these twin concerns. For example, its State Research Agency established the 'Strategic Projects Oriented to Ecological Transition and the Digital Transition' in 2022 encouraging collaborative efforts across universities and schools. Also, Cyprus is currently revising its 'National Strategic Plan for Environmental Education' to include the digital education dimension.

Given time, it is likely that more Member States will develop policy measures to support the twin transitions in education as they familiarise themselves with the value and benefits of joining efforts as well as the recently developed frameworks and tools that support their adoption (Tilbury 2023). Nevertheless, it is important to recognise that policy implementation at the national level is complicated by the frequent division of resources and responsibilities for digital education and learning for sustainability across multiple ministerial units or government departments, with little cross-sectoral collaboration taking place. It explains why national or institutional frameworks for schools on the twin transitions are mostly absent and investment in these areas difficult to access. A more connected approach to the twin transitions in education and training at national policy level is required. To advance these, there is a need to establish mechanisms for cross-sectoral coordination and cooperation between relevant government departments, agencies and stakeholders responsible for education, environment, technology and innovation.

2.3 The emergent relationship in schools

2.3.1 Trends in practice

The case study review suggests that digital tools and technologies can enhance experiences in learning for sustainability through a wide range of applications and platforms. These, in turn, support the accessing of the latest information on climate and sustainability, foster engagement with local to global environmental issues and facilitate communication with peers and stakeholders.

Digital technologies offer increased opportunities for monitoring and tracking activities related to biodiversity, waste and recycling, resource consumption and ecological footprint, climate data, or geographic information systems. They provide the means for simulation and forecasting as well as visualisation. Digital tools include learning apps, online forums and communities, digital media, digital games as well as augmented and virtual reality experiences. School experiences show how these provide access to a wealth of information and resources on climate change, the environment and sustainability as well as supporting

more engaging and innovative teaching methods[2], which can help deepen understanding of environmental and climate-related issues and enrich the learning experience.

The initial findings, however, suggest that digital tools and technologies are often interpreted narrowly as a mere set of tools, apps and platforms[3]. Tsedal & Leonardi (2022: 51), however, emphasise how digital technologies can enable a way of 'thinking and orienting to the world that shapes how we perceive, feel, and act'[4]. Learning for sustainability suffers similarly from being implemented in a limited way; primarily as thematic environmental content to be taught (Macintyre et al. 2024). However, both agendas seek to develop mindsets that influence ways of seeing the world and develop the motivation and commitment to engage with creating a better future for all (Tilbury 2023).

2.3.2 Shared experiences

Whether education systems and educators are looking to tackle the digital or green transitions separately or look to jointly embed the two agendas, the same processes are involved when translating these commitments into teaching and learning practice. They both seek opportunities to align with mainstream practices but also bring fresh perspectives in relation to curriculum, student competences and learning spaces. Tilbury (2023) documents how they can be mutually supportive as they 'bring concurrent change agendas that are increasingly influencing how we live our lives' (p.3).

These ambitions bring shared challenges when it comes to teaching and learning. The interdisciplinary nature of learning for sustainability and digital education poses obstacles as there is a tendency towards a subject-driven organisation of national and school-level curricula, which makes cross-curricular and/or joint teaching difficult to implement. They also seek to engage learners actively and build competences which requires a shift in pedagogical practices.

2.3.3 The quest for innovation

The twin transitions are aligned in their quest for innovation as they seek to drive changes not just in society but also in schools. They challenge practices and particularly *who* is involved in teaching and learning as well as *how* and *where* learning takes place. This is done by:

- *extending learning* by involving all members of the school as well as communities of practice that exist both locally and globally. The twin transitions also go beyond single subject delivery crossing boundaries to help present a more nuanced understanding of issues.

- *creating new spaces for education* taking learning outside the classroom to include school buildings, grounds and green areas as well as into local areas, parks and cultural institutions. The case studies illustrate how these new spaces for learning may take the form of extracurricular activities, learning in non-formal contexts and online platforms, networks and communities.

- *promoting participatory pedagogies* that enable the active engagement of the learner in real life issues or scenarios and build learner competences. These learning approaches give prominence to critical thinking, problem-solving and ethical considerations.

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[2] Findings from the expert workshop.
[3] Findings from the expert workshop.
[4] Tsedal & Leonardi (2022:51) describe digital mindset as a 'set of attitudes and behaviours that enable people and organizations to see how data, algorithms, and AI open up new possibilities and to chart a path for success in a business landscape increasingly dominated by data-intensive and intelligent technologies'.

A key finding of this study is that extra-curricular activities are often the preferred choice of teachers and schools when combining learning for sustainability and digital education. This is done, for example, through coding clubs that work on environmental issues or social enterprise activities that benefit people and the planet, or through eco-clubs that use a social media campaign for change within a school or locally. Some teachers feel more comfortable working with topics related to learning for sustainability and digital education in extra-curricular settings, as these provide a low-risk environment for teachers to collaborate and experiment with different pedagogical approaches. At present, these activities are not restricted by curriculum frameworks, providing an opportunity to examine how the twinning of the two could work in educational practice. This 'experimentation' has meant that learning for sustainability and digital education have extended learning and drawn in local and distant issues as well as communities of practice into the learning experience (see Gonzalves and Tilbury 2024).

The findings of this study also highlight how learning for sustainability and digital education, when combined, can create new physical and online spaces for learning. One approach could involve learning for sustainability taking place in a physical space, such as a school garden, while the digital learning component is integrated through such tools as the creation of a smart irrigation system for plants in a school garden or greenhouse. Another approach may be that digital technologies and online spaces provide the learning space and methodology through which the learning of sustainability competences happens. Connecting sustainability and digital technologies through new spaces requires a systematic approach. This includes multiple aspects such as resourcing, access to technology and supporting both students and teachers in developing competences through using these technologies.

Digital technologies can assist learning for sustainability in shifting the teaching and learning dynamic, so that students become active participants and acquire a greater sense of agency. In the literature, digital technologies are presented in connection to learning for sustainability as a means to supplement traditional teaching approaches and continue to raise awareness about environmental issues (e.g. Hajj-Hassan et al. 2024), but they can also provide immersive and rich sensory experiences that trigger emotional responses to environmental issues. They can replace the teacher as the source of all knowledge and take learning beyond the classroom into other school areas, the local community and wider world. Through studying examples of school initiatives, Tilbury (2023) identified the functions of digital technologies (e.g. whether they serve to monitor, simulate, or provide immersive experiences) and how these can extend learner participation and engagement (see Table 1).

Table 1.   The functions of digital technologies aligned with learner participation

Area of function[5]	Functions of Digital Technologies	Case Studies: Extending learner participation
Monitoring and tracking	Smart sensors, *data analytics and real-time communication* enables students to understand and get directly involved in interpreting data related to environmental issues and sustainability. They can, for example, play an active role in: Monitoring of biodiversity and wildlife in school gardens and green areas by pupils. Monitoring of waste levels and recycling rates of the school. Monitoring energy performance and carbon emissions of school buildings. Monitoring air quality in classrooms or school grounds.	*Case Study: AQUA* AQUA is a citizen science project that aims to determine and map the water quality of households. It involves secondary school students located in Northern Spain in collecting and sharing their own data from samples collected at home. A specifically designed application and webpage helps them determine the water quality of their sample. Students develop scientific literacy, digital competences and communication as they share the findings of their work. They also learn about the issues of water quality facing the communities. *Source: Queriuga-Dios et al. (2020) taken from ICF (2023)*
Simulation and forecasting	Simulation and forecasting enable the identification of options. Through *simulation, digital games and gamification* learners explore the impact of their choices and actions on the environment as well as possible alternatives. These learner-driven programmes help them assess the potential consequences of different sustainability strategies. Through *forecasting* learners gain futures perspective. These can support learners in creating alternative futures through envisioning exercises. This can help in establishing links between today's actions and more positive and sustainable futures. These learner-centred activities can be helpful in addressing eco-anxiety of young people.	*Case Study: Up to You!* This is a simulation-based programme that focuses on sustainable futures. It offers cross-curricular learning opportunities for secondary schools' students. The game-based approach engages and immerses students in situations to help them discover the interconnected nature of SDGs. The programme moves away from the 'mundane studying of scientific facts' to 'learn-by-doing'. It supports students in grasping the complexity and uncertainty underpinning the green transition. The modular learning materials consist of videos (live-action and animation), interactive components (quizzes, scenarios), dossiers and infographics. *Source: Up to You!*

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[5] As defined in Muench et al. (2022).

Virtual and Augmented Realities	Virtual and augmented realities offer new participatory learning possibilities through: **Video-conferencing** **Virtual reality experiences** **Digital storytelling** **Augmented realities** Virtual and augmented reality technology can be used to provide immersive experiences that help students situate themselves at the centre of environmental issues and understand complex interconnections between social and economic decisions.	*Case Study: You and CO2* This initiative involves 12-13 yrs olds in creating ***interactive digital stories***. They participate in workshops that enable them to explore climate change issues and then use a simple programming platform to create their own digital stories grounded in their new learning. ***Source:*** *You and Co2 (2024) taken from ICF (2023)*
Systems management	Systems management increasingly relies on Artificial Intelligence technologies, distributed ledger technology and the Internet of Things. Participative and digital learning opportunities can be created through: **Data visualisation** – Geographic information Systems – remote sensing. **Data capture and sense making** - using data in teaching, learning and other contexts.	*Case-study: Europa's Eco-Logbook* The Eco-Club partnership use a data visualisation dashboard for students to plan, monitor, and evaluate their eco-actions. The Europa's Eco-Logbook is a dashboard developed by the University College London and uses free-to-use software to create a dashboard and link it to data stored on a share drive. It is being used mostly in primary schools to support learner engagement with school ecosystems. ***Source:*** *UCL (2024)*
Information and communication technologies	**Information and Communication technologies** enable new levels of learner interaction. The ability to connect with stakeholders beyond the learners' immediate environment is also possible through these technologies supporting the sharing and communication of information and concerns relevant to their locality. These technologies can, for example, enable their participation in a virtual environmental conservation campaign, allowing them to work together and learn from one another.	*Case Study: TENEMOS* TENEMOS is a project that supports school students to investigate, write and share articles on sustainable development issues. Information and communication technologies enable secondary school learners in an urban Spanish school to take ownership of this initiative. Students use their own smart phone devices, linking these to ***shared drives and publishing software*** that allowing sharing of drafts of articles. The project offers opportunities for students to develop digital competences, collaborative writing skills and learn about responsible reporting as well as to critical reflect upon local issues to global concerns. Source: Rodriguez Corrales, 2022

Source: Adapted from Tilbury 2023.

2.3.4 Challenges, contradictions and trade-offs

Increased use of technology and digital tools when teaching sustainability can also create tensions and trade-offs. Several challenges were identified by the study:

The ***environmental impact of technologies*** is a core issue for those wanting to progress the twin agendas. The production, use, and disposal of digital hardware, tools and technologies carry a carbon burden (Muench et al. 2022). In addition, data centres that support digital platforms and cloud-based learning use considerable amounts of energy. Increasing the use of technology necessarily means increasing the environmental footprint of education and discussions are still ongoing as to whether digitisation brings 'solutions' and alternatives, 'or more pollution' to education, given the carbon footprint of digital technologies (Jisc 2024).

The digital transition may further exacerbate existing inequalities in access to technology, ICT infrastructure, digital resources and digital competence development, widening the digital divide*. **Inequalities*** exist when it comes to accessing technologies, particularly for schools and students from disadvantaged areas and regions (Rodrigues & Lowan-Trudeau 2021). Similar issues can also arise in relation to learning for sustainability with schools from districts or regions not having easy access to green or natural areas in their neighbourhoods or the resources to visit field centres or parks. This issue disproportionately affects communities from disadvantaged backgrounds or indeed rural areas (Muench et al. 2022). Persistent disparities were documented also between and within Member States with regards to access to high-speed internet connection, digital learning devices, and individual computers within schools (European Commission 2019).

At the other end of the spectrum, research documents how the intense use of digital technologies may result in *social disengagement* and have effects on the *wellbeing of the learner (*Tilbury 2023). The **excess of digital media activity** by some can lead to a potential disconnect from nature, as learners spend less time outdoors with limited opportunities for hands-on engagement with the natural world or face-to-face interaction. In these cases, finding a balanced, positive and 'mindful' use of digital technologies is also a challenge. Research is also still inconclusive as to the effects of increased digital media activity on learners and the scientific debate is far from settled.

A challenge that many educators face is the lack of experience and confidence to integrate digital technologies into the teaching and learning process. This could be because they are not familiar with the technologies or have not been offered adequate training (Brundiers et al. 2010). They might face the '***generational digital divide**,'* meaning they lack the same level of knowledge and experience with digital tools and social media as their learners[6]. This creates a double challenge: teachers need to create a digital learning environment that is safe and easy for students to use, while also improving their own digital skills to keep up with learners (Napal et al. 2018). Paradoxically, *overestimating* learners' preparedness to use technologies also poses issues and may result in disinterest or disengagement with the proposed technology. Research highlighted, for example, that learners may find navigating digital materials difficult as they lack the familiarity or confidence to engage (Seibert et al. 2020).

Safeguarding concerns arise from issues relating to data protection and the security of the digital systems. Schools have responsibilities associated with the storage, retrieval and use of data as well as with establishing the trustworthiness, completeness and impartiality of information accessed by administrators, teachers and students (Tilbury 2023). They also have to ensure the online safety of students, protecting them from harm, preventing cyberbullying or exposure to inappropriate content (Government Events, 2024).

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[6] Findings from the expert workshop.

2.3.5 Impact of digital technologies on learning

The impact of digital technologies on teaching and learning is central to the discussion on digital transformation in education and thus highly relevant for decision making at education policy levels. Yet, findings from research yield conflicting results when it comes to assessing the effectiveness of the digital education or learning for sustainability in improving learning outcomes.

The impact of digital technologies on learning needs to be understood as a complex and non-linear concept. Giannoutsou et al. (2024: 40) relate this complexity to several factors, including 'who is involved in the implementation (actors), what activities are taken to support the implementation of these technologies (e.g., national-regional policies), and several other contextual factors (i.e., school profile, socio-economic status, digital competences, etc.). The impact of digital technologies is not determined separately by each of these elements but by their interactions as a whole'. In turn, the relationship between digital technologies and sustainability is multi-faceted and complex.

Thus, unsurprisingly, there are limited insights from the literature review on the impact of the use of digital technology on the development of sustainability competences. Existing research has been mainly focused on the extent to which digital *tools* can be integrated into the classroom to enhance learning for sustainability. This literature suggests that the use of these tools can enable the development of learners' digital literacy and skills. In particular, it provides some examples of how digital tools have been used when studying climate and sustainability. However, research that would provide more compelling evidence on the effectiveness and impact of these tools on students' learning and comprehension of environmental issues is scarce. As noted in recent research, there are few opportunities for learning technology professionals and educators to come together with ESD practitioners to explore common areas of interest (Joyce 2024). Opportunities need to be created to bring these communities together for mutual, peer learning to find pathways to advance these twin agendas.

Schönfelder and Bogner (2017), for example, compared two ways of acquiring environmental knowledge. The study assessed secondary school students' knowledge about bees, their environmental attitudes, and their perceptions of bees in relation to conservation and potential danger. The researchers looked at the effectiveness of an educational programme employing two learner-centred learning methods: one involved guided interaction with living honeybees at a beehive, while the other used an e-learning tool connected to a remote beehive. The results demonstrated that both approaches led to the acquisition of conservation-related knowledge in both the short and medium term. While direct engagement with nature could be deemed as essential, the use of an e-learning tool proved to be a valuable alternative for knowledge acquisition. Adolescents with limited environmentally positive attitudes responded favourably to the online beehive experience, which enabled them to participate and benefit from an environmental learning experience free from concerns (such as a fear of bees) that could have hindered the learning experience.

Most importantly, there is limited evidence available on the impact of digital technologies on learner outcomes as they relate to generative Artificial Intelligence (AI) tools. The past few years have seen heightened levels of popular and political interest in AI, driven in particular by the public launch of ChatGPT and similar platforms. Indeed, AI-powered tools have the potential to significantly transform learning processes by making them more adaptive and more inclusive, but they also present significant ethical and ownership challenges to education. These issues require the education community to become more involved in debates and decision-making around who gets to 'set up' AI in education (see e.g. Selwyn 2024). More rigorous and extensive research is needed so that compelling and nuanced evidence can be gathered regarding the educational impact and effectiveness of these generative technologies.

3 Opportunities for joining forces

The twin agendas could be advanced by building on the emerging synergies, identifying complementary pathways but also by coming together to face common challenges. This chapter explores potential opportunities for harnessing the digital technologies in support of learning for sustainability and in ways that contribute to improved educational experiences.

3.1 Literacy

Although gaining knowledge and understanding (literacy) and developing knowledge, skills and attitudes (competences) are not unique to these areas of learning, the twin transitions are very explicit about their intentions to attain these and have developed frameworks to guide their development (see Bianchi et al. 2022; EC 2018; Perkins et al. 2019; UNECE 2011). When it comes to developing learner literacies, there is much to benefit from carving joint pathways as digital technologies can make knowledge generation a more dynamic process whilst learning for sustainability can bring a more socially critical edge to understanding the world, and how it works (Tilbury 2023).

Academics have pointed to the many kinds of literacies that exist and agree on the fact that 'literacies' helps develop the cognitive base needed to access, interpret, assess and make decisions (Kahn and Kellner, 2006). They provide a means for learners to gain understanding of the world but also influences employment and social opportunities (Martin and Grudziecki 2006). Sustainability literacy is attained when learners have gained the knowledge that allows them to understand the intricate relationships and conflicts between humanity, development, the environment and health (Colucci-Gray et al. 2006). Literacy, in this context, is also about demonstrating a deep understanding of how local and global scenarios are connected as well as how economy, environment and social wellbeing are interdependent (Stibbe 2009). Digital literacy refers to a learner's ability to find, gather, evaluate, and communicate information using digital technologies. As with sustainability literacy, it gives a focus to developing the technical and knowledge related abilities to inform understanding and action (Tinmaz et al. 2022).

Much of the sustainability learning that takes place in schools focuses on science literacy and does not provide sufficient opportunities for learners to understand the socio-economic-environmental dynamics and interdependencies that underpin sustainability challenges. Digital education can deepen and extend this practice by providing platforms, tools and opportunities to learn about and experience distant environments and other social contexts that can help learners make sense of current environmental issues. They also immerse learners in probable and possible future scenarios helping to motivate engagement as well as enrich the learning experience (Tilbury 2023).

3.1.1 Complementarities in practice

There are obvious complementarities between the two literacies as both seek to help learners develop the conceptual and knowledge frameworks needed to understand the key issues of our day. The study found that there are numerous documented examples of schools using digital technologies to teach students about climate change, the environment and sustainability as means to advance digital and sustainability literacy. This trend is captured in the literature where there is an increasing recognition of the value of integrating digital technologies into sustainability education in a mutually beneficial way (see McClaren 2020; Fernandez, Camargo, and Nascimento 2019). The box below provides two examples, *Earth Cubs* and *Questagame*, of how to foster knowledge and understanding

of environmental and sustainability issues among students through the use of digital technology and gamification.

Box 1 Game-based approach in support of the twin transition - Examples of Earth Cubs and Questagame

Earth Cubs and Questagame are two online platforms that use digital technology and gamification to foster knowledge and understanding of environmental and sustainability issues amongst primary and secondary school aged children. While the development of sustainability literacy is the primary purpose for both initiatives, there is an implicit expectation and understanding that learners will also gain and develop experience of gathering and interpreting data digitally and learn how to navigate through these digital platforms.

Earth Cubs digital platform & app

The Earth Cubs website (https://earthcubs.com/ and mobile app https://earthcubs.com/app/) are aimed at a primary school age audience with the goal of developing children's knowledge and understanding of the natural world. Earth Cubs resources intend to support children in building sustainability literacy and familiarity with the Sustainable Development Goals. Although Earth Cubs is used in over 100 countries, the resources and content are aligned with the national curricula in England for young people between the ages of 5 and 11.

The online teaching resources consist of a mixture of mini 'interactive lessons' that deliver animated, character-based environmental information and regular quizzes to test knowledge/learning alongside physical activities and game-based learning activities. These resources are designed in such a way to be self-guided so that a learner (and/or their parents) can complete the material without the need for external supervision, though ideally these resources would be used within a live classroom environment.

The Earth Cubs app is free to download and supports the development of a range of digital engagement. Through the creation of a digital avatar and the exploration of a range of games, quizzes, and other learning activities young people begin to develop their information and data literacy skills, more specifically their capacity to evaluate information and digital content. Working through the content within a classroom setting further ensures that teachers can help students understand the credibility of the information they are presented with. Additionally, the platform offers teachers accessible continuing professional development (CPD) and teaching resources. These 'bitesize' CPD resources consist of short 10- or 15- minute self-guided online modules.

Earth Cubs has been used and accessed by over 5,500 schools across 105 countries alongside 320,000 downloads of their application since its creation in 2020. Feedback received from the integration of Earth Cubs into schools indicates that the resources are easy to integrate into the classroom and helped motivate students to learn in fun and engaging ways[7].

Questagame digital platform & app

Questagame (https://questagame.com) is an interactive game that can be accessed online and through an app. It was developed in 2013 by an Australian based social enterprise. The focus is on biodiversity, and their learning offer is for primary and secondary schools. Users take photos of wildlife (e.g. plants, insects, animals) they

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[7] Based on qualitative feedback received from users, e.g. https://earthcubs.com/diary/kettleshulme-st-james-primary-school-case-study/.

come across in their local environment and upload them in the platform. They then receive a reply from experts who identify the species. Users are also encouraged to guess the species themselves. Points are acquired for each sighting and for each species they correctly identify. Currently, Questagame has over 100,000 users, primarily in Australia, the US, UK and India.

Use of Questagame also fosters information and data literacy through the management of data, information and digital content, communication and collaboration inviting users to interact and share content through the platform. Individual users can also form a 'clan', see the scores of their clan mates, and assess how they are doing in comparison to other clans inside and outside their country.

The creators of the app have produced a tailored version for schools. 'QuestaGame for Schools' is an app that any primary and secondary school can access for free. It provides an online dashboard where teachers can collate and compare data for users in their school and other schools.

Both platforms highlight the ways in which digital technologies and gamification can motivate learners to develop sustainability knowledge and understanding while simultaneously developing their digital skills. However, these platforms are reliant on schools having smartphones, tablets, computers, and other internet-connected devices. Another challenge influencing their wider adoption is how these platforms and apps align with national curriculum requirements. Frameworks or guidance outlining how such sustainability-themed game-based approaches can be integrated in schools are needed.

3.1.2 Making choices and connections

A key question is which tools and approaches have been effective in jointly developing digital and sustainability literacies. The study found that there is a large volume of apps, platforms, and games available on offer which makes selection challenging for teachers. Findings from the case study research point to the engagement of both teachers and students at various stages of the process of learning as a key success factor. When the tools include additional support for teachers, such as guidance for implementation or an online community of practice, the chances of effective implementation increase. Tools that offer diverse functionalities and sufficient flexibility are more likely to be adopted by educators. Additionally, tools that promote collaboration and communication among learners and/or educators, or with experts from the field, can potentially enable a deeper exploration of sustainability issues. Good examples of these practices can be found in the box below which provides summaries of the KlimaDatenSchule and GLOBE Observer case-studies.

Box 2: Connecting data literacy with learning for sustainability through digital tools – the KlimaDatenSchule project and app

KlimaDatenSchule ('ClimateDataSchool', https://klimadatenschule.de/), a programme which ran in Germany from 2020 to 2023, aimed to empower students to address the climate crisis through data collection and analysis. The initiative fostered media and data literacy, encouraging students to connect with local climate initiatives and NGOs. It was funded by the Federal Ministry for Climate Action as part of the national climate protection initiative (Nationale Klimaschutzinitiative, NKI) and coordinated by BildungsCent e.V, an NGO in the field of education for sustainable development.

Linking climate actions with media and data literacy, students used analogue and digital tools to observe their immediate environment, learn how to interpret data and discuss steps towards greater sustainability. Schools were provided with a toolbox of four central climate issues: trees, mobility, paper and nutrition. Students had the option to work with a web app that integrated data collection and storage. All data generated from KlimaDatenSchule projects, as well as other initiatives, remain open source and accessible for analysis and further research by any party.

Additionally, KlimaDatenSchule worked with local NGOs, conducting workshops at schools and providing support for project implementation. The programme offered support and training sessions for teachers, including online training courses, training videos, digital Q&A sessions, regular open meetings to exchange ideas and experiences, and ongoing technical support via e-mail. The initiative reached more than 6,000 schools in Germany, but despite its success, the project concluded in 2023 due to a lack of funding.

GLOBE programme and app

The Global Learning and Observations to Benefit the Environment (GLOBE, https://observer.globe.gov/) programme is a hands-on, worldwide science and education initiative focusing on the environment. Operating in over 120 countries, it aims to promote science education, environmental literacy and stewardship, and scientific discovery. It was established in 1995 as a White House Initiative, involving NASA, the National Oceanic and Atmospheric Administration, the National Science Foundation, and the US Department of State.

With a focus on scientific literacy and global community building, GLOBE has engaged around 40,000 schools worldwide, facilitating connections among students, teachers, researchers and citizens. The aim of the GLOBE programme is to deepen student understanding of climate change through the collection and analysis of data, including atmospheric, soil and land cover data. It is aimed at school students getting involved in collecting and validating data on climate change that NASA is observing from space. Students utilise the data to create maps and graphs, collaborating with scientists and fellow GLOBE students around the world.

While originally developed for analogue use, GLOBE has since developed the GLOBE Observer app allowing users to upload observations on clouds, mosquito habitat, land cover, and trees and track changes over time. The app includes tutorials that guides users through the data collection steps. GLOBE supports teachers with regional and virtual trainings, contact to regional coordinators, conferences, networking opportunities and various documents and handbooks.

Despite challenges associated with its large scale, GLOBE benefits from consistent funding, allowing for ongoing evaluation, adaptation, and the planned expansion of the GLOBE Observer app. The GLOBE programme plans to expand the GLOBE Observer app in the coming years, responding to the interest from schools and citizen scientists. The app will be integrated into the main GLOBE programme and funded as a key component of the initiative.

A wide range of initiatives and apps using game-based approaches to promote sustainability exists. However, one needs to reflect on the 'shelf-life' of available digital tools. Many of these apps are no longer available 3-5 years after their inception, or if they are accessible, they are no longer updated. The potential challenge this presents for schools is knowing which apps they should encourage teachers to use.

It is advisable that the selection of appropriate digital tools follows certain established quality criteria. One step in this direction has, for example, been taken by the German

National Platform on Education for Sustainable Development[8], by publishing a set of guidelines and quality criteria for digital materials for education for sustainable development[9]. These criteria focus on aligning digital learning materials with the 17 Sustainable Development Goals (SDGs), ensuring they are factually accurate and relevant. Additionally, the guidelines stress the importance of data protection, accessibility, and the non-commercial nature of the content. The criteria are categorised into content, methodology, and formal design. The aim is to assess how engaging, accessible, and supportive of independent judgment and critical media literacy these educational materials are.

Another key consideration, as advised by Napal et al. (2020), is the need for teachers to engage with educational technology specialists and/or schools' ICT coordinators to ensure that their choice of digital tools, platforms or apps is suitable to the hardware and software available to the schools.

In summary, there is a wide variety of digital tools available that can support the development of sustainability and digital literacies in tandem, although they were not necessarily developed with this intention. Examples from the case study research show how these tools can be used for this purpose, especially when they grant schools and teachers sufficient flexibility to adapt the tools and their application to their context, needs, and interests.

3.2 Frameworks for building learner competences

While literacy can be understood as the foundational knowledge needed in a specific domain, competence goes a step further by involving the practical application of that knowledge in relevant situations. The attention of the education community has been more recently focused on identifying and developing competences and to addressing these through the core curriculum. This interest may be explained in part by rising levels of eco-anxiety amongst young people and the need to support them to take positive action for sustainability in order to counter these negative emotions. For example, learners may be concerned about the future of the climate and may wish to actively engage in actions to address this concern. Competence-based learning can give them the ability to translate their knowledge and concern into action.

Digital education and learning for sustainability are both concerned with empowering the learner to participate in society (Tilbury 2023). They complement the focus on cognitive learning ('head') with a 'heart and hand' approach that engages the learner in embodying and enacting their choices.

The most known competence framework for digital education is the European Commission's Digital Competence Framework (DigComp) that has been available for several years, with the most recent update (DigComp 2.2) released in 2022. The Framework summarises the skills and attitudes that help citizens engage confidently, critically, and safely with digital technologies (see Figure 3).

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[8] https://www.bne-portal.de/
[9] Leitlinien und Gütekriterien digitaler Materialien für Bildung für nachhaltige Entwicklung (BNE) (Guidelines and quality criteria for digital resources for Education for Sustainable Development (ESD); in German), retrievable at: https://www.bne-portal.de/bne/shareddocs/downloads/files/beschluss-np-guetekriterien-bne-materialien.pdf?__blob=publicationFile&v=1

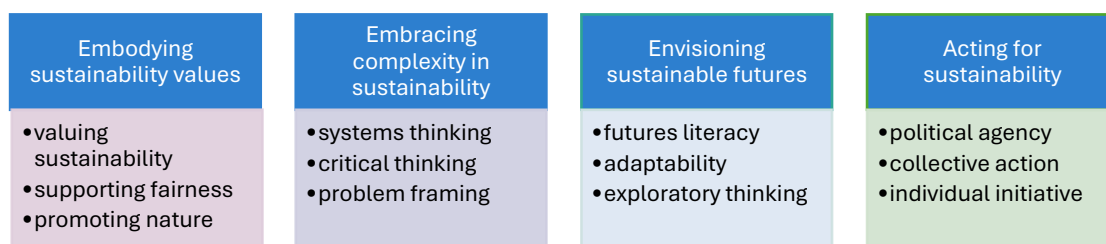**Figure 3. DigComp—The European Digital Competence Framework**

Information and Data Literacy	Communication and Collaboration	Digital Content Creation	Safety	Problem Solving
• Browsing, searching and filtering data, information and digital content • Evaluating data, information and digital content • Managing data, information and digital content	• Interacting through digital technologies • Sharing information and content through digital technologies • Engaging in citizenship through digital technologies • Collaborating through digital technologies • Netiquette • Managing digital identity	• Developing digital content • Integrating and re-elaborating digital content • Copyright and licences • Programming	• Protecting devices • Protecting personal data and privacy • Protecting health and wellbeing • Protecting the environment	• Solving technical problems • Identifying needs and technological responses • Creatively using digital technologies • Identifying digital competence gaps

To further support digital skills and competences development in schools, and to assist educators in responding to changing demands in this sphere, the European Commission also developed the Digital Competence Framework for Educators (DigCompEdu). Directed at educators across all levels of education, the framework describes 22 competences across six areas: professional engagement, digital resources, teaching and learning, assessment, empowering learners and facilitating learners' digital competence. In parallel, the Digital Competence Framework for Organisations (DigCompOrg) seeks to guide a process of self-reflection towards the comprehensive integration of digital learning technologies across organisations, including schools[10].

Several years later, and in line with the European Council recommendation on learning for sustainability (EC 2022a), the European Sustainability Competence Framework, known as GreenComp (Bianchi et al. 2022), was developed. This framework identifies and defines a set of specific competences necessary to move towards a sustainable way of acting and living. GreenComp seeks to help educators (and policy makers) and support learners of all ages to build the skills they need to thrive in changing environmental, social, cultural and economic contexts.

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[10] At European level, the European Reference Framework for Digitally Competent Educational Organisations (DigCompOrg) has been developed as a pan-European approach to organisational digital capacity. See https://joint-research-centre.ec.europa.eu/european-framework-digitally-competent-educational-organisations-digcomporg_en. For an example at national level, see for example Portugal's Digital Education Transition Plan: https://digital-skills-jobs.europa.eu/en/inspiration/good-practices/digital-education-transition-plan-portugal and https://portugal2020.pt/project/ptde-plano-de-transicao-digital-da-educacao/ (in Portuguese). Last accessed 13/02/2024.

Figure 4. GreenComp – The European Sustainability Competence Framework

Embodying sustainability values	Embracing complexity in sustainability	Envisioning sustainable futures	Acting for sustainability
• valuing sustainability • supporting fairness • promoting nature	• systems thinking • critical thinking • problem framing	• futures literacy • adaptability • exploratory thinking	• political agency • collective action • individual initiative

Although DigComp and GreenComp competences do not overlap, they share important thematic connections. For example, DigComp's safety pillar specifically calls for an understanding of the environmental impact of digital technologies. This competence area highlights the importance of understanding how the use and disposal of digital devices contribute to environmental challenges, such as energy consumption, e-waste, and resource depletion. It encourages individuals to adopt sustainable practices in their digital usage, including optimising energy efficiency, reducing unnecessary digital consumption and responsibly recycling devices.

More generally, however, both transitions share a quest for a more capable and engaged learner and require participatory approaches to learning. This ambition is reflected in both frameworks (Tilbury 2023). Indeed, it is recognised that digital tools and technologies can potentially support student-centred, project-based, problem-based, and interactive educational approaches which are particularly useful for the development of green competences (e.g. Agbedahin 2019). Specifically, active learning and participatory pedagogical practices are advocated for the development of these competences, making it possible (and beneficial) for these to be fostered and developed together (Tilbury 2023).

Research also indicates that environmental topics provide a valuable pedagogical opportunity for educators to introduce real-world problems into the learning environment and present learners with a chance to develop their digital competences and knowledge (Lin, Chai, and Jong 2019). The initiative, 'You & CO2' illustrates this in practice (see Box 3). Notably, digital technologies can make knowledge generation a more dynamic process by involving the learner in the co-creation of knowledge, whilst learning for sustainability can bring a more socially critical edge to learning. ensuring that contexts, values, and validity are questioned by the learner.

Policy measures and incentives as well as guidance, training and support can assist in the joint development of sustainability and digital competences for the benefit of learners. However, it is worth noting that research to date has been focusing mainly on how digital tools can be integrated into the classroom while research delving into the actual impact of these competence frameworks on students' learning is absent. Similarly, there is less focus in the literature on how teachers interact with sustainability and technology to advance the development of learners' competences (see also section 2.3.4).

Box 3: Case study: 'You & CO2'

The 'You & CO2' programme (https://youandco2.org/) consists of a series of workshops for secondary school students. Using multiliteracies and interactive, non-linear digital stories written specifically to be read from digital devices, You & CO2 engages students in reading, writing, coding, multimodal communication, group and individual work, creativity and non-linear thinking. Coordinated by the University of

Swansea in Wales, the programme incorporates four interdisciplinary perspectives from chemistry, psychology, pedagogy and literature.

Students first read a futuristic story with different endings, exploring the impact of various actions. They then write their own digital stories, delving deeper into their ideas and approaches around personal responsibility, climate change, and its impacts. They are given free rein to research issues that are close to their interests, while also combining digital stories and expressive writing through game design and coding. The programme was trialled in Wales in 2018 and since has been introduced in schools in several countries, including South Africa, the US, Australia and New Zealand.

'You & CO2' encourages students to research and demonstrate the effects of complex topics that affect their daily lives. In addition to developing students' green and digital skills, the programme also encourages creativity by engaging them in interactive digital storytelling.

Supporting the programme's methodological approach, research by Finnegan (2022) suggests that digital storytelling is also a compelling tool for engaging and motivating students. Finnegan also observed that in addition to developing competences in sustainability and digital, the digital storytelling approach also empowered students, helping them feel more connected and hopeful regarding climate futures.

Examining the programme through a different lens, Ross et al. (2023) assessed how it developed students' competences and found the approach successful and flexible enough to be adaptable to a variety of learners' needs and practitioner skillsets, further boosting the transferability of You & CO2 across multiple contexts.

3.3   Whole-School Approaches

Whole-School Approaches (WSA) have been used to promote education in many areas such as health, global citizenship education, human rights, and inclusion (UNESCO 2018b). They are seen as core to advancing sustainability efforts and embedding digital education in schools. They both seek learning environments where students live, learn and benefit from the choices related to digital technologies and sustainability at their school.

3.3.1 Understanding the WSA

In essence, a school that adopts a WSA will connect what students learn through the curriculum with what the school practices through its management, operations, procurement, as well as outreach. This approach seeks to take learning outside of the classroom walls by engaging students in school decisions, involving them in community projects and global initiatives (Tilbury and Galvin 2023). It also encourages partnership engagement from community groups involving students in real-life experiences and actions.

The WSA adopts an 'ecological' or connected view, where everyone in the school community plays a part in delivering the changes needed. The school community is understood in its broadest sense and includes multiple stakeholders, such as principals, teachers, students, school staff, families and other members of the local community. Essentially, it advocates for a school that serves as an open learning hub, providing support to its neighbourhood and, in turn, receiving support from the local community (EC 2015)[11]. A recent study reinforced the importance of such collaborative arrangements between

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[11]   https://education.ec.europa.eu/sites/default/files/document-library-docs/early-school-leaving-group2015-policy-messages_en.pdf.

staff, students, parents and the wider community as a vital precondition to securing an effective and durable WSA (Bosevska and Kriewald 2020).

In addition to connecting the various aspects of the school so that they align to sustainability or digitisation, a WSA to education is also about redesigning students' experiences so that they can meaningfully develop mindsets and competences that enable them to contribute to sustainability and digital education (Tilbury 2023).

3.3.2 Ambitions into practice

While WSAs are increasingly applied in schools, there is a lack of documented experiences of how they may be designed or adopted to promote a coordinated approach to learning for sustainability and digital education. The literature does suggest that the complexities of developing and maintaining WSA may be most effectively addressed through change management strategies and methodologies (see Scott, Coats & Anderson 2008; Barr, Cross & Dunbar 2014; Mogren et al. 2018; Marjanovic 2021). In parallel, authorities and schools seeking to advance digital education or learning for sustainability in practice have learnt that embedding these areas of learning requires building a critical mass of engaged and motivated staff, enabling the effort to grow beyond a small, localised effort of a handful of people[12]. They have understood that WSA are complex and cannot be tackled by individual teachers, administrators, or school leaders alone; efforts must go beyond mobilising champions. Thus, whether schools are seeking to tackle the digital or green transitions separately or jointly, they should provide opportunities for staff members to join these efforts, feel invested and share their ideas on how to empower students.

The *Eco Schools* programme of the Foundation of Environmental Education (FEE 2024) provides a case study of how these two agendas can come together in practice through the adoption of a WSA (see Box 4). Reaching over 68 countries to date, this programme supports schools in improving their environmental footprint while also engaging multiple stakeholders in transformative learning experiences. Whilst *Eco Schools* assist schools in developing a tailored action plan, it does not prescribe what this should look like in individual schools. Instead, it requires schools to adapt the programme to their own contexts, with the school's vision for learning for sustainability emerging as part of the process. For some schools, this flexibility has created space for them to adopt digital technologies as a way of delivering on their *Eco Schools* programme.

Box 4: Eco Schools Programme

Schools that implement the seven-step Eco-Schools programme are awarded a green flag in recognition of their commitment to the environment and sustainability. To date, approximately 19,000 flags have been awarded. The seven steps are: (1) forming an Eco-Committee; (2) carrying out an environmental review; (3) making an action plan; (4) linking to the curriculum; (5) informing and involving; (6) monitoring and evaluating; (7) producing an eco-code, a statement that represents the school's commitment to sustainability.

The Eco Schools programme works with twelve environmental themes: biodiversity and nature, climate change, energy, food, global citizenship, health & wellbeing, litter, marine and coast, school grounds, transport, waste and water.

Although digital technologies are not officially part of the methodology, reports from schools participating in the programme indicate that they are increasingly connecting

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[12] Findings from the expert workshops.

the two agendas in practice. There are examples of using digital technology in almost every step of the programme, including:

Iin the ***environmental audit process***, with sensors, apps and digital devices used to measure air quality, pollution, waste production, carbon impact along with Geographic Information Systems tools that help map and analyse local environmental data.

In ***project management***, with digital tools and platforms used during the action planning stages. Cloud-based solutions proving helpful in keeping track of progress; collectively editing documents; manage feedback surveys as well as monitoring and evaluation data.

In improving the ***student experiences***, with virtual field trips and interactive simulations of environmental issues enriching the curriculum. Social media is used to support the communication of the eco-code and showcasing actions, progress and impact.

In supporting ***professional development***, with the Eco Schools platform providing webinars, resources for online learning, educational materials such as lesson plans, as well as curated lists of external resources. Furthermore, it regularly features inspirational practice examples from Eco-Schools all over the world.

3.3.3 Engagement and leadership

The literature suggests that strong leadership is essential to encourage participation and developing a shared vision across the school (UNESCO 2014). WSAs entail the regular and structured participation of teachers and learners in designing, planning, and taking actions for sustainability across the school (UNECE 2021). However, the identification of opportunities and the development of teams take time and buy-in from the school leadership, as can be seen in the case of Kinsale Community School in Ireland. Showcasing how a WSA can blend learning for sustainability and digital education, this secondary school provides students with the practical skills and tools to work with nature, and to utilise digital tools in a meaningful and sustainable manner to enhance their learning in both areas (see Box 5). A key element facilitating the school's approach has been the creation of collaborative spaces and the encouragement of a culture of collaboration across the school to build a critical mass of engaged and motivated staff.

The example of Kinsale Community School underlines that distributed leadership, as opposed to the 'heroic style' or 'champion approach,' aligns better with the increased participation of all stakeholders involved in WSAs (UNECE 2021; UNESCO 2012; UNESCO 2014; UNESCO 2017). As evidenced in the literature, leaders play a critical role in empowering stakeholders and promoting participatory decision-making across the school along with allocating staff, time and resources to ensure an effective and efficient implementation (Mogren et al. 2018, Bosevska and Kriewald 2020; Marjanovic 2021; UNECE 2021). In fact, Barr, Cross, and Dunbar (2014) argue that that the greatest potential for change is realised when decision-making is transparent, participatory, and empowering. This means that not only should all relevant stakeholders participate in the decision-making process, but they should also be provided by the schools' senior management team with the resources necessary to implement those decisions.

Box 5: The Whole School Approach at Kinsale Community School, Ireland

Catering for students aged between 12 and 18 years, Kinsale Community School in Ireland has developed its own whole-school planning approach to combining learning for sustainability and digital education. These two learning areas have been part of the school's activities for several years, although a more strategically blended and complementary approach was established three years ago.

Motivation: During the Covid pandemic, the school's staff noticed students becoming more disengaged and displaying heightened signs of concern, fearing the effects of climate change and other environmental issues. This resulted in a whole-school-level decision to develop a school environment to support learning for sustainability and tackle eco-anxiety. A key step along this journey was the appointment of a member of staff as 'Sustainability Chaplain' acting as the first point of contact for sustainability actions in the school and who recognised the negative emotional responses this agenda could trigger. Over the years, this staff member has provided hands-on engagement of learning and championed the physical transformation of the school's grounds into a sustainable, nature driven, educational environment.

Living and learning the transitions: The physical transformation of the school included developments such as solar panels, water harvesting systems, water fountains, and efforts to increase biodiversity through a botanical glass house, the planting of a hedgerow, an orchard with native Irish trees, and a wildflower garden. These changes were linked to classroom-based learning, with a mindful use of digital tools supporting the process. Every student, in every year, across the 1,500-student school, can study digital and sustainability topics. Linked with a large technology provider, the school utilises digital technologies both in the classroom and for school communications.

Professional development: The school has structured support available for teaching staff to build in the digital into their teaching practice such as formal training opportunities in the school and staff teaching and learning days for sharing good practice. The appointment of several colleagues as digital leaders also supports teacher development and fosters peer learning.

Partnerships beyond the school: The school also has an active community engagement approach, for example its partnership with Kinsale Town in the Transition Town Council initiative on sustainable and resilient communities. A notable example included a student project that explored town attitudes around reusable coffee cups and other recyclable materials in restaurants and cafés, with ongoing developments around using a 3D printer to design coffee cup sleeves from recyclable materials. This and similar past initiatives support practice-based learning, the development and embedding of competences, and empower students to see how their involvement can make a difference locally.

Figure 5. Map of Kinsale Community School Green.

Mindful technology: The reflective nature of whole-school approaches enabled the school to review their experiences and explore tensions between the two agendas both in their own local and national contexts. The school's policy of mindfully using technology as a supportive tool, and not something to engage with for its own sake, has been key to its success. Monitoring 'screen time' is thus an important priority of the school, ensuring that technology is used in a conscious manner. Tying this approach to developments happening in the country, students explore the environmental impact of the growing number of data centres in Ireland and their implications for energy usage; this connects local learning with broader national issues. The school's approach to using social media and related digital tools in a way that supports student creativity, learning of new skills such as digital video production while learning about the impact of such digital technologies has also been effective in advancing the twin agendas.

Learning from experience: The school has shown how finding and developing opportunities for linking sustainability and digital in school life takes time and dedication, particularly when it comes to the curriculum. Currently the two areas are integrated into different subjects across the curriculum, but the school is actively working on encouraging opportunities for blending the two. Another learning experience has been mastering the digital tools and technologies in ways to support engagement and community building, data collection and analysis, documentation of learning and social media engagement.

Leadership and engagement: A key strength of the Kinsale Community School approach is the leadership's support for creating collaborative spaces across the school curriculum and the school grounds. The creation and sustained support for collaborative spaces and the empowering of students created a sense of community across the whole school, where all are invited and motivated to participate. The school culture of encouraging student participation and staff collaboration is also key to fostering creativity.

3.4   Facing common challenges together

The study found that the green and digital agendas both share complex challenges which can include a lack of freedom or authority for schools to adopt innovative practices; the omission of national policies, guidelines or frameworks for schools to facilitate this; the rigidity of existing curricular frameworks; insufficient digital infrastructure and technical support available in schools; and a lack of robust scientific evidence of what effective and meaningful practice looks like[13]. The literature, on the other hand, points to the missed opportunities in initial teacher education and limited opportunities for professional development for leaders, administrators, support staff and educators (Mula and Tilbury 2022; Gottschalk and Weise 2023).

3.4.1 Authority to innovate

The ability to innovate practice at the school level differs across education systems depending on the level of centralisation/decentralisation of responsibilities. While school leaders enjoy greater operational freedom in decentralised education systems, more centralised education systems can limit experimentation at school level (Ouchi 2006; McGrath, Hampe-Nathaniel and Desmedt 2022) making it challenging to progress either of these agendas. In terms of options, there is also the possibility of central authorities setting general reform frameworks with national objectives, targets, and dedicated funding streams, and then devolving the implementation of those objectives to individual schools. Exploring this challenge in the context of WSA for sustainability, Henderson and Tilbury (2004) found that successful innovations either align themselves with national priorities or successfully develop as tools for implementing national policies. This was seen to increase their relevance, effectiveness, and longevity, offering possible pathways for progressing both digital and sustainability learning ambitions.

3.4.2 Policies, frameworks and exemplars

Policy commitments and actions that support both green and digital education are key to address the difficulties that schools face when trying to innovate. These commitments would need to be resourced so that digital infrastructure and equitable access to technology and resources is possible. It is also likely that greater investment in empirical research is needed to generate evidence on effective approaches to jointly address sustainability and digital themes in education. A meta-analysis of data and grounded practice will also give weight to such policies.

The study found that authorities, agencies, and schools need not only to understand the value but to recognise also the opportunities in aligning these two agendas[14]. Guiding frameworks are needed to address these issues, which are currently preventing these educational innovations from being tackled jointly. For example, multiple studies caution against the overuse of technology as it can lead to student distraction and disconnection (Thomas and Munge 2017; Hills, Kraalingen and Thomas 2023). However, integrating digital technologies with outdoor and experiential learning can lead to an improved learning experience while at the same time mitigating the risk of an excess of passive 'screen time'. Simultaneously, this practice would see digital tools and resources being used in a meaningful and effective way to deepen learners' understanding of sustainability-related issues, cultivate critical thinking about sustainability challenges and inspire innovative ways of engaging in change.

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[13] Findings from the expert workshops.
[14] Findings from the expert workshops.

Case studies should be used to exemplify the core elements identified in these frameworks and to illustrate the coming together of digital education and learning for sustainability. They can serve to inform effective implementation of policies. The National Education Nature Park initiative (UK DFE 2023) is an example of a project that uses digital technologies to engage children and young people with nature while also encouraging school estate administrators to work with students to improve biodiversity on school grounds (Tilbury 2023). Another example is Kinsale Community School (see Box 5 above) that has found another way of navigating the potential overuse of technology. The school adopts a mindful and reflective approach to digital technologies whilst promoting the development of digital skills and competences through authentic learning experiences which focus on sustainability. Indeed, findings from the literature suggest that a balanced approach can bring multiple benefit to learners (Greenwood & Hougham 2015; Hills and Thomas 2019).

The Young Reporters for the Environment programme exemplifies how the tensions between digital and sustainability learning can be used as a basis for developing capabilities associated with both areas of learning. It is an example of student-led learning which operates in 40 countries globally and involves learners in identifying and researching environmental issues and identifying potential solutions. The digital element of the programme helps students research and document their findings and reach an audience beyond their local communities to create a broader appeal and ripple effect. Furthermore, the programme's flexibility and focus on issues of interest to students helps them connect their learning to local contexts. These core elements are worth featuring and exemplifying in educational policy frameworks and guidance documents.

Box 6: Young reporters for the Environment

The *Young Reporters for the Environment* (YRE) programme engages young people (aged 11 to 25) in creative environmental journalism. Since its first iteration in 1994, the programme has reached almost 500,000 young reporters across 43 countries (https://www.yre.global/).

The programme engages students in investigating local environmental problems or issues and reporting on these, along with proposed solutions through articles, photos or videos. They are also tasked with disseminating the reports produced and information on the actions taken through various platforms.

The research and investigative steps involve mapping local stakeholders, analysing the local context and its links to the wider global picture, collecting data through various means, including conducting interviews with key individuals. These steps align well with the principles of learning by doing and encourage engagement with their local communities.

This strong focus on investigative skills also allows students develop their research skills, critical thinking and creativity. YRE students are encouraged to go beyond the investigation of an environmental problem through researching and proposing their own feasible and effective solutions.

In addition to using digital tools for research and content creation, students also learn how to choose the most appropriate media for communicating their findings to their peers and the wider public. Therefore, the programme succeeds in fostering environmental awareness and action, whilst equipping students with digital and media literacy skills. To encourage and motivate students, each country implementing the YRE programme can organise national competitions to select the best entries for the annual YRE international competition. The international jury, composed of experts

including filmmakers, judges entries against several criteria, one of which is dedicated to dissemination.

3.4.3 Networks for innovation and support

Evidence suggests that joining an established school network can motivate and encourage schools to explore the relationship between the green and digital agendas more closely and practically. For example, the Austrian ÖKOLOG network has, through knowledge sharing, provided tangible examples of how schools can address the environmental impact of digital technologies.

Box 7: ÖKOLOG network: supporting schools to create a sustainable school environment

ÖKOLOG is a school network (https://www.oekolog.at/) that has been in existence for 20 years. Initiated by the Austrian Federal Ministry of Education, the network is coordinated by the University of Klagenfurt and brings together 700 ÖKOLOG schools, from primary level to upper secondary level as well as 14 Austrian university colleges of teacher education.

Its vision is to establish ecologically, socially, and economically sustainable designs for the school's physical environment and to involve the extended school community in the process. The network offers a framework based on a set of eight areas for action, which have been developed through a participatory process together with the ÖKOLOG regional teams.

The framework includes a distinct area called 'Digitalisation and Media' to highlight the essential role of digitalisation in sustainability. This area focuses on the influence of digitalisation on the environment and climate; critical media use; sustainable use of digital technologies; sustainable use of natural resources and technology in assessment. ÖKOLOG also addresses the topic of digitalisation through actions such as a dedicated month of digitalisation and sustainability where additional information and resource on the topic are provided to schools.

ÖKOLOG network's activities include the following:

- Collecting materials, examples and ideas for learning and teaching for sustainability (and digitisation) distributing them through the ÖKOLOG website. This also includes relevant research publications.

- Disseminating information on relevant events, further training, workshops and competitions – both through its website and social media (Instagram, Facebook).

- Providing several online tools addressed to schools, including a self-assessment tool to identify strengths and weaknesses by area (with digitalisation and media displayed separately), and a carbon footprint calculator for schools.

- Hosting an annual ÖKOLOG Environmental Week: a series of online workshops addressed to learners over the course of three days (https://www.oekolog.at/veranstaltungen/detail/27). Additionally, schools can showcase their activities and projects by uploading a short video to the ÖKOLOG website. Schools can then vote on the best submitted projects.

ÖKOLOG provides a self-assessment tool for schools based on series of statements across eight areas. The fictional school shown in Figure 6 below achieves very high scores in the area of digitalisation and media, but only low scores in the area of sustainable use of resources. If the self-assessment is repeated annually, schools can easily track their developments.

This network is an example of how educators can be supported through the exchange of information and experiences as well as through assessment tools linking digital education and learning for sustainability in ways that help bring educational innovation into schools.

Figure 6. dimensions covered by Ökolog.
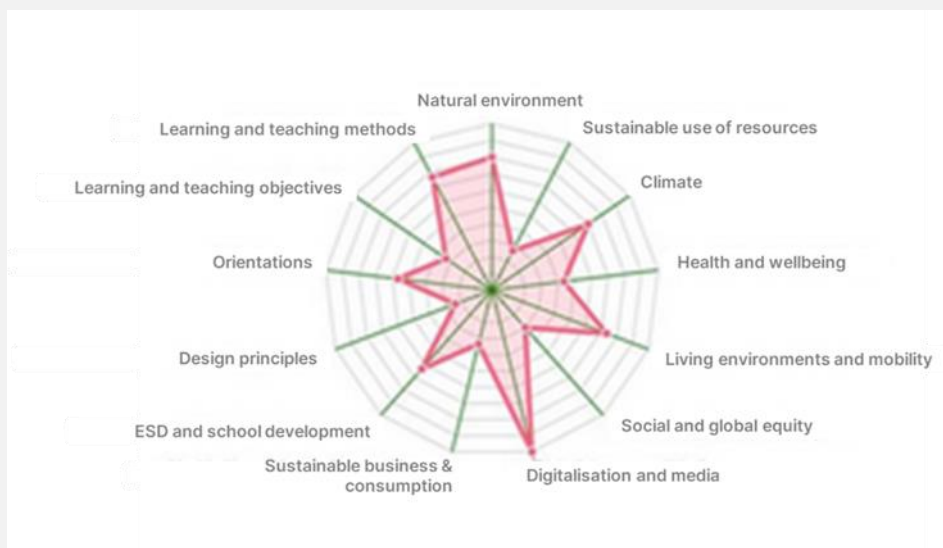
Image source: https://www.oekolog.at/; edited with own translations.

Another key challenge is the lack of technical support and the issue of potential technology upgrades, repairs and replacements over time. From a sustainability perspective, schemes that encourage and support schools in accessing services to support the long-term use of resources, rather than replacing technology, can be a useful addition. The sharing of expertise and experiences via localised school networks could also be valuable in this context.

3.4.4 Embedding change through teacher education

Successful approaches to whole-school engagement are those where digital education and learning for sustainability become integral pillars, rather than merely projects with a limited timeline. Such approaches enable the twin transitions to move from the margins of school experiences to being embedded in the culture and vision of the school. The literature suggests that the key to embedding these changes lies in teacher education and professional development.

On an individual level, teachers require support to successfully adopt the new pedagogies and assessment approaches that underpin both agendas (Tilbury 2022). They also need guidance to build their confidence in the ethical and effective use of digital tools, the successful planning of external visits or field trips and in building partnerships with the community, and engaging with the non-formal sector, which are all important components of these innovative areas of learning.

It is important to recognise the missed opportunities in initial teacher education (ITE) as well as the limited offerings in continuing professional development (CPD) for teachers in these areas[15]. The need for guidance and actions to help boost the confidence and capability of educators is a key issue for both agendas and thus could be jointly tackled. Supporting educators throughout their professional lifecycle, from pre-service training to continuing professional development opportunities, is not only a key driver of improvement for all education systems but also essential for developing teacher competences and embedding the green and digital agendas in schools.

Practically, this could be approached in multiple ways such as through a combination of in-person and technology-based education offerings, the development of digital teaching materials and learning resources, and supporting teachers in networking and sharing good practice approaches through digital platforms. Digital tools and platforms can offer online and in-person training options as well as synchronous and asynchronous learning options (Haleem et al. 2022). Online platforms offer a wide range of sustainability-focused courses designed specifically for teacher education as well as communities of practice (such as online forums, social media groups, and professional networks) that can facilitate peer exchange and collaboration across institutions.

Research highlights how Massive Open Online Courses (MOOCs) can be leveraged as an effective and scalable solution for teachers' professional development (Vivian et al. 2014; Jobe et al. 2014). The advantages of MOOCs are well documented, particularly in terms of how they can enhance employability by giving learners access to various skill-based courses, as well as how they allow working professionals to study at their own pace, from anywhere and at any time (Haleem et al. 2022). Participating in communities of practice (including online forums, social media groups, and professional networks) can facilitate peer exchange and support the building of collaborative networks. These would support teachers in their use of digital technologies to enhance the development of students' sustainability competences. Aligning policy commitments in these areas ensures the more efficient use of resources and enables this joint approach.

Providing structured support for teachers is key to boosting their engagement, preparing them to face challenging issues, and giving them the confidence to design quality learning experiences. There are numerous frameworks, such as the European Commission's Framework for the Digital Competence of Educators (DigCompEdu)[16], that can provide a starting point and reference framework for building approaches to digital competence development. In addition, the framework has been used to provide a self-reflection tool for teachers[17] (see Box 8).

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[15] Findings from the expert workshops.
[16] https://joint-research-centre.ec.europa.eu/digcompedu_en
[17] https://joint-research-centre.ec.europa.eu/digcompedu/digcompedu-self-reflection-tools_en

SELFIEforTEACHERS is a free online tool to support teachers in early years, primary, and secondary education to reflect on and improve how they use digital technologies in their practice. Users answer a series of statements on how they currently use digital tools in six different areas. This takes around 30 minutes to complete. Teachers then receive a personalised report with their results (from 'newcomer' to 'pioneer') as well as suggestions on how to further improve.

Teachers can identify their weaknesses and strengths and plan their professional learning paths to further build their digital competence. They can initiate a self-reflection process at any time and complete it at their own pace in as many sessions as they need. The tool can also be used in a group context with teachers of the same discipline, a student teacher group or teachers that belong to a network of schools or region. In this case, the tool provides a report with aggregated data which can be used to plan professional development activities as a group. The figure below illustrates the SELFIEforTEACHERS areas and items.

Figure 7. Overview of areas and items covered by SELFIE for Teachers.

Source: SELFIEforTEACHERS infographics, 2021.

SELFIEforTEACHERS was developed by the European Commission and is available in all official EU languages. It may also be used together with SELFIE for schools to gain a holistic view of the school's use of digital technologies (https://education.ec.europa.eu/selfie).

3.4.5 Resource repositories for schools

A growing number of online repositories and digital platforms offer teaching and learning resources related to the climate crisis and environmental sustainability. These websites host teaching materials such as learning plans and resources for classroom use and frequently facilitate the exchange of ideas through communities of practice (see Box 9).

Box 9: Resource repositories for schools

There are several EU and global initiatives and platforms that support networking and exchange among educators. While most of these are not specifically focused on jointly promoting green and digital education, they can potentially provide in important role in bringing these two together:

Climate Action Project: (https://www.climateactionproject.org/about): *a global initiative where schools collaborate on climate change projects to raise awareness and promote action. It connects students and teachers globally to work on real-world climate solutions.*

Education for Climate Coalition (https://education-for-climate.ec.europa.eu/community/): a *European Commission initiative that brings together students, educators and stakeholders to co-create climate education solutions. It supports collaboration and knowledge exchange on climate action in schools and beyond.*

European School Education Platform (https://school-education.ec.europa.eu/en): *a hub by the European Commission for the school education sector. The platform offers resources, training, news and networking opportunities.*

EPALE platform for adult learning in Europe (https://epale.ec.europa.eu/en): *a multilingual online space dedicated to adult education professionals, offering resources, articles, and community interaction. Run by the European Commission, it supports adult learning policies and practices across Europe.*

Scientix community for science education in Europe (https://www.scientix.eu/community): *a platform that promotes and supports science education in Europe through collaboration among teachers, researchers, and policymakers. It provides access to teaching materials, projects, and events on STEM education.*

UNESCO ESD for 2030 Global Network (https://www.unesco.org/en/education-sustainable-development/esd-net): *a global network aiming to promote Education for Sustainable Development in all levels of education worldwide.*

In addition to the above platforms, The Office for Climate Education[19] (OCE) provides free resources and teaching kits available in English, French, German and Spanish. These target primary and secondary school teachers and include interactive multimedia videos and activities for classroom use (see Box 10). OCE has also developed two online courses for teachers teaching climate change in schools. While these courses are focused around content and various types of resources, they also provide teachers with guidance on using the resources in their context. Additional support includes guidance in preparing lesson plans to apply these resources in a sequence.

Box 10: Digital platform offered by the Office for Climate Education[20]

Established in 2018 and operating under the auspices of UNESCO since 2020, the Office for Climate Education (OCE) is an international initiative for climate change education. The OCE coordinates a large network of over 70 national and international actors to support primary and secondary school teachers with quality educational resources and professional development. Resources include materials for inquiry-based learning activities such as investigation-based activities, project-based learning, role-playing games and debates. While promoting action and positive thinking, these resources also touch on the social issues inherently linked to climate change adaptation and mitigation challenges.

Following the first teaching kit addressing climate change, ocean and cryosphere (2021), the OCE launched another teaching kit in 2022 on 'Climate Change and Land' (OCE, 2023, p. 13). This kit includes such materials as:

Interactive multimedia activities (multimedia animations) allowing primary and secondary school students to understand topics such as the carbon footprint of food, visualise the connections between different species and study different farming solutions. In the video clips tailored for classroom use, experts and scientists explain different characteristics or phenomena linked to land in the context of climate change.

Targeting primary and secondary school teachers, in 2022 the OCE developed an online course on teaching climate change. This course comprises 53 videos and around 100 activities, with completion expected to take approximatively 30 hours in a self-paced mode (OCE, 2023, p. 12). In 2022, over 11,000 teachers took the course (OCE, 2023, p. 19), indicating a growing need for such a resource.

Platforms such as OCE are accessible to teachers around the world, supporting the development of communities of practice involving peers from different countries. Such exchanges between practitioners may inspire teachers to engage in learning for sustainability in the longer term and, in turn, motivate their learners to develop sustainability literacy and competences. A further important factor in making such digital platforms successful is their credibility and their ability to 'translate' empirical evidence into suitable teaching materials and thus ensure that sustainability education remains relevant and up to date.

3.4.6 Supporting teacher networks with Erasmus+

Participating in communities of practice, including online forums, social media groups, and professional networks, can facilitate the exchange of experiences with peers and assist the joint implementation of the twin transitions in schools (European Commission 2022).

In Europe, several digital projects have also been developed through the Erasmus+ programme which bring together the green and digital agendas. The Erasmus+ Teacher Academies, for example, aim to create networks of communities of practice in teacher education and offer courses, modules, and other learning opportunities on topics such as learning in the digital world, sustainability, equality and inclusion. Three Erasmus+ Teacher Academies currently developing professional development modules and courses for teachers on climate and sustainability are noteworthy[21]. These include:

- Climate change teacher's academy (CLIMADEMY).
- Teaching Sustainability: content, competences &approaches for Europe's pre- and in-service teachers (TAP-TS); and
- the Sustainable Future Educators (EduSTA).

The approach of EduSTA, for example, is to offer pre- and in-service teachers the possibility to acquire digital badges to demonstrate their competences (see case study in Box 11 and Asikainen 2023 for more details). Such structured opportunities that acknowledge and certify teachers' competences are important for the future of learning for sustainability as well as that of digital education (Tilbury 2023). Through the digital open badges approach of EduSTA, teachers can showcase their competences following a transparent assessment and certification process (Asikainen 2023).

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[21] For more details, see: https://claudi.chemistry.uoc.gr/ (CLIMADEMY), https://tap-ts.eu/ (TAP-TS), and https://projects.tuni.fi/edusta/ (EduSTA).

Box 11: The Erasmus+ Teacher Academy for Sustainable Future Educators (EduSTA)[22]

The Erasmus+ Teacher Academy for Sustainable Future Educators (EduSTA) brings together five teacher education institutions around Europe (Czechia, Finland, Netherlands, Spain, Sweden). Running from 2022 to 2025, the programme intends to promote and certify specific sustainability competences through the development of tools and learning resources for initial teacher education and continuous professional development of teachers.

The project was initiated to address the competence needs set out in sustainability frameworks such as GreenComp (Bianchi et al. 2022) and to make teachers' sustainability competences concrete while recognising prior learning. EduSTA is developing a set of digital open badges to acknowledge and document teachers' sustainability competences in four areas including sustainability literacy competence, educational competence, enabling action competence, and reflective competence. The competence areas also refer to using GreenComp in the educational context and designing learning processes that promote the development of students' 'green competences' (Askiainen and Ruhalahti 2023; EduSTA 2023b). The digital open badges are being piloted in 2024 in teacher education institutions participating in the project. As part of the ongoing project, the project team is also investigating how sustainability competences impact curriculum development, pedagogical design and assessment of micro-credentials in learning for sustainability. Badges developed for different competence areas along with the 'Sustainable Future Educator' meta badge for teachers who complete most of the micro badges (EduSTA 2023a, b). It is important to note that the project uses digitisation as a tool rather than explicitly identify and systematically build the digital competences of teachers to support learning for sustainability.

Figure 8. overview of EduSta: Educator for sustainable future.

Certified learning is an important aspect of professional development, which in turn requires transparent competence assessment and certification processes. Digital badges offer a flexible, transferable and transparent methodology for in-service educators. While there are currently few examples, such as EduSTA, that offer digital badges as a way of demonstrating sustainability competences, this opens such possibilities for the future.

Taking a different approach, *Digistainable* is a national initiative in Slovenia to develop teachers' digital and sustainability competences (see Box 12). Digistainable aims to provide a nationally driven professional development opportunity for teachers, school managers and leaders in all areas of education. Incorporating managers and school leaders into the professional developmental framework is a significant element of the initiative. As mentioned previously, school leaders play a critical role in encouraging collaboration among school staff and supporting whole-school learning environments. The initiative has built-in methodologies to ensure that the competence catalogue and the corresponding courses are adaptable to local needs, providing a valuable opportunity for schools and educators to tailor the materials as closely to their needs as possible.

Box 12: Digistainable teacher initiative in Slovenia

Started in 2023 and funded by NextGenerationEU, the Slovenian project sets out to achieve a digital, sustainable and financial transformation of education by training over 20,000 teachers and managers in education. A competence catalogue has been developed for the training programme, with around 40 development groups being set up to elaborate the programme (most likely 24 for digital competences and eight for each of the two other areas), consisting of experts from the fields, including practitioners from schools, representatives of companies and researchers. Training is offered at national level (online or on-site) and at school level, with trainers at national level passing on their knowledge to trainers at schools.

The programme can be tailored to local school needs through the formation of development teams that consist of the school management and teachers who decide how to set the objectives for these three areas in their schools, how to identify needs and what kind of training they should undergo (at least 40% of the training must be online).

It is expected that at least half of the educational institutions in Slovenia will participate over the lifecycle of the project. There are also plans to establish e-learning communities at national and regional level to exchange knowledge and provide mutual support. Furthermore, a digital platform will also be set up to support teachers and managers. The image below provides an overview over the expected results of the project (Hodak 2023):

Figure 9. Project results for Digistainable teacher.
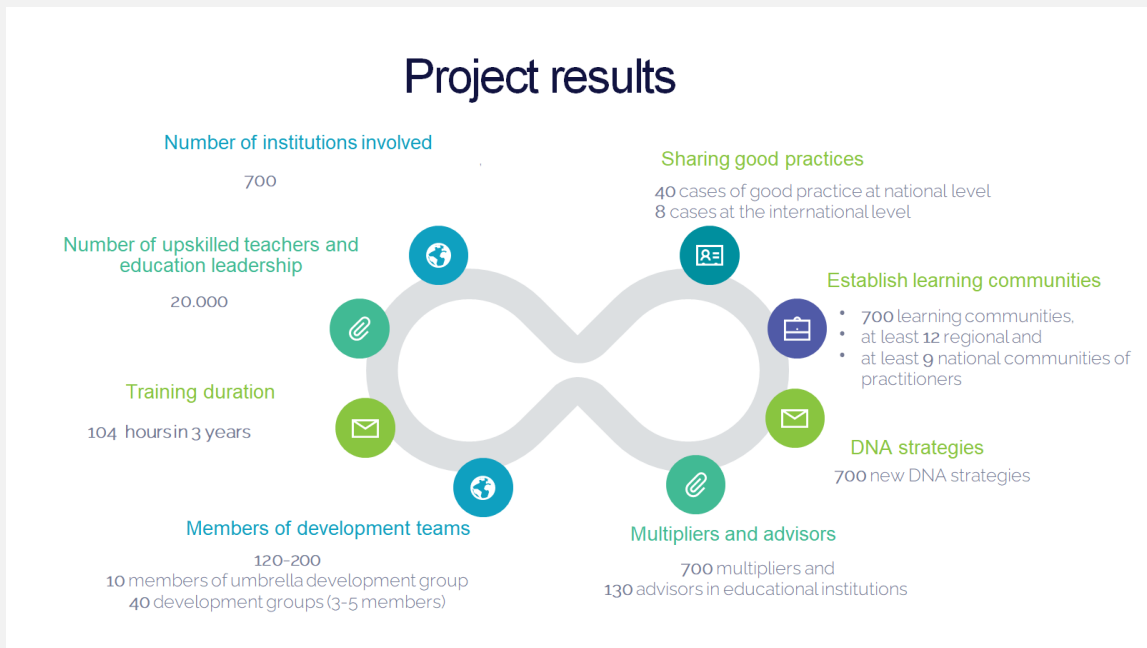
4 Conclusions and recommendations

4.1 Concluding remarks

When considering sustainability and digital education together, a complex landscape of synergies, opportunities and tensions emerges. Overlaps and complementarities between learning for sustainability and digitalisation are clear. Digital tools and technologies can provide access to a wealth of information and resources on environmental issues, sustainable practices, enriching the learning experience both for learners and educators. Learning for sustainability can promote the development of digital skills (including digital media literacy) and create a need for the use of new technologies in education and wider society. At the same time, digitalisation opens a new perspective on learning for sustainability and its delivery. Both thrive on active learning pedagogies acting as catalysts for educational innovation agendas in schools.

A shared aspect of both agendas is the quest for innovative and transformative learning, whole-school and competence-based approaches. In addition, both agendas require educators to adopt active, hands-on approaches to learning and new spaces for cross-curricular learning, which requires motivated and skilled educators. The combined implementation of digital and sustainability education can only occur if educators are supported accordingly in this endeavour.

Although this study identified few initiatives where a joint focus on the green and digital agendas plays an explicit role in teacher education and training, there are signs that countries increasingly pay attention to how they could be addressed in a mutually reinforcing way. In a complementary manner, there are several digital platforms available or being developed – including at European level – to provide tools and resources to support teachers' professional learning for sustainability (e.g. Erasmus+ Teacher Academies).

A key challenge is the curriculum that needs to make space to address sustainability and digital education requirements. Other obstacles to advancing the twin transitions in education include insufficient digital infrastructure and technical support and the lack of robust scientific evidence on effective and meaningful coordinated approaches.

Equally, the lack of evidence available on the impact of the use of digital technology on the development of sustainability competences is problematic. Existing research has been mainly focused on the extent to which digital tools can be integrated into the classroom to enhance learning for sustainability.

Schools increasingly need to deal with the fact that growing concerns for the environment go hand in hand with the rapidly expanding use and role of digital technologies in many areas of life, including education. Any discussion related to the future of education will also need to consider the rapid rise of Artificial Intelligence (AI) and the opportunities and challenges it presents. Inequalities arising from AI technologies, alongside the resource consumption related to its use, require the education community to become involved in debates and decision-making around the future use of technology in education. Overall, there is still much to learn and agree on when it comes to advancing the green and digital education agendas in a mutually reinforcing way.

4.2 Policy recommendations

The recommendations outlined below are informed by the findings from the literature review, the expert workshops and the case study research.

National level policies and strategies
Creating value and strategic vision: Policies should aim to raise awareness of the interconnectedness of sustainability and digital agendas and the value they bring to

education. This could help frame a strategic vision for addressing these transitions jointly in education processes and systems. Document and collect case studies that illustrate how the transitions can be combined and feature these prominently in policy frameworks and strategies to illustrate possibilities.

Overcome policy silos: Promote collaboration across existing policies to effectively address the twin transitions in education and training, e.g. by establishing mechanisms for cross-sectoral coordination and cooperation between relevant government departments, agencies, and stakeholders responsible for education, environment, technology, and innovation.

Support whole-school development: Develop national-level policies and strategies that allocate time and space for schools to integrate sustainability and digital themes into their culture and teaching processes effectively. Provide support for the development of digital infrastructure and equitable access to technology and resources.

Promote the cultivation of a digital mindset among educators and learners: Emphasise that digital technology is not just a set of tools but also a mindset to successfully navigate through an increasingly technology-driven world.

Balance benefits and environmental impacts: Develop policies and strategies that aim for a balance between the benefits of technology and its ecological footprint, emphasising sustainable education practices and mitigating the digital divide to ensure equitable access to resources and opportunities for all learners. Support schools to adopt energy-efficient devices, implement responsible e-waste recycling programmes and encourage sustainable digital practices among students and staff.

Teaching and learning in an era of green and digital transitions

Promote transformative pedagogical approaches: Support the integration of pedagogical approaches that are transformative and promote critical thinking, problem-solving, and creativity in addressing sustainability and digital themes. Provide guidelines on curriculum implementation following these methods, enabling educators to design learning experiences that encourage active engagement with real-world issues and promote sustainable practices. Allow adequate flexibility in curricula for educators and learners to jointly address green and digital agendas effectively.

Advance innovation in assessment: Encourage the development of new approaches to assessment that align with competence-based learning and reflect the integration of sustainability and digital themes. Establish assessment criteria and methods that measure not only knowledge acquisition but also the development of critical skills, attitudes, and behaviours towards sustainability and responsible digital citizenship.

Support school leadership in learning for sustainability and digital education

Support school leadership: Provide strategic guidance and technical support to school leadership teams to better link learning for sustainability and digital education, towards establishing a school culture in their institutions that meaningfully embeds sustainability and digital themes in education and training. This process can be helpfully supported by EU tools such as the Digital Competence Framework for Educators (DigCompEdu), the Digital Competence Framework for Organisations (DigCompOrg), the European Sustainability Competence Framework (GreenComp), and the SELFIE self-reflection tools for schools and teachers that support digital capacity building.

Community and school networks

Promote collaboration: Strengthen community connections and networks for professional collaboration, providing opportunities for sharing good practices, experiences and funding for networking activities and collaboration (e.g. Erasmus+ Teacher Academies).

Improve schools' possibilities to engage in partnerships: Support schools in opening up and strengthening links with their surrounding communities. This can include partnerships

between schools, with families, municipalities, providers of non-formal learning or research partners.

Encourage participation in established networks: Encourage schools to actively participate in established networks and initiatives focused on sustainability and digital education. The availability of a structured framework to adhere to, paired with resources and peer support can help schools demonstrate their long-term commitment and progress towards sustainability and digital education goals.

Teacher education and teacher support

Build capacity in initial training and continuing professional development for educators: Support educators in addressing sustainability and digital themes, and in putting transformative learning processes into practice. Support the development of both pedagogical and technical digital skills.

Emphasise the added value: Demonstrate with practical examples the added value for practitioners of learning through digital technologies. Provide guidance and resources that demonstrate how digital tools and technologies can enrich learning experiences, enhance student engagement, facilitate personalised learning pathways, and promote deeper understanding and application of sustainability concepts.

Professional development opportunities: Develop in-person and technology-based education offerings as well as digital teaching materials and learning resources. Support teachers in networking and sharing good practice approaches through digital platforms. Aligning policy commitments in these areas ensures the more efficient use of resources and enables this joint approach.

Digital tools and technologies to support learning for sustainability

Ensure equitable access: Ensure equitable access to digital technologies and resources to mitigate the digital divide.

Strengthen pedagogical use: Strengthen the pedagogical use of technology in learning for sustainability. Provide support for the selection of digital tools, e.g. based on a set of established quality criteria. Support schools to reflect on and improve their digital capacity and teachers to reflect on and improve their digital skills.

EU level policies and action

Generate robust evidence through further research: Invest in research to generate evidence on effective approaches for addressing sustainability and digital themes jointly in education. This includes promoting studies on teaching and learning processes, whole-school approaches, and the impact of technology on sustainability competences.

Encourage dialogue and partnerships: Facilitate networking, exchange and joint projects involving educators, schools, communities, and external partners, including through the Erasmus+ programme. This can play a key role in facilitating knowledge sharing and collaboration to address sustainability and digital education goals, and in disseminating examples of good practice.

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Annex Methodology

To address the five main research questions, the research methodology of the study weaved various research activities together: a literature review, multiple case studies and the organisation of two stakeholder workshops (see figure A1 below).

Figure A1. Project overview
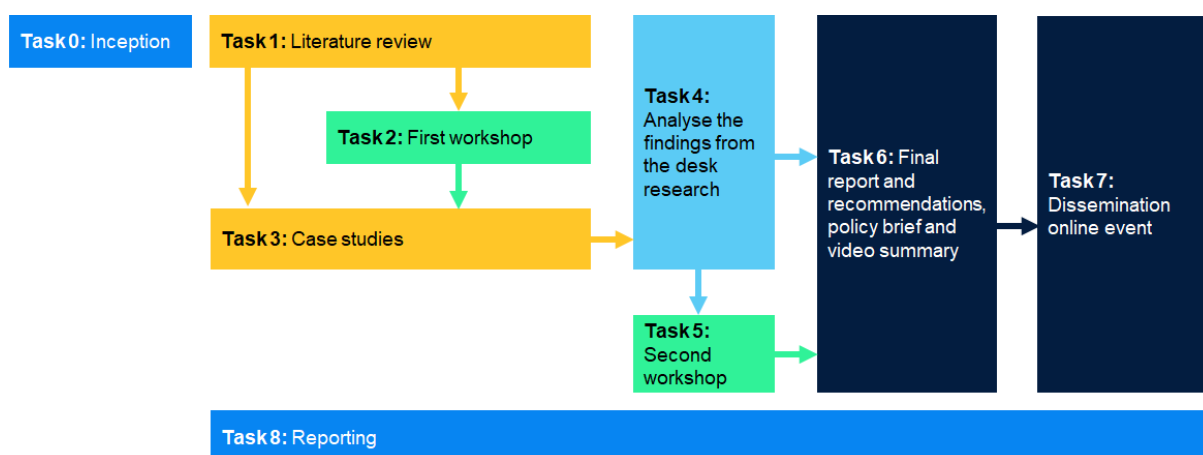
The first phase of the study started with the literature review based on the five research questions. Results from the literature review then fed into the core themes selected for discussion at the first expert workshop held on 3rd and 4th of July 2023 in an online format. 55 attendees from 16 countries took part in the event. This first expert workshop represented an opportunity to reflect on the conceptual links between learning for sustainability and digital education from the perspective of practitioners. A further objective of the workshop was to gather participants' insights regarding existing synergies, challenges and opportunities when developing learning for sustainability and digital education in tandem. Some experts provided preliminary recommendations already in this phase for the better integration of digital education and learning for sustainability in schools, and for the joint fostering of the two agendas.

The key discussion questions were as follows:

- What are the existing tensions and complementarities between the green and digital education agendas? Are these concepts understood as complementary or indeed competing priorities?
- How is the increasing demand for digital and sustainability competences affecting curricular design and implementation? What have been the policy responses so far?
- Are there school-level practices we can identify that show promise in building both types of competences - either jointly or in complementary ways?
- What specific support do educators and school leaders need to promote the green and digital agendas in efficient and effective ways?

Parallel to this activity, a short survey was circulated among participants and wider education networks to identify interesting examples that could be explored further as potential case studies. Based on the survey results and additional research activities,

eleven case studies were selected in agreement with the European Commission. The eleven case studies were grouped around the following six themes:

- Connecting data literacy with learning for sustainability through digital tools;

- Supporting teachers in building competences for sustainability and digital education;

- Game-based/gamification approaches to jointly foster green and digital skills;

- Creating digital narratives on sustainability and the environment;

- Promoting a joint focus on sustainability and digital through established school networks; and

- Combining sustainability and digital focus in a whole-school planning approach.

Each theme featured one to three initiatives or examples. The case studies were developed based on desk research and interviews with key actors and participants of the identified initiatives. The initial desk research offered information on such areas as the overall aims and objectives of the initiatives or approaches, their scope of activities, and potential milestones achieved.

The interviews provided an opportunity to hear practitioners' insights on such topics as key success factors, transferability to other contexts, barriers encountered, future plans, and impact and lessons learnt. The case studies offered rich insights from various approaches and initiatives, and the patterns and clusters of perspectives emerging from these case studies also informed the study's thematic chapter structure.

Weaving together the results from the literature review, the case studies, and the insights gathered during the first expert workshop supported the identification of key analytical findings and policy recommendations. The second expert workshop, held on the 13th and 14th of December 2023, again delivered in an online format, provided a prime opportunity for the study team to present the emerging themes and key findings. It was attended by 33 participants from across Europe. In addition to seeking practitioners' feedback on the study's findings and initial policy recommendations, the workshop offered experts a forum for exchanging views on possible future directions and critical aspects to consider when fostering the two agendas, individually or jointly. It focused on the following key questions:

- What do existing research and case study findings tell us about the complementarities and synergies between learning for sustainability and digital education?

- What are the main practical challenges when integrating both agendas in education delivery? What are good practices in tackling those challenges?

- How could policy makers support the development of sustainability competences and digital skills jointly? Are there any policy levers identified that could foster the implementation of both agendas?

This final report documents the key research findings, gathered good practices, and identified patterns of opportunities, challenges, barriers and facilitators across various topics related to the linkages between learning for sustainability and digital education.