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Ενδυνάμωση της Περιβαλλοντικής Εκπαίδευσης: Ο Ρόλος των ΤΠΕ στην Ενίσχυση της Ευαισθητοποίησης και των Βιώσιμων Πρακτικών

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Ενδυνάμωση της Περιβαλλοντικής Εκπαίδευσης: Ο Ρόλος των ΤΠΕ στην Ενίσχυση της Ευαισθητοποίησης και των Βιώσιμων Πρακτικών

Empowering Environmental Education: The Role of ICT in Fostering Awareness and Sustainable Practices

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Περίληψη

Η εργασία αυτή διερευνά τον ρόλο των Τεχνολογιών Πληροφορίας και Επικοινωνίας (ΤΠΕ) στην Περιβαλλοντική Εκπαίδευση στη σύγχρονη ελληνική σχολική πραγματικότητα. Μέσα από 20 θεματικές ενότητες, αναλύεται πώς οι ΤΠΕ ενισχύουν τη συναισθηματική εμπλοκή, τη δημιουργική έκφραση, τη συνεργατική μάθηση και τη συστημική σκέψη των μαθητών. Παρουσιάζονται συγκεκριμένα παραδείγματα από ελληνικά σχολεία, καθώς και επισημάνσεις σχετικά με προκλήσεις, επιμορφωτικές ανάγκες και ζήτημα ισότιμης πρόσβασης. Η εργασία τεκμηριώνεται αποκλειστικά με βιβλιογραφία μετά το 2015, με έμφαση στην ελληνική ερευνητική παραγωγή. Καταδεικνύεται ότι οι ΤΠΕ, όταν χρησιμοποιούνται παιδαγωγικά, μπορούν να μετατρέψουν τη γνώση σε δράση, ενισχύοντας τη σύνδεση του σχολείου με την κοινωνία και το φυσικό περιβάλλον. Παρά τις δυσκολίες, διαφαίνεται ότι η τεχνολογία μπορεί να λειτουργήσει ως γέφυρα ανάμεσα στη μάθηση και τη βιωσιμότητα, αρκεί να εντάσσεται με σκοπό και συμπερίληψη.

Λέξεις-κλειδιά

περιβαλλοντική εκπαίδευση, ΤΠΕ, ψηφιακός γραμματισμός, συμμετοχή μαθητών, βιωματική μάθηση, βιωσιμότητα

Abstract

This paper explores the role of Information and Communication Technologies (ICT) in Environmental Education within the Greek school context. Through 20 thematic sections, it examines how ICT fosters emotional engagement, creative expression, collaborative learning, and systems thinking among students. Drawing on recent Greek case studies and literature post-2015, it highlights practical applications, challenges, teacher training needs, and issues of digital equity. The analysis shows that when used pedagogically, ICT can transform knowledge into action—strengthening the connection between school, society, and nature. Despite access and support limitations, ICT is shown to be a powerful bridge between learning and sustainable change, provided it is used with purpose and inclusivity.

Keywords

environmental education, ICT, digital literacy, student engagement, experiential learning, sustainability

Introduction

Environmental education helps students understand how nature and human activity are connected. But awareness alone cannot bring change unless learning touches emotion and action. Research confirms that awareness must be coupled with experiential and emotionally engaging learning to produce sustainable behavioral change (Marouli & Duroy, 2019; Sinakou et al., 2019).

In recent years, schools have moved beyond textbooks. Teachers aim to develop critical thinking, collaboration, and environmental responsibility—and ICT plays a major part. Studies in Greek and European contexts show that digital environments enable inquiry and reflection that foster these competencies (Angelaki et al., 2024; Hajj-Hassan et al., 2024).

ICT provides access to authentic data, interactive simulations, and global dialogue. Students don't just read about climate change—they explore and respond in real time (Moshou & Drinia, 2023). They can research local problems, create awareness campaigns, or join projects with peers from other regions. This aligns with findings

that ICT enhances student agency and empathy in sustainability learning (García-Hernández et al., 2023; Kougias & Efstathopoulos, 2020). Such work builds not only knowledge but also motivation and a sense of agency—key elements of inclusive teaching.

However, access and confidence vary across schools and teachers, affecting outcomes. Research shows that teachers' confidence and infrastructure strongly shape how ICT contributes to sustainability education (Papadakis et al., 2020; Vaiopoulou et al., 2021).

This paper explores how ICT fosters emotional engagement, collaboration, and systems thinking—the ability to understand how environmental, social, and economic factors interact—among Greek students, while identifying effective practices and challenges. As environmental issues intensify, education must cultivate skills, values, and action-oriented mindsets. ICT can play that transformative role—if used purposefully and inclusively—reflecting the transition from environmental education to education for sustainability (Ampartzaki et al., 2021).

From Environmental Education to Education for Sustainability

Environmental education once focused mainly on nature awareness: plants, animals, and ecosystems. Today, this focus must expand. The environmental, social, and economic dimensions of sustainability are deeply connected. Educators now refer to "education for sustainability," a holistic approach linking ecological understanding with social justice and responsible decision-making, consistent with international frameworks (García-Hernández et al., 2023; Sinakou et al., 2019).

In Greece, this shift unfolded gradually. National and regional programs encouraged schools to move beyond the transmission of facts toward value-based, action-oriented learning—helping learners think and act sustainably (Kougias & Efstathopoulos, 2020). Teachers integrated topics such as recycling, renewable energy, and water use into interdisciplinary projects connecting science, geography, and civic education to everyday life. Similar approaches effectively promote systems thinking and responsible citizenship (Ampartzaki et al., 2021; Moshou & Drinia, 2023).

Schools also formed Environmental Education Networks that fostered collaboration between schools, NGOs, and local authorities. Students created digital posters, videos,

and campaigns extending project impact beyond classrooms (Marouli & Duroy, 2019; Repetto et al., 2024). This transition—from knowing about nature to cultivating sustainable mindsets—paved the way for deeper technological integration. Research shows that digital environments make sustainability learning more participatory by connecting global issues with local experiences (Angelaki et al., 2024; Hajj-Hassan et al., 2024).

Still, key pedagogical questions remain: *how can we foster interdisciplinary and systemic thinking and promote long-term engagement with issues that seem abstract or distant?* Addressing these requires focusing not only on what we teach but how we teach it. International research highlights that sustainability education must balance cognitive understanding with emotional engagement to inspire durable behavioral change (Arslan & Karakuş, 2024; Ouariachi et al., 2020).

ICT as a Tool for Emotional Engagement and Environmental Awareness

Students often feel emotionally distant from large-scale environmental problems. Events like melting glaciers or dying reefs may seem far away. Technology makes these realities tangible—visually and experientially. Digital environments connect abstract global issues with personal experience, strengthening empathy and awareness (Arslan & Karakuş, 2024; Hajj-Hassan et al., 2024).

When students use virtual reality or immersive simulations to explore forests or polluted coasts, they experience and empathize. This connection transforms awareness into care, and care into motivation for action (Ouariachi et al., 2020). Interactive videos, 360° images, and digital storytelling allow them to step into real-world scenarios—enhancing understanding and engagement (Marouli & Duroy, 2019; Repetto et al., 2024).

Greek teachers use mobile apps like *Seek* or *PlantSnap* during fieldwork. Students scan plants, photograph species, and build digital diaries linking observation with reflection. They return with stories and insights that deepen learning. Experiential, ICT-based learning enhances motivation and empathy (Ampartzaki et al., 2021; Drosou, 2023).

Even simple tools like videos or photo diaries support reflection: *What did they see? What surprised them?* These moments link understanding with emotional

engagement, helping students recognize their role in the ecosystem. Integrating such tools supports emotional literacy and self-regulated learning (Papadakis et al., 2020; Vaiopoulou et al., 2021).

Collaborative Learning and Student Voice through ICT

Learning doesn't happen in isolation. When students face complex problems like waste or biodiversity loss, they need collaborative spaces to exchange and co-create knowledge. ICT provides that space. Digital collaboration enhances environmental awareness, empathy, and problem-solving (García-Hernández et al., 2023; Marouli & Duroy, 2019).

Platforms such as *eTwinning*, *Padlet*, and *Google Workspace* enable authentic teamwork. Students co-develop presentations, conduct surveys, and share feedback with peers. These exchanges build communication skills and shared responsibility (Repetto et al., 2024).

When students feel their ideas are valued, motivation grows. Choosing topics or leading phases nurtures student voice and agency—core elements of democratic and sustainable education. ICT amplifies this agency: learners design campaigns, create podcasts or videos, and share them widely (Angelaki et al., 2024; Sinakou et al., 2019). Collaboration also fosters diversity and empathy. Through online exchanges, students discover how environmental issues affect communities differently. Intercultural dialogue mediated by ICT promotes awareness and collective agency (Arslan & Karakuş, 2024; Hajj-Hassan et al., 2024). Education for sustainability invites students to think with others. ICT makes this process interactive, inclusive, and empowering.

Working with Data: Digital Literacy in Environmental Education

Working with data is central to digital literacy—the ability to locate, interpret, and apply information responsibly. In environmental education, this competence is essential: ICT makes data abundant yet demands critical thinking and ethical use. Developing data literacy is key to environmental citizenship (García-Hernández et al., 2023; Kougias & Efstathopoulos, 2020).

In Greek schools, students use *Google Earth*, climate databases, and interactive maps to monitor local conditions. They may track temperature changes, study erosion, or

analyze energy use. These activities help visualize processes and link data to lived experience (Angelaki et al., 2024).

Teachers use graphs and dashboards to show trends. Students learn to detect patterns and ask questions: Why do CO_2 levels change? How does rainfall affect crops? Such practices encourage systems thinking (Hajj-Hassan et al., 2024; Sinakou et al., 2019). Even simple comparisons—waste quantities, energy use—develop numeracy and source evaluation skills. Students also learn to assess data reliability; this critical stance fosters responsible digital citizenship (Papadakis et al., 2020; Vaiopoulou et al., 2021). Working with data trains students to think analytically, linking environmental, social, and economic implications (Moshou & Drinia, 2023).

Interdisciplinary and Systemic Thinking in Greek Classrooms

Environmental challenges are complex and interconnected with health, economy, and behavior. To address them, education must connect disciplines. In Greece, many schools integrate science, history, geography, and the arts to show how systems interact.

A project on water may combine chemistry, culture, and local history: students explore aqueducts, analyze use, and assess drought risks. Such approaches promote interdisciplinary and systemic thinking, reflecting international models linking sustainability to problem-solving (Angelaki et al., 2024; Sinakou et al., 2019).

ICT supports this process. Students use timelines, collaborative documents, and multimedia presentations to connect ideas across subjects. Some trace land-use changes via aerial images, others create short films merging data and interviews (Arslan & Karakuş, 2024; Repetto et al., 2024). In rural areas, projects often engage families—students interview elders or document land changes, strengthening community ties (Marouli & Duroy, 2019).

When learning becomes interconnected, sustainability turns into action grounded in place and shared understanding—fostering long-term ecological literacy (Moshou & Drinia, 2023).

Teacher Training and Confidence in Using ICT

No matter how advanced a digital tool is, its impact depends on the teacher's confidence and pedagogical purpose. In many Greek schools, educators still feel uncertain about integrating ICT effectively. Research shows that teachers' self-efficacy is crucial for ICT-based environmental education (Angelaki et al., 2024; García-Hernández et al., 2023).

Continuous, practice-oriented professional development is essential—not a one-time seminar, but sustained guidance, peer exchange, and time for experimentation. Teachers stress the need for adaptable materials and mentoring that fits classroom realities (Drosou, 2023). Training must link ICT with inclusive, student-centered pedagogy.

National and regional initiatives, such as *PEKES* and local networks, provide valuable models. Educators share tools like *Canva*, *Thinglink*, and mapping apps to design engaging activities. When training connects pedagogy with sustainability goals, teachers sustain digital practices longer (Ampartzaki et al., 2021; Moshou & Drinia, 2023).

Yet gaps persist. Some educators lack infrastructure or time; others work in isolation. Addressing these needs requires both resources and community support (Kougias & Efstathopoulos, 2020; Sinakou et al., 2019). Effective training must be practical, ongoing, and empowering. When teachers feel confident and supported, students engage more deeply.

Access and Equity in ICT Use in Greek Schools

Equal access to digital tools remains a major challenge for Greek schools. Urban institutions often enjoy faster internet and better equipment, while rural or island schools face shortages. These disparities affect learning opportunities. When only some students participate in digital activities, inclusion and sustainability are undermined (García-Hernández et al., 2023).

Educators strive to bridge this divide by sharing devices, designing offline projects, or using open-source platforms and mobile phones to ensure participation. These practices, though valuable, often rely on individual initiative rather than systemic

support. Equity in ICT access is widely recognized as a prerequisite for sustainability education (Angelaki et al., 2024; Kougias & Efstathopoulos, 2020).

True equity demands coordinated action—investment in infrastructure, targeted support for disadvantaged regions, and training for inclusive digital pedagogy. Teachers must learn not only how to use technology, but how to adapt it creatively when resources are limited (Sinakou et al., 2019). Inclusive design ensures participation for all students, regardless of ability or access level.

Environmental education cannot promote sustainability without equal digital participation. True sustainability is both ecological and social—it flourishes only when every learner can engage, create, and contribute.

The Role of Family and Local Community

Learning extends beyond the classroom. In many Greek regions, family and community life remain closely tied to nature—through farming, traditions, or shared spaces. These relationships form a living foundation for environmental learning (Marouli & Duroy, 2019; Moshou & Drinia, 2023).

ICT strengthens these bonds by linking home, school, and local culture. Students record interviews with grandparents, design digital maps of gardens, or document community stories. Local knowledge becomes a source of environmental insight (García-Hernández et al., 2023; Goulgouti et al., 2019).

When schools share student-made videos or exhibitions online, families feel proud and students see their work as meaningful. In small towns, learners use apps to log biodiversity during walks—combining digital skills with civic engagement (Ampartzaki et al., 2021; Ouariachi et al., 2020). Many schools collaborate with local organizations or municipal teams, turning projects into collective community action (Angelaki et al., 2024; Kougias & Efstathopoulos, 2020).

Involving families and communities transforms environmental education into a shared process of care and responsibility, showing that sustainable change begins close to home (Drosou, 2023; Sinakou et al., 2019).

Student Creativity and Expression through ICT

Environmental education is not only about knowledge—it's about how learners internalize and express meaning through imagination and action. Creativity bridges understanding and engagement (Andrikopoulou & Koutrouba, 2019; Marouli & Duroy, 2019).

ICT offers many creative pathways. Students design digital posters, record podcasts, or produce short films that communicate both information and emotion. A poem on deforestation or a digital collage on ocean pollution transforms learning into empathy (Ampartzaki et al., 2021; García-Hernández et al., 2023).

Many schools use digital storytelling, where students combine photos, sound, and text to craft multimedia narratives. This fosters empathy and awareness (Hajj-Hassan et al., 2024; Lampropoulos, 2024). Tools like *Canva*, *Powtoon*, or editing apps support collaborative campaigns on water saving or urban greening. When used pedagogically, such tools give students ownership of expression and social impact (Drosou, 2023; Megalou et al., 2022).

Creative activities also promote inclusion, offering alternative expression to learners with different abilities. Through visuals or spoken word, all students contribute meaningfully (Papadakis et al., 2020; Vaiopoulou et al., 2021). When learners create something of their own, they become active voices for change (Arslan & Karakuş, 2024; Ouariachi et al., 2020).

Gamification and Motivation in Environmental Learning

Many students disengage when learning feels abstract. Gamification—using game elements like points and challenges—turns learning into curiosity and active involvement (Arslan & Karakuş, 2024; Ouariachi et al., 2020). Research shows that such methods enhance engagement and sustainability awareness when applied authentically (García-Hernández et al., 2023; Hajj-Hassan et al., 2024).

Greek classrooms use platforms like *Kahoot!* and *Quizizz* for topics like recycling or energy. These tools promote excitement and knowledge retention through play. Gamification also improves participation in STEM-related sustainability themes (Papadakis et al., 2020; Vaiopoulou et al., 2021).

Beyond quizzes, schools design eco-challenges where students earn points for real actions—turning off lights, biking, reducing waste. Such apps foster habits and a sense of achievement (Angelaki et al., 2024; Tsai et al., 2025). Gamification links awareness with behavior (Kougias & Efstathopoulos, 2020; Repetto et al., 2024).

Games motivate through autonomy and feedback—drivers of intrinsic motivation. Small missions like "map the school's carbon footprint" make learning purposeful (Ampartzaki et al., 2021; Marouli & Duroy, 2019). When designed mindfully, gamified experiences turn environmental knowledge into participation (Drosou, 2023; Sinakou et al., 2019).

Monitoring Environmental Behavior and Reflection through ICT

Learning deepens when students not only act but monitor and reflect on their behavior. ICT supports this by offering tools for documentation, feedback, and self-assessment. Students can track their ecological footprint, log sustainable actions, or evaluate progress over time.

Digital journals and dashboards allow learners to visualize results. For example, students record weekly water use or waste reduction, then reflect on patterns. These activities foster self-awareness and responsibility, linking learning with personal growth.

Reflection is key to sustainability education. When students analyze their behavior, they develop metacognitive skills—thinking about how they think and act. ICT facilitates this through prompts and visual feedback, strengthening environmental commitment and engagement.

In Greek schools, some projects include student-led evaluations, where learners assess their group contributions or community actions—enhancing ownership and accountability. Combined with digital tools, reflection becomes structured and impactful. Ultimately, ICT makes this process visible and empowering, turning environmental education into a journey of awareness and change.

ICT in School Environmental Networks and Local Partnerships

Environmental education grows stronger when schools collaborate. In Greece, many schools participate in Environmental Education Networks—groups that share

sustainability goals and exchange ideas on topics like waste reduction or biodiversity (Goulgouti et al., 2019; Marouli & Duroy, 2019).

ICT facilitates this cooperation by allowing teachers and students to exchange materials, co-develop ideas, and present shared outcomes using platforms like *eTwinning* or cloud services. For example, a student from Karditsa can collaborate with one from Syros on a joint project. Such uses of digital tools for fostering sustainability awareness are increasingly highlighted in recent research (Hajj-Hassan et al., 2024).

Some networks extend beyond schools and include local authorities or forestry departments, linking education with real environmental management. Students conduct interviews, co-create awareness campaigns, or help map green spaces. These activities promote local engagement and align with broader efforts to integrate sustainability goals into education through ICT (Angelaki et al., 2024; Khalifé et al., 2022).

ICT also helps schools share their work beyond local borders. Many projects are now presented on European platforms, school blogs, or social media—rewarding student effort and inspiring others.

By working through networks and partnerships, schools show students that learning is collaborative and applied, deeply connected to place and community (Sinakou et al., 2019). This reflects the view that powerful sustainability learning environments foster both social and environmental literacy through technology-enhanced collaboration (Ouariachi et al., 2020).

Risks and Misuse of ICT in Environmental Education

While digital tools support learning, they don't always work as planned. Sometimes they distract more than they help. Other times, they emphasize style over substance. In some classes, students focus too much on flashy presentations or collecting likes online, losing sight of environmental depth. Teachers report that without guidance, ICT use may encourage superficial engagement or passive consumption of content (Vaiopoulou et al., 2021).

There's also the risk of digital fatigue. Excessive screen time or poorly structured activities can reduce motivation and limit experiential learning. Environmental education thrives on real-world contact—fieldwork, observation, and community

interaction—which technology should complement, not replace (Ampartzaki et al., 2021; Marouli & Duroy, 2019).

Moreover, unequal access to devices or internet may lead to exclusion. If ICT is used without considering students' diverse circumstances, it can deepen gaps rather than bridge them (García-Hernández et al., 2023; Kougias & Efstathopoulos, 2020).

To avoid misuse, ICT must be integrated with clear pedagogical purpose. Teachers need to design activities that balance creativity with substance, and ensure that digital tools serve learning—not distract from it. This requires training, reflection, and inclusive planning (Angelaki et al., 2024; Sinakou et al., 2019).

When used thoughtfully, ICT enhances environmental education. But when used carelessly, it risks undermining its goals. Awareness of these risks is essential for responsible and effective integration.

National Policies and Institutional Support for ICT in Environmental Education

In Greece, the use of ICT in schools is shaped by both teachers and national policies. Over the past decade, strategies have increasingly recognized digital literacy as a core competence, while environmental education has gained visibility—though it often remains project-based or optional (García-Hernández et al., 2023; Moshou & Drinia, 2023).

The Ministry of Education supports Environmental Education Centers (KPE) and newer Centers for Education for Sustainability (CES), which offer training, materials, and online platforms. Many promote digital tools through seminars and repositories, linking technology with sustainability goals. This institutional support provides a framework for ICT integration, though its impact depends on local implementation and teacher engagement (Angelaki et al., 2024; Kougias & Efstathopoulos, 2020).

Recent reforms introduced more flexible curricula. Teachers now have "Thematic Weeks" and project time to integrate ICT into environmental topics. Yet not all schools take full advantage. Some need clearer guidelines, while others face time pressure due to exam-oriented priorities (Drosou, 2023; Sinakou et al., 2019). Even with supportive frameworks, sustained training and leadership are needed for lasting innovation (Ampartzaki et al., 2021; Hajj-Hassan et al., 2024).

Platforms like the *Greek National School Network* and *e-me* provide cloud spaces, collaborative tools, and resources for sustainability projects. However, teachers report technical limitations and uneven access, especially in rural areas. These disparities highlight the need for equitable infrastructure and responsive support (Megalou et al., 2022; Papadakis et al., 2020). Equal access remains central to the sustainability of ICT-based education (Marouli & Duroy, 2019; Vaiopoulou et al., 2021). Regional Educational Support Centers (PEKES) organize ICT workshops, but their frequency and continuity vary. Teachers emphasize the need for long-term planning and stable structures, rather than short pilot initiatives. Institutional continuity and investment in professional learning communities are key to turning policy into practice (Angelaki et al., 2024; Repetto et al., 2024).

When schools, ministries, and communities collaborate effectively, digital innovation becomes sustainable practice. Educational policy should listen to teachers' experience and support it consistently—with time, tools, and trust (Arslan & Karakuş, 2024; Goulgouti et al., 2019).

Integrating ICT in Formal and Non-Formal Environmental Education

Environmental learning does not stop at the school bell. Many powerful experiences happen outside the timetable. ICT supports both formal teaching and non-formal projects, helping students connect knowledge with real life (Ampartzaki et al., 2021; Sinakou et al., 2019).

In Greek schools, environmental clubs, student councils, and open-day events often run sustainability activities. Students organize clean-ups, recycling drives, or seed planting. With digital tools, they record efforts, create reports, and share results with their community—building ownership and visibility (Drosou, 2023; García-Hernández et al., 2023). These examples, drawn from literature and practice, show how ICT enhances student agency in informal contexts (Goulgouti et al., 2019).

Outdoor education programs increasingly use mobile apps or GPS-based tasks. Students may identify plants during hikes or take geo-tagged photos for later analysis. Teachers guide the process to keep learning focused and safe (Lampropoulos, 2024; Repetto et al., 2024).

Field trips to environmental centers or protected areas also benefit from technology. Several centers offer online guides, AR maps, or interactive quizzes linked to habitats, enabling active and contextual learning (Angelaki et al., 2024; Megalou et al., 2022). Research highlights that these hybrid approaches foster deeper ecological understanding by linking experiential, emotional, and cognitive dimensions (Hajj-Hassan et al., 2024; Marouli & Duroy, 2019).

Non-formal settings like weekend programs or youth groups use ICT to create blogs, podcasts, or videos that show how small changes matter. These relaxed spaces encourage experimentation and collaboration (Arslan & Karakuş, 2024; Ouariachi et al., 2020).

By linking formal and informal learning through technology, schools show that sustainability is not just a subject but a living mindset (Kougias & Efstathopoulos, 2020; Tsai et al., 2025). These blended approaches connect learning with lived experience. As challenges grow, students also need tools to think across systems, anticipate consequences, and explore future scenarios (Khalifé et al., 2022; Vaiopoulou et al., 2021).

Digital Tools for Systems Thinking and Environmental Foresight

Environmental issues are interconnected—climate, food, water, cities, energy. Helping students think in systems is key, and ICT tools can support that (Hajj-Hassan et al., 2024; Sinakou et al., 2019).

In Greek classrooms, teachers use modeling apps or simulators. For example, students explore how deforestation affects rainfall, soil, and farming. One change leads to others. Seeing that chain helps them grasp the big picture (Kougias & Efstathopoulos, 2020; Lampropoulos, 2024). This fosters systems thinking—the ability to understand dynamic relationships across environmental, social, and economic domains (García-Hernández et al., 2023).

Interactive maps or tools like World's Largest Lesson let learners study UN goals, link them to local issues, and test changes. Even spreadsheets can simulate water use or carbon footprint, with charts showing outcomes in real time. These tools promote scenario-based learning and critical thinking (Angelaki et al., 2024; Drosou, 2023).

Some schools use digital timelines and story maps to trace environmental history. How did a wetland become farmland? What changed when a highway was built? These tools guide students through causes and effects, supporting interdisciplinary learning across geography, history, and civic awareness (Ampartzaki et al., 2021; Repetto et al., 2024).

Systems thinking also builds foresight. Students ask: What if temperatures rise 2°C? What if our school saves 10% energy? ICT turns such questions into tests, not guesses—cultivating strategic thinking and responsibility (Marouli & Duroy, 2019; Tsai et al., 2025).

Research shows that systems thinking through technology deepens understanding and empowers students to act with agency and optimism (Arslan & Karakuş, 2024; Ouariachi et al., 2020). Thinking this way takes time, but prepares students to face complex futures with clarity.

By exploring scenarios and system dynamics, students see how small actions lead to meaningful change. The next step is turning understanding into practice (Khalifé et al., 2022).

From Awareness to Action - Sustainable Practices in Schools Supported by ICT

Awareness is only the beginning. Environmental education aims to shape habits, not just thoughts. ICT can help turn ideas into real actions (Ampartzaki et al., 2021; Hajj-Hassan et al., 2024).

In many Greek schools, students apply what they learn and track it digitally. They use apps to measure water use, design posters for recycling, or document clean-up actions with before-and-after photos (Drosou, 2023; Megalou et al., 2022). These examples, drawn from literature and practice, show how ICT supports the shift from awareness to behavioral change (Goulgouti et al., 2019; Tsai et al., 2025).

Some schools keep online sustainability journals. Student groups upload reports on tree planting or energy-saving efforts. Others use spreadsheets to monitor changes over time. These activities foster critical thinking and collaborative planning, linking environmental knowledge with real-world decisions (Angelaki et al., 2024; García-Hernández et al., 2023).

Digital tools help sustain efforts. Students reflect on what works, adjust plans, and feel proud of visible results. This feedback loop reinforces motivation and deepens learning (Arslan & Karakuş, 2024; Ouariachi et al., 2020).

Technology provides structure, continuity, and visibility—turning environmental learning into sustained action (Repetto et al., 2024). Research shows that schools using digital tracking and reflection tools see stronger long-term engagement with sustainable practices (Khalifé et al., 2022; Lampropoulos, 2024).

Yet for change to be truly sustainable, it must be inclusive. Environmental education must ensure that every learner can participate meaningfully, regardless of background or ability (Marouli & Duroy, 2019; Vaiopoulou et al., 2021).

Inclusive Environmental Education - Supporting All Learners Through ICT

Not every student learns the same way. Some need more time. Others face physical, emotional, or language barriers. True sustainability includes everyone. Environmental education must ensure that all learners—regardless of ability, background, or learning style—can participate meaningfully. ICT makes that possible by offering flexible, multimodal pathways to engagement (Ampartzaki et al., 2021; Vaiopoulou et al., 2021).

In Greek classrooms, teachers use text-to-speech apps, subtitles, and image-based tools to support students with learning differences. For example, a student with dyslexia can follow a documentary with audio and visual cues. Another can create a photo diary instead of writing a report (Lampropoulos, 2024; Papadakis et al., 2020). These examples are drawn from documented school practices (Goulgouti et al., 2019).

Multimedia tools also support students who speak different native languages. Short videos, digital comics, and translated visuals make complex ideas easier to grasp. Students can express themselves with photos, voice notes, or drawings—expanding participation beyond written text (García-Hernández et al., 2023; Khalifé et al., 2022). Research shows that when ICT enables multimodal expression, environmental education becomes more accessible and emotionally engaging for diverse learners (Arslan & Karakuş, 2024; Marouli & Duroy, 2019).

Some schools use simple coding tools like Scratch to let students build stories or games on topics like clean water or recycling. These platforms work well even for students

with limited language skills or attention span, helping them feel capable and proud (Ouariachi et al., 2020; Tsai et al., 2025).

Inclusive teaching refers to designing learning environments that accommodate diverse needs and access levels, ensuring every student can engage meaningfully with environmental topics (Sinakou et al., 2019).

Inclusive environmental education reflects the values it teaches. When ICT opens doors for every learner, it affirms that sustainability is not only ecological, but also social and educational (Angelaki et al., 2024; Hajj-Hassan et al., 2024). As digital tools evolve, educators must look ahead—not only to new technologies, but to how they support inclusive, future-oriented learning (Repetto et al., 2024).

Looking Ahead - The Future of ICT in Environmental Education

ICT has already changed how students learn. But more change is coming. As tools evolve, schools must decide not just what to use, but why and how (García-Hernández et al., 2023; Hajj-Hassan et al., 2024).

In Greece, digital tools are expanding in everyday teaching. More schools add robotics kits, coding clubs, and digital labs. These offer new opportunities for environmental learning, like using sensors to track temperature or smart bins that display recycling data (Angelaki et al., 2024; Megalou et al., 2022). Studies show that integrating such tools into sustainability projects enhances systems thinking and digital literacy (Lampropoulos, 2024; Sinakou et al., 2019).

But more technology is not always better. The key is pedagogical intent. ICT should serve values: care for people, nature, and fairness. Teachers must choose tools that deepen thinking, not just entertain. Students must learn to question, create, and reflect (Arslan & Karakuş, 2024; Marouli & Duroy, 2019).

Future efforts should focus on:

- Equitable teacher training across all regions (Papadakis et al., 2020)

- Stable funding for infrastructure and access (Kougias & Efstathopoulos, 2020)

- Projects that connect schools to real environmental challenges (Repetto et al., 2024)

- Systems that include every learner and foster agency (Ampartzaki et al., 2021; Vaiopoulou et al., 2021)

Young people will grow up with climate as daily reality. Schools must equip them with skills, empathy, and resilience. When used wisely, ICT becomes a bridge between learning and sustainable transformation (Ouariachi et al., 2020; Tsai et al., 2025).

Conclusions and Future Perspectives

The initial goals of this paper—fostering critical thinking, emotional engagement, collaboration, and systems thinking—have guided the exploration of ICT in environmental education.

Environmental education gains depth when ICT bridges knowledge, emotion, and action. As shown across the twenty thematic sections, digital tools strengthen critical thinking, collaboration, and practical environmental skills (Goulgouti et al., 2019; Hajj-Hassan et al., 2024).

When students analyze data, reflect on choices, and collaborate digitally, they don't just acquire information—they learn to question, empathize, and act. ICT becomes a catalyst for transformative learning, nurturing agency and ecological responsibility (Arslan & Karakuş, 2024; Tsai et al., 2025).

Teachers are key facilitators. Their choices—tools, framing, and safe spaces—shape how students connect facts with values and global challenges with local realities. Professional development that supports interdisciplinary, inclusive ICT-based activities is essential (Angelaki et al., 2024; Vaiopoulou et al., 2021).

Schools that align ICT with environmental goals evolve into learning communities of shared responsibility, where technology supports creativity, care, and participation. These approaches reflect Education for Sustainable Development (Ampartzaki et al., 2021; Marouli & Duroy, 2019).

Looking ahead, the challenge is to keep digital innovation human-centered and ethically grounded. Research and practice must explore how ICT cultivates empathy, systems thinking, and sustainable citizenship—skills essential for future learners and leaders (García-Hernández et al., 2023; Sinakou et al., 2019).

Long-term evaluation is also vital. Studying the impact of ICT-supported environmental learning helps refine strategies and identify what drives real change (Drosou, 2023; Repetto et al., 2024).

In this way, ICT-supported environmental education becomes not just a method, but a commitment to shaping a more just, resilient, and sustainable future (Khalifé et al., 2022; Kougias & Efstathopoulos, 2020).

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