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Systematic Review

Environmental Education: A Systematic Review on the Use of Digital Tools for Fostering Sustainability Awareness

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Abstract: Recently, sustainable development practices have increased attention as climate change and environmental impacts have increased. Interventions to encourage sustainability awareness are developing, so fostering them through education is crucial. Evidence-based studies conducted in this field have suggested the use of different digital tools to promote environmental learning gains and to foster better sustainability awareness among students. Following the PRISMA method, we found 21 articles published between 2013 and 2023 showing an interest in the use of digital tools in environmental education to foster sustainability awareness among learners. Findings indicate that virtual reality tools and climate change topics are the most trending in this research area. Further, the results show a positive impact of the use of digital tools on students' concern for the sustainability of the planet.

Keywords: sustainable development goals (SDGs); environmental education; digital tools; sustainability awareness

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1. Introduction

The adaptation of the 2030 Agenda, through the United Nations intergovernmental negotiations, led to the elaboration of 17 sustainable development goals (SDGs) [1]. Since 2015, the SDGs have proved to be crucial in ensuring human development, offering students empowerment in decision-making, integrity in achieving environmental responsibility, social justice, and economic viability [2]. As such, students develop future-oriented skills, as well as the ability to think critically, solve problems, and learn in a self-directed manner [3]. Furthermore, in the flow of achieving Goal 15 of the SDGs, which is to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss" [1], UNESCO considers education as crucial to achieving the goal. In fact, biodiversity education not only contributes to integrating the protection of ecosystems and biodiversity into students' local and national values but also helps students to develop processes, set strategies, and accounts to reduce poverty [4]. According to Lysgaard et al. [5], the implementation of sustainability and SDGs in education has so far failed to have a real impact on environmental sustainability projects in policy circles. In this regard, Kopnina [6] underlines the need to assess the integration of SDGs in education in general and in environmental education in particular [7]. Rieckmann [8] suggests that if education at all levels integrates sustainable development principles into its practice, then education itself could be a powerful tool for achieving the SDGs; that is, learners are prepared with knowledge about the SDGs and with the ability to achieve the SDGs. However, for this to happen, education itself needs to be transformed and new approaches need to be adopted [9].

Today, voices are being raised about how digital technology, due to its critical cross-sectoral nature, will be the contributing force that will make it possible to achieve the

SDGs [10]. In addition, digital technologies have been incorporated into teachers' training and practice to promote SDG awareness among them and their students [11]. According to Lay, a variety of digital technologies can be used to engage students in environmental stewardship, including video conferencing, mobile applications, virtual reality, and augmented reality. Students can be captivated by such technologies as they capture experiences of local and distant environments, collect data, and share findings. That is, digital technologies in EE can contribute to developing students' sustainability awareness on issues related to SDG 15, such as eco-citizenship, climate change, ecology, and environmental sustainability.

This systematic review aims to cover the state of the art of digital tools used in environmental education (EE) to promote sustainability awareness among learners at all stages of learning. Given the relevance of the use of digital educational approaches in strengthening environmental awareness strategies to reduce the severity of environmental complications [12], it is important to investigate the impact of the trend in the use of digital technologies that can benefit educators by providing them with insights into their effectiveness for learning and teaching. Although this field has been covered by Fauville et al. [13], no literature review has addressed this topic in the last decade. According to Dubé and Wen [14], little attention has been paid to the changes brought by the effects of rapid technological development. Therefore, it is relevant to update the list of trending digital tools used in the service of EE topics.

1.1. Contribution

The concept of self-exploration in EE emphasizes the importance of first-hand experience with nature as part of the learning process [13]. Nevertheless, Fauville et al. [13] pointed out that self-exploration experiences are not often a viable option due to a variety of factors, including budget constraints, time constraints, and even students' security concerns. According to the Tbilisi Declaration, educators face challenges when teaching abstract topics that are far from students' everyday realities [15]. Thus, new technologies have turned out to provide interesting alternatives and foster opportunities for virtual explorations and travel in space and time [13]. The digital tools used in EE, previously revealed by Fauville et al. [13], were the following: digital maps, video podcasts, computer-assisted virtual environments, video games, and augmented reality. Our study goes beyond the literature held by Fauville et al. [13], covering the last decade of research in this field, to reveal the most recent educational technologies fostering environmental learning and awareness.

1.1.1. Digital Maps and EE

Often used alongside land use mapping and census data, computer mapping has been around since the 1950s [16]. One of the recent digital mapping tools used for cartography is Google Earth, an interactive 3D virtual globe using satellite imagery and aerial photographs. Research in the field of environmental awareness and education has been carried out using Google Earth digital maps in schools. For instance, Guertin et al. [17] studied middle school students' information recall and understanding of past oil spills after introducing them to the 50 most disastrous oil spills in history from around the world using Google Earth. The Google Earth file created and presented to the students provided resources for each disaster, including location, photos, and data such as type of spill, cause, date, amount of oil, and other resources. Nevertheless, the study did not reveal students' learning outcomes but sought mainly to develop a content knowledge activity about global oil spill disasters based on their spatial and temporal distribution. Another study conducted by Dave et al. [18] developed alternative virtual experiences for the students to learn environmental concepts using Google Earth learning activities (GELA) [19]. The study was conducted on 156 senior high school students, revealing a significant increase in students' environmental awareness and attitude. Thus, GELA was found, overall, to be an effective teaching tool in enhancing students' environmental awareness but was not tested on students' learning outcomes.

1.1.2. Video Podcasts and EE

Students' performance in EE has been shown to be impacted positively by video podcasts in three different ways: test scores, self-reports, and changes in practice [20]. In their study, Hill et al. [21] examined the utility of using video podcasts about exotic ecosystems on students' learning outcomes. Through a written questionnaire, focus groups, and summative assessment results, the effectiveness of learning about exotic locations was assessed. Students were invited to watch six podcasts in the university's computer labs or download them to their personal computers or mobile devices. The podcasts were accessible through the university's virtual learning environment. The results show that the students found the podcasts to be complementary to the lectures and helpful for their active learning. Further, the podcasts proved beneficial for revision and assessment by offering visual stimuli for factual recall and revealing knowledge gaps. However, the authors add that no significant differences were observed in exam essay grades before and after adopting podcasts, and conclude that enhancing the student learning experience seems to hinge on refining current pedagogic strategies rather than adopting new ones. Hill et al. [21] suggest integrating individual podcast learning with group exploration and critical discussion within a collaborative learning framework. That is, the combination of passive and active technologies in the classroom.

1.1.3. Computer-Assisted Virtual Environments and EE

Various past research has sought to develop computer-assisted virtual environments for EE. Jacobson et al. [22] built virtual field trips (VFT) for academic courses in universities on the links between soil and civilization. The design goal was to get students thinking about how the demise of powerful and vast civilizations has been mostly attributed to the misuse of natural resources, which can cause soil degradation and environmental damage. The Chinampa region of Mexico City's former Lake Xochomilco was chosen as the site for this VFT. The envisioned VFTs were not tutorials or field/lab exercises; instead, they aimed to be intricate representations of past or present civilizations and their interactions with the environment. Jacobson et al. [22] suggest the use of media resources in VFTs effectively engages students with diverse subjects such as environmental science, history, and world cultures. This approach allows students to explore individual topics, make connections, and gain a deep understanding of sustainability concepts.

Another study, carried out by Tarng et al. [23], sought to develop a virtual marine museum for educational purposes in elementary schools in Taiwan. Working in their own classrooms, the virtual museum aimed to offer students the ability to understand the significance of marine ecology and develop an understanding of environmental protection. The authors conducted a qualitative research study testing the use of the online museum on fifth and sixth grades students, as well as on computer-skilled teachers. The findings indicate that a virtual marine museum could increase students' enthusiasm for learning and interest in their studies. While authors outlined the potential of the virtual museum in promoting interest in marine ecology and the ecological preservation of oceanic areas, no quantitative research assessed students' learning outcomes.

In the same research field area, resulting in computer-assisted virtual environment creation for EE, virtual laboratories were also targeted by researchers. In fact, Ramasundaram et al. [24] created an environmental virtual field laboratory (EVFL) to mimic real field trip learning experiences, presenting environmental characteristics and processes of Florida's flatwood landscapes (soil series with poor drainage created by marine sediments). In this activity, students explore how different forest management regimes affect the hydrological response of the flatwood landscape. The focus questions encourage students to choose a scenario (such as silvicultural treatments) in order to carefully observe its effects on ecosystem processes and to interpret the causality. The study provided a simple tool description without reporting any student learning outcome evaluation. However, Ramasundaram et al. [24] suggested that while virtual field labs may lack real-world experiences, such as mosquitoes, humidity, and getting dirty, they complement existing courses and are not intended to replace field experience.

Another virtual laboratory tool was developed by Fauville et al. [25], testing the effect of variation in seawater acidity on marine larvae. This tool sought to allow high school students to obtain a thorough understanding of ocean acidification, one of the most important environmental challenges of the twenty-first century. The authors assessed the knowledge outcome of this virtual laboratory for high school students in California and Sweden and found a significant increase in knowledge following the virtual laboratory's use. Fauville et al. [25] suggested that computer-based virtual activities can simulate and complement real lab experiments, providing students with a taste of the actual experience related to environmental issues involving the acquisition and analysis of real data.

1.1.4. Video Games and EE

According to Tkotzyk et al. [26], the term "game-based learning" was spread earlier in the 1990s, and digital games were already being employed to foster knowledge. Video games targeting EE, e.g., River city, were also developed to allow students to use avatars in a computer-based city simulation, where they could interact with objects and fellow students' avatars [13]. Ketelhut et al. [27] investigated the learning outcomes of 500 seventh-grade students using the video game River City compared with traditional teaching, including physical experimentation, which allowed water sampling and microbial testing at different stations in a virtual city. Ketelhut et al. [27] found that virtual experimentation engages all students; however, the girls excelled the most in learning through virtual experimentation, while boys in the physical experimentation group outperformed those in the virtual group.

1.1.5. Augmented Reality (AR) and EE

Incorporating augmented reality (AR) into handheld computing has the potential to help students understand science as a social practice in which investigation is a process of combining multiple data sources, forming and revising hypotheses in situ [28]. Thus, AR potentials seem particularly pertinent for EE, as it can be effective for learning activities that are difficult to be replicated in reality, such as experiencing spreading pollutants to study their effects on the environment [13]. According to Fauville et al. [13], one of the most well-known AR software applications used in EE is Environmental Detectives (ED). The game's objective is to provide students with a hands-on experience managing a challenging environmental science inquiry under time, place, and social restrictions [28–30]. In groups of two or three, ED participants assume the role of environmental engineers looking into a chemical spill in a watershed. ED offers a simulation that allows students to collect virtual samples, conduct virtual interviews, and learn about the local geography while moving through the real world. Additionally, students get the chance to conduct virtual interviews with specialists in several spill-related sectors. As a result of their studies, Klopfer et al. [30] concluded that the AR simulation enabled students to experiment with various inquiry techniques in a secure environment, and failure in completing the activity is both conceivable and advantageous for learning.

Another AR-based application is "E-junior" sought by Wrzesien et al. [31]. Based at the aquarium "L'Oceanogràfic" in Valencia (Spain), this application is intended to be a serious virtual game that introduces a unique ecosystem to the Mediterranean Sea: beds of the seagrass Posidonia Oceanica. It combines educational content and computer games. Students engage in the photosynthesis of the beds and assess the effects of humans on various animal and plant species using the virtual environment through polarized glasses and employ paddles equipped with augmented reality (AR) technology to move around the scene. Wrzesien et al. [31] studied the effect of E-junior use on 48 students and found no statistical gains in terms of learning effectiveness in favor of the game. However, students from the traditional learning group showed less engagement and enjoyment during the class, while students from the virtual group showed greater and better participation.

In addition, other immersive environments, such as VR and metaverses, are now broadly used in the field of education and training [32]. These benefits are generally explained by a higher degree of immersion [33] and engagement [34] in learning situations in VR compared to non-VR, thanks to a stronger embodied experience [35]. Virtual reality generates highly sensory and emotional experiences through user interactions with the virtual environment [36]. It is a mediated experience that immerses the user in an artificial environment in which he can feel and interact in real-time via sensory-motor interfaces. VR also increases the sense of presence, defined as the degree of "being here", strongly linked to the senses of immersion and interaction [37]. The degree of presence felt is often equated with the degree of realism (social, perceptual, cognitive): a strong sense of presence can generate an illusion of immediacy (i.e., an unmediated relationship) in the VR user [38]. The concept of embodied cognition is increasingly used to study learning and several studies have demonstrated the link between virtual reality and learning [35]. By offering a virtual experience similar to a real experience, virtual reality allows an almost automatic transfer of learned skills [39] with scenarios that would be too dangerous to implement in the real world.

In summary, the examples provided concerning digital tools used in EE, previously revealed by Fauville et al. [13], indicate that digital tools such as digital maps, video podcasts, computer-assisted virtual environments, and video games can be complementary to traditional teaching, such as physical laboratories and experimentation. In other words, these technologies can simulate and represent reality quite well, giving students visual access to environments that would otherwise be difficult to experience. Several of the studies suggest that this promotes students' interest and engagement in the topic of environmental issues. However, few of the studies provide findings that indicate that digital tools affect students' scientific knowledge and learning of environmental issues. There is research that indicates that visual representation, such as virtual laboratories, do not always succeed in helping students. López and Pintó [40] examined how students (14–16 years old) understand visual representations when using two virtual laboratories. The results revealed that students do not always grasp the connection between what is presented in a virtual laboratory and how the scientific phenomenon manifests in their everyday lives. Another challenge, described by Evangelou and Kotsis [41], is that students in virtual laboratories can not use their senses to perceive physical properties, such as weight, which is possible in physical laboratories. However, the use of immersive environments such as VR and AR could be the answer to these issues. As previously described, the use of, for example, virtual reality (VR) in learning, attributed to increased immersion and engagement, results from a more potent embodied experience compared to non-VR settings. Virtual reality creates rich sensory and emotional experiences [33–35].

In their paper, Dubé et al. [14] studied the changing trends in educational technology between 2011 and 2021. Their findings indicate a consistent trend in mobile and analytics technologies over time, a shift towards maker technologies and games in the early part of the decade, and a future prediction of emerging technologies, such as VR and AI, gaining traction. Therefore, it is of particular interest to investigate the development in recent years on the use of digital tools in EE to promote sustainability awareness among learners, as well as what impact the use of these digital tools can have on students' environmental knowledge and concern for the sustainability of the planet [42].

2. Objectives and Research Questions

Considering the relevance of covering the gap in the literature of the last decade, as well as furthering the research and revealing the possible effects of different digital tools on students' sustainability awareness and education to achieve SDG 15, we aim in this study to answer the following research questions:

RQ1: What does the literature reveal about the state of the art of digital tools used for environmental awareness and education?

RQ2: Does digital tool use foster better scientific knowledge gains about environmental issues?
RQ3: What role can digital tools play in the fostering of sustainability awareness among learners?

The hypotheses that the present literature review is testing can be listed as follows:

H1: *Virtual reality environments are significantly used for education in environmental awareness, thanks to empathy, sense of presence, and immersion.*

H2: *Using digital tools leads to efficient learning and performance in EE topics.*

H3: *Using digital tools for teaching EE fosters sustainability awareness among students.*

H4: *Immersive environmental learning fosters better environmental learning and awareness.*

The studies included in this review will cover topics in education related to SDG 15, including environmental education, eco-citizenship, climate change, ecology, and environmental sustainability. In addition, this systematic review will cover the scope of revealing the effect of digital tools on students' SDG learning in K-12 and higher education.

3. Methods

This review was designed based on the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) (see Supplementary Materials). Formulating research questions, as stipulated by PRISMA [43], requires having a broader perspective on previous works, which will help to develop distinct early questions. Thus, in order to shed light on the different digital tools employed in targeting SDG 15, a scoping review was conducted using the platform "Web of Science" which provided access to reliable databases. This review was not registered and presents no amendment nor a prepared accessible protocol. Records were identified following the succeeding inclusion criteria:

(a) documents that included in their title, abstract, and keywords (from the author and/or plus), the words: (environmental education OR sustainability education OR climate change education OR ecology education Or SDGs education Or sustainable development education) OR (environmental awareness OR sustainability awareness OR climate change awareness OR ecology awareness Or SDGs awareness Or sustainable development awareness) OR (environmental literacy OR environmental concerns OR environmental responsibility OR ecofriendly awareness Or green awareness) AND (ICT OR "Video gam*" OR "Google Earth" XR OR VR OR MR OR AR OR "Virtual reality" OR "Mixed reality" OR "augmented reality" OR "Extended reality" OR digital OR "online platforms"). Keywords were identified after developing an understanding of key concepts, compiling a complete list of synonyms related to the study subject, and confirming the usefulness of natural language terms by testing them out and finding controlled vocabulary;
(b) studies covering all educational levels (K-12, primary school, college education, secondary education, university education, lifelong learning, adult education);
(c) reporting empirical studies;
(d) publication dates between 2013 and 2023 following the 10-year rule proposed by Robinson, A. [44] to cover the aforementioned literature gap.

The database search was conducted between June and July 2023. The keyword found was split into multiple searches in each combination of one keyword about environmental education, sustainability, and digital tools.

The Boolean search resulted in 6195 records (Figure 1) that were transferred to EndNote to be treated. Records excluded before screening were deleted based on the following exclusion criteria: (a) publications written in a language different than English (n = 5); (b) no abstract (10); (d) duplicated records (n = 2417); (e) conference article reports (n = 665), literature review (89), documentary review (5), meta-analysis (30), literacy in fields not related to this review field of interest (22), essay (n = 2). After screening, the 2950 left records were shortcut to 68 reports sought for retrieval. At this stage, articles were excluded for the following reasons: (a) documents associated with areas other than education, technology and sustainability (n = 355) (b) documents related to the following topics: applied engineering ((architecture and design (n = 3); chemical engineering (n = 231); agriculture engineering (n = 4)); cultural reflection (socio-culture history (n = 9); cultural heritage (n = 72)); SDG-8 (sustainability in tourism (n = 24)); industrial research and manufacturing (n = 90); solid chemistry research fields (structural chemistry, mineralogy, geochemical, precursor activity, nanoparticles, bioanalytical chemistry, polymer research, molecule synthesis, medicinal chemistry, gas emission (n = 733)); solid biochemistry research fields (hormones, spectrophotometry for poly-ionic liquids, toxicology, diabetes (n = 90)); solid biology research fields (cellular biology, bio interface, microbiology, environmental neuro-microbiology, immunology, genetics; serology; forensic science; functional ecology (n = 323)); environmental actions and research (soil management; land research, scientific discovery about environmental damage with no educational purposes, ceramic impact on environment, and research about robust, mining, flood, fossil atmosphere, satellite observations and water waste handling strategies without teaching and learning contexts (n = 295)); solid physics research fields (hydraulic efficiency, research on energy and electricity production, conductive material, photovoltage (n = 12)), medicine and medical interventions (clinical research, patient therapy and diagnosis, research on allergic rhinitis, cancerology, cardiology and encephalography (n = 260)); economy and politics (economic growth, economic sustainability and employment, political sciences (n = 196)); business (blockchain, supply chain (n = 39)); sports (football robots (n = 3)); education (leadership; teacher practices, homeschooling, impact of COVID-19 on overall learning, outdoor learning, obstacles in electronic exams (n = 58)); psychology (bullying, stress, behavioral research, mental health, ontology (n = 71)); others (analytical support tools for civil servants (n = 1); home appliance (n = 1), alcohol consumption (n = 1), feminist practice (n = 1), democracy (n = 3), social inclusion (n = 4), public health (n = 1), globalization (n = 2)).

The 68 held records were put down to 16 for the following reasons: (a) not in English (n = 6); (b) theoretical approach (n = 2); focusing on digital literacy (n = 6); paid access required (n = 4); no digital tools involved (n = 3); articles that are not in the scope of environmental education (n = 4); tools for environmental management (not for educational purposes) (n = 3); other reasons implying the research is neither focused on digital tools nor on environmental awareness and education (behavioral learning (n = 4); psychological well-being (n = 2); employability (n = 1); socio-economic development (n = 2); health care education (n = 2); ICT skills development (n = 2); teachers practices (n = 3); business (n = 1); tool conceiving methodology (n = 3); tool analysis (n = 1); architecture education (n = 1); technology access rate (n = 1); human capital in environmental sustainability (n = 1)).

The references section of each document obtained in the databases and texts included in the introduction section of this review were examined, as well as the reference section of the 16 articles held after the exclusion process, and 5 articles were added to the studies included in the review, enclosing in total n = 21 articles sought for analysis. Although the total number of articles included in this review is limited, it is still wide in scope. As the number of papers depends on the research topic, evidence on digital technology use for sustainability awareness in particular was found restricted. Although attempts to develop sustainability measuring tools are rising, sustainably awareness of behavioral change due to digital use was only qualitatively assessed based on observational research methods. Observational studies lack randomization to allocate by chance risk factors to an outcome [45]; hence, the number of articles found was restricted.

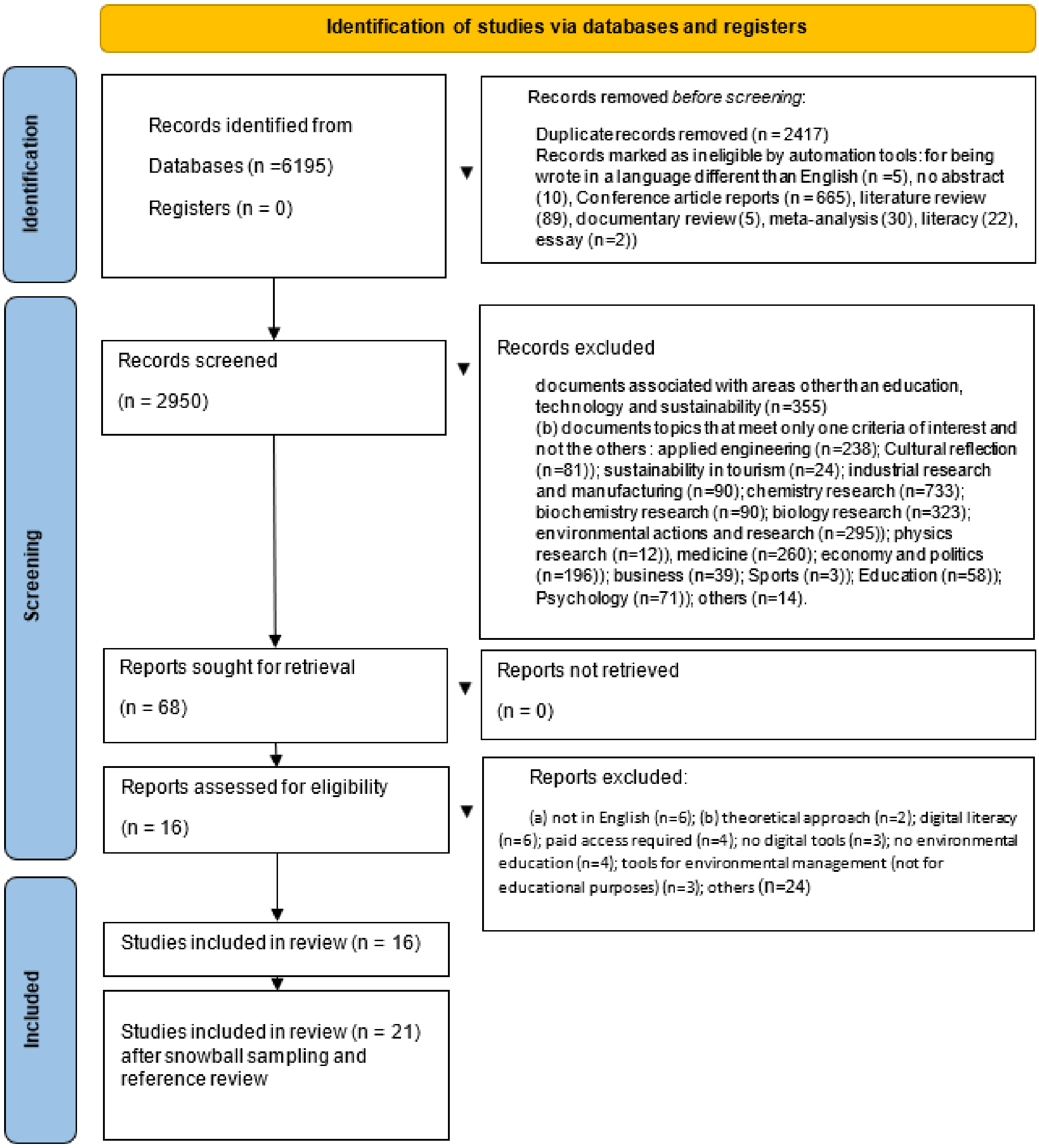

Figure 1. Flow diagram of review stages.

After considering the following characteristics: authors, year of publication, origin, topics discussed, and results, 20 articles were selected for further analysis. A summary of the article details was performed and listed in a descending chronological order, as shown in Table 1. Although the search covered the period between 2013 and 2023, no articles that met the inclusion criteria were published in 2013, 2014, and 2015.

Table 1. Summary of documents included in the literature review.

N	Authors	Year	Journal or Book	Country	Topic	Method	Sample	Education Level Target	Title
[46]	Queiroz, A.; Fauville, G.; Abeles, A.; Levett, A.; Bailenson, J.	2023	Sustainability	USA	Climate change.	Qt	Schools, universities, museums, aquariums, VR arcades, libraries, and foundations from 17 locations across the U.S., the U.K., Canada, and Denmark.	Life long learning	The Efficacy of Virtual Reality in Climate Change Education Increases with Amount of Body Movement and Message Specificity.
[47]	Zhou, Y.; Zhengyan L.; Meng Wang, R.; Kechen D. & Xiao-Guang Y.	2023	Ekonomska Istraživanja	Japan	Renewable energy demand.	Qt	(Old data sought for linear regression)—sample not identified.		Evaluating the impacts of education and digitalization on renewable energy demand behavior: new evidence from Japan, Economic Research-
[48]	Sajjadi, P., Bagher, M. M., Myrick, J. G., Guerriero, J. G., White, T. S., Klippel, A., & Swim, J. K.	2022	Frontiers in Environmental Science	USA Philadelphia	Soil.	Qt	152 participants.	Adult learning	Promoting systems thinking and pro-environmental policy support through serious games.
[49]	Ricoy, M.; Sánchez-Martínez, C.	2022	International Journal of Environmental Research and Public Health	Spain	Ecological awareness.	Qt	156 students.	Primary school	Raising Ecological Awareness and Digital Literacy in Primary School Children through Gamification.
[50]	Álvarez N.; Álvarez-García C.; Anguita, L.; Sanz-Martos, S. & López-Medina, I.	2022	BMC Nursing	Spain	Climate change.	Qt	81 pairs of students throughout their four-year academic university.	University education	Effectiveness of scenario-based learning and augmented reality for nursing students' attitudes and awareness toward climate change and sustainability.
[51]	Barnidge, M.; Sherrill, L.A.; Kim, B.; Cooks, E.; Deavours, D.; Viehouser, M.; Broussard, R.; & Zhang, J.	2021	Mass Communication and Society	USA	Climate change.	Qt	133 participants.	University learning	The Effects of Virtual Reality News on Learning about Climate Change

Table 1. *Cont.*

N	Authors	Year	Journal or Book	Country	Topic	Method	Sample	Education Level Target	Title
[52]	Diolaiuti, G.; Maugeri, M.; Senese, A.; Panizza, M.; Ambrosini, R.; Ficetola, G.; Parolini, M.; Fugazza, D.; Traversa, G.; Scaccia, D.; Franceschini, M.; Citron, L.; Pelfini, M.	2021	Geografia Fisica e Dinamica Quaternaria	Italy	Climate change impacts on glaciers.	Qt	150 first-year students.	University learning	Immersive and virtual tools to see and understand climate change impacts on glaciers: a new challenge for scientific dissemination and inclusive education.
[53]	Guo, S.	2021	International Conference on Advanced Learning Technologies	Taiwan	Environmental protection.	Qt	32 students between grade three and grade six.	Elementary school	Utilizing Digital Storytelling to Foster Pupil's Language and Environmental Awareness and Action.
[54]	Pratiwinindya, R.; Alfatah, N.; Nugrahani, R.; Triyanto, T.; Prameswari, N. & Widagdo, P.	2021	IOP Conference Series: Materials Science and Engineering	Indonesia	Animal conservation education.	Mx	32 students in the 4th grade.	Children education	The use of interactive multimedia to build awareness against animal exploitation in environmental conservation education for children.
[55]	Lo, Jung-Hua & Lai, Yu-Fan & Hsu, Tzu-Lun. (2021).	2021	Sustainability	Taiwan	Ecological environment protection.	Mx	30 students in a primary school in a rural area.	Primary school	The Study of AR-Based Learning for Natural Science Inquiry Activities in Taiwan's Elementary School from the Perspective of Sustainable Development.
[56]	Fernández, A.	2020	Texto Livre: Linguagem E Tecnologia	Spain	EE broadly.	QL	300 students of the Master's Degree in Teacher Training at an Andalusian University.	Higher education	Relation of the ICT with neuroeducation, inclusion, pluriculturality and environmental education through a Confirmatory Factorial Analysis study.

Table 1. *Cont.*

N	Authors	Year	Journal or Book	Country	Topic	Method	Sample	Education Level Target	Title
[57]	Sebastián-López, M.; de Miguel González, R.	2020	Sustainability	Spain	Eco-citizenship.	Qt	Documentation of 188 academic works as a result of training teacher workshops for primary education at the University of Zaragoza, Spain. Each of these works, used to assess and grade students.	Lifelong learning	Mobile Learning for Sustainable Development and Environmental Teacher Education.
[58]	Huh, J.; Park, I.; Sunwoo, Y.; Choi, H. & Bhang, K.	2020	Sustainability	Korea	Air pollution.	Qt	182 female, first-year high school students.	High school	Augmented Reality (AR)-Based Intervention to Enhance Awareness of Fine Dust in Sustainable Environments
[59]	Fokides, E., & Chachlaki, F.	2019	Technology, Knowledge, and Learning.	Greece	Protection of the Mediterranean monk seal.	Qt	326 students (10–12-years old).	Primary school students	3D Multiuser Virtual Environments and Environmental Education: The Virtual Island of the Mediterranean Monk Seal.
[60]	Weng, T.	2019	Proceedings of the 3rd—ICEMT	Taiwan	Environmental protection.	QL	56 students.	university students	Life-Changing Digital Education on Environmental Protection and LOHAS.
[61]	Ouariachi, T.; María Dolores O.; José, G. & Edward, M.	2018	Environmental Education Research	Netherlands	Climate change.	QL	12 key experts 17 students aged from 12 to 18 years.	School education	A framework for climate change engagement through video games, Environmental Education
[62]	** Markowitz, D. M., Laha, R., Perone, B., Pea, R., & Bailenson, J. N.	2018	Frontiers in Psychology	USA	Climate change, particularly ocean acidification.	Qt	270 participants from four different learning settings.	High school, college students, adults learning	Immersive Virtual Reality Field Trips Facilitate Learning About Climate Change.

Table 1. *Cont.*

N	Authors	Year	Journal or Book	Country	Topic	Method	Sample	Education Level Target	Title
[63]	Schönfelder, M. L., & Bogner, F. X.	2017	International Journal of Science Education	Germany	Awareness for pollinator conservation in education.	Qt	354 students.	Secondary school	Two ways of acquiring environmental knowledge: by encountering living animals at a beehive and by observing bees via digital tools.
[64]	Kleinhenz, P. N., & Parker, M. S.	2017	Applied Environmental Education & Communication	USA	Animal protection from the Endangered Species Act.	Qt	140 students.	School education	Video as a tool to increase understanding and support for the Endangered Species Act.
[65]	** Fuller, I. C., & France, D.	2016	Journal of Geography in Higher Education	New Zealand	Physical Geography field experiments.	Qt	58 students.	University education	Does digital video enhance student learning in field-based experiments and develop graduate attributes beyond the classroom?
[66]	Diniz dos Santos, A. D., Strada, F., & Bottino, A.	2016	Games and Learning Alliance	Italy	Raising awareness on sustainability topics	QL	Alpha testers.	Not identified	The Design of an Augmented Reality Collaborative Game for Sustainable Development.

Document obtained from database search; ** document obtained through snowball sampling. Theo = theoretical/QL = qualitative; Qt = quantitative; Mx = mixed.

4. Results

The studies selected in this review were dispersed over almost all of the selected period of publishing years in this review except for the years 2013, 2014, and 2015 (Figure 2). In fact, studies were mostly published in 2021 (n = 5; 23.8%) and are more frequently published (n = 13; 61.9%) between 2020 and 2023, underlying the novelty of the digital tool usage trend for environmental education purposes.

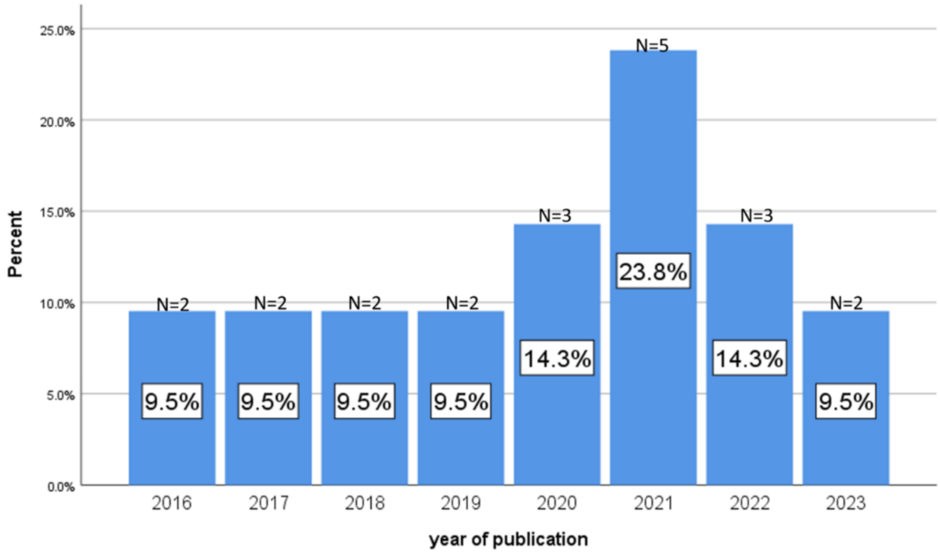

Figure 2. Percentage of dispersion of studies over the years.

Studies in this review sought to test the learning outcome of digital tools used among students. Thus, most studies (76.2%) followed a quantitative research design, (14.3%) followed a qualitative method, and (9.5%) followed a mixed research approach.

As for the geographical provenance of articles, studies were mostly published in the USA (23.8%) and Spain (19%) (Figure 3). Nevertheless, on a continental level, the studies included in this review were mostly coming from Europe (42.9%), Asia (28.6%), America (23.8%), and only (4.8%) from Oceania.

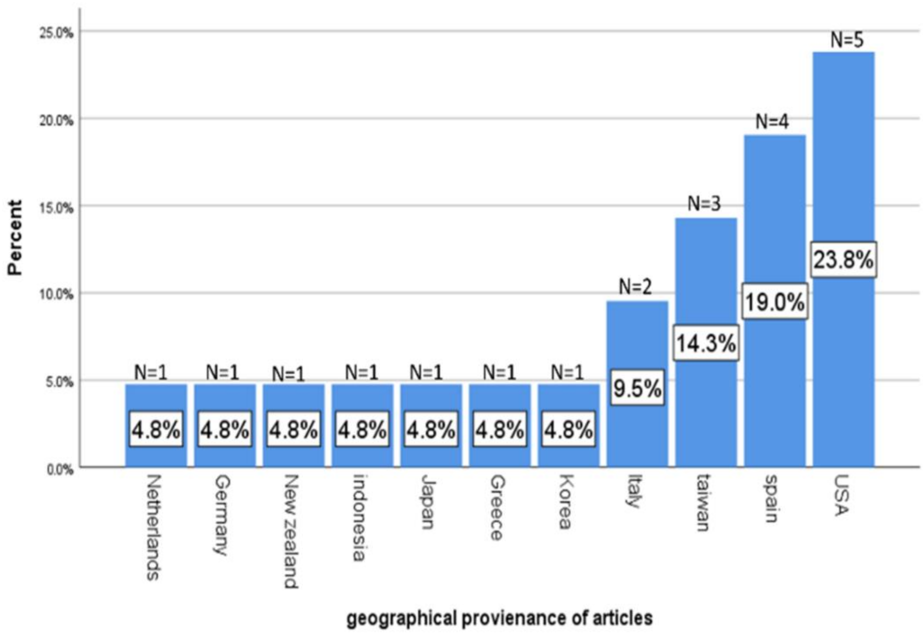

Figure 3. Geographical country distribution.

4.1. Digital Tools Integrated for Environmental Awareness and Education

Results revealed that digital tools for educational awareness are mostly used in climate change topics (n = 6; 28.6%), as shown in Figure 4. In fact, animal protection (n = 4; 19%), environmental protection (n = 2; 9.5%), and ecological protection (n = 2; 9.5%) are also trendy topics educated using digital tools.

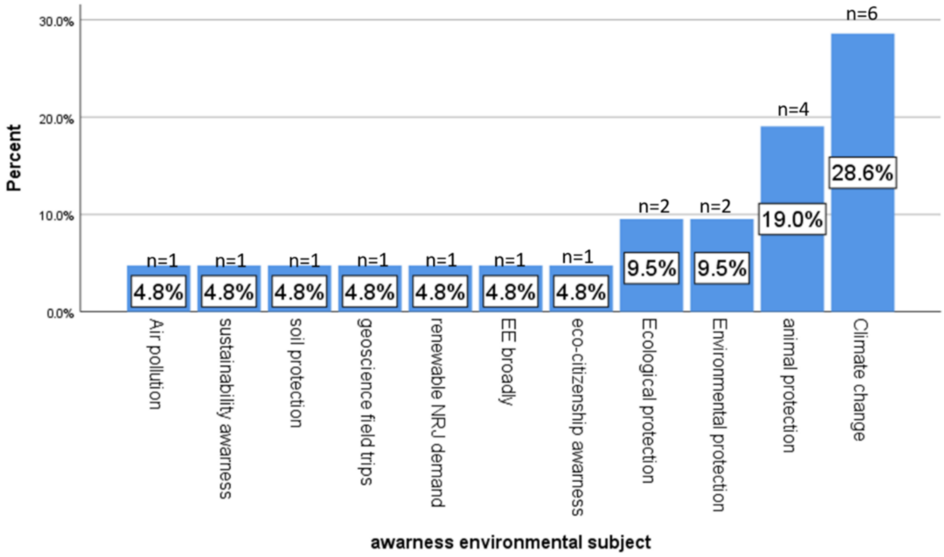

Figure 4. Environmental subject awareness.

In each retrieved article, information about the digital tool used, the variable tested, and the main research outcome of the studies are listed in Table 2:

Table 2. Digital tool used and study outcomes.

Study Number	Digital Tool Used for EE	Tested Variables	Outcomes
[50]	Augmented reality	Augmented reality use and environmental awareness.	• Attitudes and environmental awareness toward climate change and sustainability increased significantly as students received the learning sessions over the 3 years.
[51]	Virtual reality and 360 videos	Immersive VR news story and 360°-video learning.	• No main effects on the learning outcomes. • Indirect effects on cognitive elaboration, which are conditional on preexisting knowledge about climate change.
[52]	Immersive 360-degree videos	See and understand the consequences of climate change on Alpine environments.	• Very positive opinion for the immersive experience • many virtual visitors learned for the first-time notions on the magnitude and rate of the impacts of climate change on glaciers.
[66]	Augmented reality collaborative game	Augmented reality, collaborative gaming, and raising awareness on sustainability topics.	• Preliminary evaluation sessions indicate the game success in immersing the players in a collaborative experience and in raising their awareness on sustainability.
[56]	ICT	ICT with neuroeducation, educational inclusion, environmental education, and pluriculturality.	• Strong relationship between ICT use (education technologies) and educational inclusion, and between the former and pluriculturality. • Less strong relationship between ICT use and environmental education and neuroeducation

Table 2. *Cont.*

Study Number	Digital Tool Used for EE	Tested Variables	Outcomes
[59]	3D Multiuser virtual environments	Measure students' views and environmental attitudes.	• Students using 3D virtual environments had better learning outcomes. • As for attitudes toward eco problems, the outcomes were better. • Fun and an increased motivation for learning were evident. • MUVE was a better tool for raising students' awareness on Environmental issues.
[65]	Digital videos	Fieldwork experience and development of attributes.	• Deployment of digital video reinforces student learning and connects with core graduate attributes.
[53]	Digital story	digital environmental storytelling and traditional presentations.	• Students in the digital storytelling group enhanced their understanding of English and strengthened their concern about environmental protection.
[58]	Augmented reality	Augmented reality (AR) and attitudes regarding fine dust-related matters.	• The use of AR in fine dust environmental education in classes is effective in arousing students' interest and inducing participation for better engagement in learning activities.
[58]	Gamification tools	Examine the impact of a learning program on ecological awareness.	• Children assimilated new habits on the better usage of water and electricity and recycling paper and plastic. • They acquired more efficient strategies for finding information online by using apps and developing content with digital tools.
[64]	Video learning	Environmental issues learning environmental attitudes.	• The study provides additional support for the effectiveness of video content as an environmental education tool.
[55]	Mobile learning Augmented reality	Acceptance of the augmented reality and awareness of environmental protection.	• The results indicated that students who perceived the AR application to be easier to use also perceived the app to be more useful. • Results indicated that students who perceived the usefulness of the AR application to be higher also had a more positive attitude toward using the application.
[62]	Immersive virtual reality (VR)	The efficacy (VR) and climate change knowledge gain and awareness.	• Experiencing immersive VR, people demonstrated knowledge gains or inquisitiveness about climate science.
[61]	Video games	Cognitive, emotional, and behavioral engagement in environmental education.	• There is a preference for constructivism, facilitating a multi-outcome-oriented system in which the learning experience draws on different perspectives, gives rise to a variety of actions, and offers a fuller understanding of the topic.
[54]	Interactive multimedia	Interactive multimedia and environmental conservation awareness.	• Interactive multimedia becomes the right strategy to deliver information in an effort to build awareness against animal exploitation in environmental conservation education for children's.
[46]	Virtual reality	Students learning and climate change behavior.	• Embodiment settings: • Higher self-efficiency less learning outcomes; • Seated settings: • Better learning outcomes.
[48]	Digital serious game "CZ investigator"	Assess student's learning experience, systems thinking about the FEW nexuses and support for policies.	• Students learning experience was improved. • Those who played the serious game reported greater presence effective learning, challenge, happiness, awe, science interest) and less negative emotions (boredom and anxiety) with the serious game than the website. • Positive learning experiences (ease and enjoyment, sense of presence, effectiveness.
[63]	eLearning tool connected to a remote beehive	Environmental knowledge of bee's attitudes and perception in regard to bee conservation and dangerousness.	• Both approaches lead to the acquisition of conservational knowledge in the short and medium term

Table 2. *Cont.*

Study Number	Digital Tool Used for EE	Tested Variables	Outcomes
[57]	Mobile learning	Potential of mobile devices and their applications in environmental education.	• Positive impact of mobile learning in environmental education.
[60]	E-books	Environmental conservation and digital e-books.	• Dynamic picture e-books can arouse students' reading interest and improve their attentiveness and understanding, which will facilitate a change of their reading attitudes. • Dynamic images can further supplement the meanings of written words, facilitate reflection on environmental conservation, and deepen the understanding of such education, forming wholesome and natural living environments that are free of pesticides.
[47]	ICT	Digitalized education and renewable energy demand.	• The higher the level of education in Japan, the higher the renewable energy demand. • Increased digitalization help facilitate the renewable energy demand in Japan.

Results show that the digital tools used for environmental education are the following: virtual reality, augmented reality, video games, ICT, digital videos, mobile applications, e-books, interactive multimedia, and e-learning tools (Figure 5). The research focus was mostly (35%; n = 7) on innovative digital tools fostering extended reality (VR: 20%; n = 4 and AR: 15%; n = 3) for environmental education, and least on e-learning tools to teach students remotely (4.8%; n = 1) as interactive multimedia (4.8%; n = 1) was categorized alone for representing at the time VR, video learning and mobile applications. Immersive tools were mostly used (61.9%; n = 13) for EE, while 38%; n = 8 of the tools used were non-immersive digital ones.

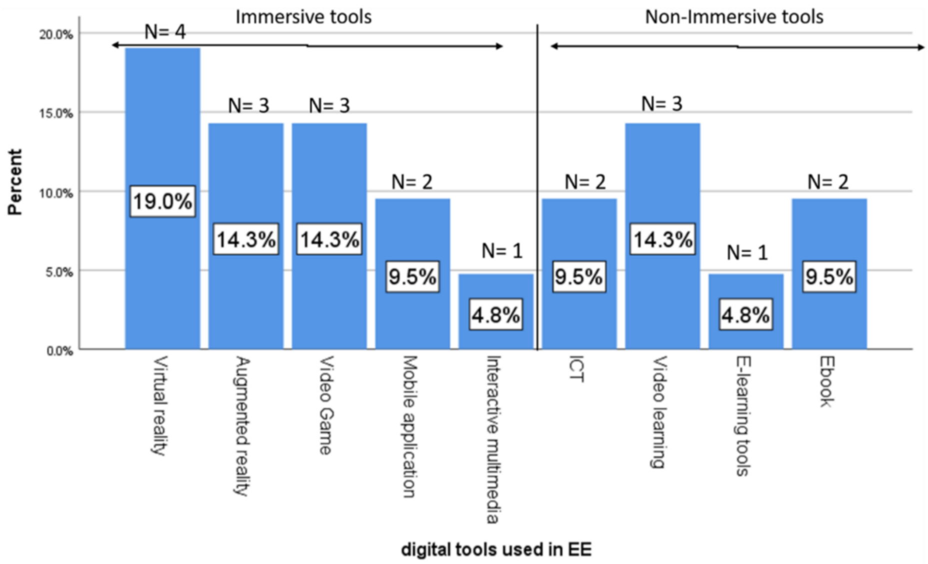

Figure 5. Digital tools used in EE.

4.2. Digital Tools Affect Students' Scientific Knowledge of Environmental Issues

According to Table 2, studies intended to trigger sustainable awareness by using different digital tools, except that research methods were hoping to either test the sustainable behavior of students directly, evaluate the digital tool design's overall effectiveness, or test students learning outcomes and knowledge. According to the main aim of the included studies, 38.1% of the studies tested the learning outcomes on environmental topics using digital tools, 38.1% of the studies investigated the direct positive behavior after using digital tools on sustainability awareness, and only 23.8% of the studies tested the effectiveness of digital tools. Although all studies revealed positive links between the tested variables and some studies disclosed additional findings (Table 2):

- students' EE learning in seated settings is more efficient than in embodied settings;
- learning EE using digital tools foster students' sense of presence and enjoyment;
- students' have very positive opinions on immersive EE experiences.

4.3. The Role Digital Tools Play in the Fostering of Sustainability Awareness

In order to qualitatively address the environmental fields for which digital tools can be effective, data was gathered from articles of this review and listed (Table 3). We show the topics in which digital tools contributed to enhancing different knowledge, indirectly influencing sustainability awareness.

Table 3. Findings from articles on EE fields fostering sustainability.

Study Number According to Table 1	Findings on Sustainability Awareness
[50]	Integrating mainstreaming sustainable healthcare, raising awareness, and changing attitudes and increasing attitudes and environmental awareness toward climate change and sustainability.
[51]	Increase knowledge about climate change and other environmental issues, garner public support for climate policy, and formation of attitudes and perceptions to policy support.
[52]	Knowledge about the glacier environment, awareness about the crucial role that glaciers have for water storage and availability, and understand the impacts of climate change on the cryosphere.
[56]	Embed in the natural sciences, geography, geology, or biology beyond the traditional classroom fosters sustainable development.
[59]	Facilitate reflection on environmental conservation, and awareness about environments that are free of pesticides.
[65]	Foster environmental awareness by facilitating sustainability instruction in ecology, economics, politics, and culture
[53]	Study the environment and find solutions for environmental problems, raise awareness and concern for the marine environment, and protect the marine environment.
[58]	Protection of the Mediterranean monk seal and how the natural environments function to help them develop behaviors that will enable them to treat the ecosystems in a sustainable manner
[64]	Awareness of environmental issues in environmental fieldwork, foster environmental attributes and competencies.
[55]	Raise awareness about the importance of the ecological environment, and put into practice the protection of the ecological environment in plant teaching activities.
[62]	Awareness of loss of biodiversity, raise awareness on pollinator conservation, fostering students' environmental attitudes and perception of bees in regard to conservation and dangerousness.
[61]	Awareness about the consequences of climate change and ocean acidification.
[54]	Raise awareness about the preservation of biological resources, flora, fauna, and the environment, as well as awareness against animal exploitation.
[46]	influence climate change behavior, and increase ocean acidification awareness.
[49]	raise environmental awareness, develop pro-environment behaviors, improve sustainable development, assimilate habits on the better usage of water and electricity, and recycling paper and plastic
[48]	Understand interconnections, solve environmental problems, develop systems thinking about the environment, and support policies to protect the environment.
[63]	Awareness about environmental issues and the protection of endangered species
[57]	(AR)-based intervention enhances awareness about fine dust.
[60]	Awareness of climate change, sustainability issues, energy issues by facilitating the development of helpful thoughts, feelings, and actions.
[47]	Reduce and control CO_2 emissions, increase renewable energy consumption awareness, and facilitate the renewable energy demand.

According to Table 3, findings showed that the use of different digital tools can foster sustainability awareness whether directly or indirectly assessed by research done in this field. Indeed, sustainability in education can be fostered in the field of knowledge enhancement in different scientific topics such as the glacier environment, ocean acidification, the marine environment, preservation of biological resources, flora, fauna and the environment, environmental protection via plant teaching activities, geography, geology, or biology, fine dust, protection of the Mediterranean monk seal, environmental conservation from pesticides, stages of protection of endangered species, ecology, economics, politics, and culture topics to trigger students' environmental awareness. Additionally, studies also revealed the potential of fostering sustainable competencies and attitudes towards renewable energy demand to control CO_2 emissions, interconnections within complex systems skills to solve environmental problems, better usage of water and electricity and recycling paper and plastic, mainstreaming sustainable healthcare to develop climate change attitude, public support for climate policy, climate change and energy issues to develop helpful thoughts, feelings, and actions, environmental attitudes towards perception of bees to reduce loss of biodiversity.

5. Discussion

The studies included in this review cover topics in education related to SDG 15, including environmental education, eco-citizenship, climate change, ecology, and environmental sustainability. The aim of this systematic review was to answer the following research questions: RQ1: "What does the literature reveal about the digital tools used for environmental awareness and education?", RQ2: "In what way does the use of digital tools affect students' scientific knowledge of environmental issues?", and RQ3: "What role can digital tools have in the fostering of sustainability awareness among learners?". Despite the availability of reviews linking the role of using digital tools for sustainability awareness, this paper explicitly uncovers the direct outcome of using digital tools to foster students' environmental education and environmental sustainability awareness.

5.1. State of the Art of Digital Tools for Fostering Environmental Awareness

Results show that different digital tools are used to teach environmental education topics to foster awareness about sustainable development. In fact, according to Suarez et al. [67], environmental education can be both education for sustainable development to foster awareness and education about sustainable development using education as a tool to achieve sustainability. In this context, the included research focused on different digital tools to achieve SDG 15, out of which Information and communications technology (ICT) and interactive multimedia, including extended reality (VR/AR), video games, video learning, mobile applications, e-books, and online learning are being used. Utilizing the potential benefits of ICT, according to Khalifé et al. [12], is urgent to develop students' sustainable development competencies. Dave et al. [18] found ICT to be an effective teaching tool in enhancing students' environmental awareness. The descriptive statistics of our systematic review show that VR technology is mostly used in the field of environmental education. Queiroz et al. [46] underlined the potential of VR in fostering knowledge gains and self-efficacy in learning. Indeed, Immersive environments such as VR and metaverses are now broadly used in the field of education and training [32]. Barsalou [68] demonstrated the important role of body movements in learning, as it creates environmental attachment on both social and psychological dimensions [69], and therefore inducing behavioral and attitude change [70]. Previous research supports the link between virtual reality, embodied cognition, human learning, and interactions with a human avatar, allowing the identification of the user; based on that, several cognitive sub-processes are involved in the very complex self-identification. These benefits are generally explained by a higher degree of immersion [33] and engagement [34] in learning situations in VR compared to non-VR, thanks to a stronger embodied experience [35]. For example, individuals expressing themselves through physical objects [71], or interaction with a human avatar calls for empathy [72]. Mental and motor imagery, observation of action, and embodied cognition are indeed part of the components of empathy: we perceive others through our own embodied cognition [73]. Students who are empathic in environmental education use it to form a connection to nature and to develop a sense of responsibility for the environment [74], just as they would in forming a strong connection with nature. Thus, the first H1 hypothesis proposing that: "Virtual reality environments are significantly used for education in environmental awareness, thanks to empathy, sense of presence and immersion" is accepted.

The findings of this study reveal a possible link between climate change learning and using VR, as findings revealed that both VR tools and climate change topics are the most trending in this research field area. This differs from the previous review by Fauville et al. [13], where the findings indicated a greater focus on visual representation, such as virtual laboratories. This change in the use of technologies can be an effect of previous research outcomes, which show that students have difficulties making connections between experiences in virtual laboratories and their experiences in everyday life (see, e.g., [40]. Furthermore, the lack of using senses to perceive physical properties in a virtual laboratory make the learning experience less complete in comparison to immersive learning such as VR and AR. Thus, the use of environments such as VR and AR seems to be an upcoming answer to these issues since it creates rich sensory and emotional experiences [33–35]. Studies have found that the optimal way to promote sustainable behavior change and awareness is to trigger students' emotions [75]. Therefore, the results of our study manifest previous findings by Dubé et al. [14] and their prediction of VR as an emerging technology in education. Hence, H4, which states that "immersive environmental learning fosters better environmental learning and awareness." is accepted.

5.2. Digital Tools Can Promote Learning in Environmental Education

Since environmental education is important in fostering awareness about sustainable development [67], increasing student knowledge in EE is relevant. Results from this review showed that studies that sought to investigate student's EE learning outcomes resulted in drawing positive direct and indirect links between using different digital tools and an increase in learning outcomes or knowledge acquisition in environmental education. Consequently, the H2 hypothesis proposing that "Using digital tools leads to efficient learning and performance in EE topics" is accepted. Herbert [76] suggests that digital tools can stimulate knowledge acquisition by fostering better incorporation of natural phenomena and information integration about EE, as well as providing students with an intuitive environment beyond the human scale. According to the project "Learning tree" [77], an increase in environmental knowledge significantly correlates with an increase in conservation behavior as well as a significant pro-environmental one: "the more people know, the more likely they are to recycle, be energy efficient, conserve water, etc." [77]. Tarng et al. [23] found that digital tools could increase students' enthusiasm for learning and interest in environmental education. Ramasundaram et al. [24] suggest that while virtual field labs may lack real-world experiences, they are a good complement to existing courses fostering environmental knowledge with more incorporation in the environment and are not intended to replace field experience as aforementioned in the literature. Thus, students learn environmental issues and maintenance better using digital tools, as they feel enthusiastic and engaged.

5.3. Digital Tools Can Foster Sustainability Awareness

The research identified in the area of digital tools for fostering students' sustainability awareness, particularly in environmental education, has shown the potential of technology to be used in sustainability education contexts. The findings suggest the potential of using digital technology to develop students' awareness of climate change, biodiversity conservation, pollution prevention, sustainable development, and environmental policy. These latter fall under the environmental education scope according to environmental education—benefits, importance, objectives, and scope. This review also shows positive outcomes in terms of digital tool design to help enhance students' sustainable behavior and concerns about climate change effects, glaciers' importance, ocean acidification, and marine environment, as well as developing concerns about the preservation of biological resources such as flora, fauna, animals, ecological system, and atmosphere. Thus, the H3 hypothesis proposing that "using digital tools for teaching EE fosters sustainability awareness among students" can be accepted. These results confirm that the incorporation of digital technologies into teachers' training and practice to promote SDG awareness among them and their students [11] was successful. According to Lay, using digital technologies is key to fostering students in environmental stewardship. Moreover, outcomes from the included articles in this review show that it is possible to increase students' awareness about renewable energy and recycling using digital tools, as well as about the importance of economics and political strategies for sustainable climate support policy. These findings fall under the triple bottom line categories referred to as the triple "P's" standing for "people, planet, and prosperity" developed by the United Nations, which are essential components for sustainability (2015) [1]. Thus, digital tools can ensure attaining the United Nation goals in attaining sustainability through "people, planet and prosperity".

Although this review focuses on the role of digital technology in fostering sustainability awareness through education, one must be aware of the negative impacts of ICTs on the environment. Indeed, ICT tools, according to Mahdavi et al. [78], can improve energy efficiency, as it contributes to reducing CO_2 emissions and the degradation of the environment, but manufacturing and using digital devices can constitute a major cause and source of gas emissions. According to Mahdavi et al. [78] digital devices also constitute a major cause of environmental damage as their body structures often contain non-recyclable and non-renewable components. Nevertheless, by utilizing digital technologies, environmental conditions can also be more easily managed, and participation in management can be extended widely. According to Aristia and Salehin [79], carbon capture and mitigation is made possible by blockchain technology, which promotes eco-friendly supply chain transparency. Thus, green information technology (IT) use can offer a solution to combine digital and environmental sustainability, and it is through awareness that eco-friendly technology can be adopted to ensure a green future.

The review was narrowed by aspects such as the limiting aspects in the included studies' data availability allowing us to classify digital tools according to their efficiency in fostering sustainability; the lack of tool information datasets allowing the elaboration of a list including the application name used in each study; the diversity of the studies' assessment tools limiting the ability to explicitly compare the use of each digital tool type on students' EE outcomes, awareness, efficiency and digital skills; the scarcity of research articles revealing the effect of digitalization on students' long term sustainable competence behavior and practices; the scarcity of articles tackling environmental education in which authors explicitly show the link between digital EE learning and sustainable development goals.

The results of this review can help researchers and teachers find the appropriate digital tools to be used in future research investigations or in formal and informal educational settings to promote students' sustainability awareness in relation to the sustainable development goals, especially Goal 15. In addition, despite the limited findings of this review, this study can help to provide a theoretical background to this area of research, as it will guide future research into the potential of digital tools in shaping environmental education. For example, embodied cognition [35] can provide a relevant theoretical framework for investigating the effects of digital immersive environments such as VR and AR in raising awareness of environmental issues and sustainability by allowing learners to be virtually present in scenarios involving environmental disasters or in natural settings that are otherwise difficult to access or observe naturally.

This systematic review was conducted using descriptive statistics and qualitative assessment of previous research findings. However, conducting a meta-analysis based on quantitative statistical tests in the same field may yield richer results on the efficiency of tools and highlight links between EE themes and different types of digital tools and devices. For future work, we suggest broadening the research criteria to include all tools used in EE, with or without an explicit focus on students' sustainable behavior change. In addition, we suggest conducting further studies to identify the type of student behavior and contribution that is fostered by the use of digital tools for EE. Furthermore, we suggest using new keywords revealed by this research, such as the type of digital tools advanced or EE topics in which research has been conducted in this area of interest. Furthermore, this literature can be complemented by other works that address other sustainable development goals, such as in the industrial, economic, and citizenship fields. In addition, it would be relevant to study the links between the level of education (school, university, lifelong learning) and the environmental awareness brought by digital tools. Another recommendation is to shed light on students' technology behavior, as it can be both environmentally beneficial and damaging. Future research should focus on using digital tools to balance both their positive and negative impact on the environment and foster students' awareness to switch to devices and products that use renewable energy to reduce carbon emissions.

By incorporating multimedia, gamification, and simulations into sustainability education, technology can enhance it and make it more engaging and interactive. Digitalization and emerging technologies are promising future trends that play a key role in education for sustainable development (ESD) by influencing and evaluating learners' behavior. It is suggested that sustainability be measured qualitatively along with environmental motivation and behaviors to endorse students' environmental contribution and awareness. Alongside, improving learning outcomes strategies about environmental threats in immersive interactive conditions is highly encouraged using the embodiment learning method.

6. Conclusions

The paper provides a fuller discussion of the relevant research context, particularly in relation to the need for sustainable development as presented by the international community, and the impact of new technological developments on education. This review provides a more comprehensive overview of relevant theories and perspectives. In this review paper, we emphasize the importance of fostering sustainability awareness among students through education, as this plays a major role in raising concerns about environmental issues. The findings indicate a positive impact of the use of digital tools on students' environmental knowledge and sustainability awareness. The results also show that VR tools and climate change issues are the most trending in this area of research. The use of immersive environments, such as VR and AR, is attributed to increased immersion and engagement, which results in a more powerful embodied experience than non-VR settings. Students can use multiple senses to also perceive physical properties, creating rich sensory and emotional experiences [33–35]. This provides them with a more complete experience, which promotes learning in EE and fosters sustainability awareness.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16093733/s1, PRISMA Checklist.

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