Research Article

USE OF REPRESENTATION TECHNOLOGY FOR THE EDUCATION FOR SUSTAINABLE DEVELOPMENT: A SCOPING REVIEW

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Abstract

Representation technology is used to deliver teaching content in different formats due to robust technological development, thereby enabling learners to receive information based on dynamic, virtual and sensory expression, which assists them to construct new knowledge in the learning process. The aims of this scoping review are to explore the application of representation technology in the education for sustainable development and to generate an understanding of its impact on teaching and learning. The review is constructed using the six-stages framework of Arksey and O'Malley, and the results indicate that virtual reality, scenario games, 3D modelling and a user-generated content platform are the frequency formats of representation technology required for teaching and learning education for sustainable development. Moreover, a learner-centred and experience-based learning environment is crucial for students to gain a deeper understanding of sustainable concepts and environmental issues. These formats improve the collaboration between environmental issues and higher education, thereby positively affecting students' awareness of the real world. Future researchers could investigate the opportunities and barriers to applying representation technology from a teaching perspective. Moreover, different genders' perception of learning based on representation technology could be examined to contribute to students' effective learning.

Keywords: Representation Technology, Education for Sustainable Development, Teaching and Learning, Scoping Review

Introduction

Education for sustainable development (ESD) is an emerging component of educational institutions due to dramatic economic, social and environmental changes. The aim of ESD is to cultivate responsible global citizens, who can identify sustainable development issues and apply multidisciplinary thinking to promote ecological and environmental sustainability (Buckler & Creech, 2014; Hensley, 2020; Howlett et al., 2016). Higher education institutions implement ESD in the curriculum and academic activities to encourage students to be global citizens with a great sense of sustainable development (Dan, 2010; García-Feijoo et al., 2020). However, despite the heightened awareness of ESD, there are still gaps in this teaching and learning approach. Previous researchers

have maintained that embedding ESD in the curriculum is considered to be the core of pedagogical innovation (Henderson et al., 2019; Mintz & Tal, 2018; Storey et al., 2017) that enables teachers to deliver content in a way that cultivates students' sense of sustainability. Therefore, representation technology based on rapid technological development is now being widely used to teach and learn ESD in various formats.

Representation technology is a medium that enables learners to receive information and knowledge and mentally link it to the relevant domains of previous knowledge to construct new content (de Jong, 2014; Vahey et al., 2020). Representation technology has rapidly evolved from a two-dimensional form to dynamic 3D expression based on the application of software programmes, such as 3D modelling and animation, that enhance visual content. Dynamic representations like web-based interactive teaching tools and applications for mobile devices enable learners to interact with the learning process (de Jong, 2014). Furthermore, reified objects and haptic experiences have been developed and applied in the educational environment (de Jong, 2014). For example, Liu et al.'s (2018) developed an electrostatic feedback device called a fruit sorting game, which combines a touchscreen with tactile feedback, thereby succeeding in increasing effective communication and intuitive manipulation for a brainstorming discussion. Sensory augmentation tools have been integrated with traditional classrooms to create an interactive environment, such as SMALLab, which increases students' engagement (SMALLab Learning, 2021). The development of representation technology ensures that the learning process is influenced by dynamic, visual and sensory expression so that the implementation of different forms of this technology generates a constructive knowledge process, as well as enhances the effectiveness of teaching and learning. On the other hand, according to de Jong (2014), although representation technology brings new opportunities for learning, some pitfalls are also emerging in terms of whether the application of this technology provides an impetus for pedagogical innovation in face-to-face classes or distance learning. ESD researchers emphasise the need to redefine these two ways of learning in view of the COVID-19 pandemic (Quay et al., 2020); therefore, the aim of this study is to examine the effect on students' learning of the implementation of representation technology in ESD.

Research Methodology

Scoping reviews are increasingly applied as a guide to identify and summaries literature on education (O'Flaherty & Phillips, 2015), and Davis et al.'s (2009) maintain that a scoping review is an effective method to clarify concepts and identify primary and secondary literature. According to Arksey and O'Malley (2005), the purpose of a scoping review is two-fold. Firstly, it is used to produce a full systematic review based on examining the extent, range and nature of the research activity in order to determine the study's value and secondly, it enables the research findings in a particular field to be published and disseminated by identifying gaps in the existing literature. This study is based on the scoping review methodology of Arksey and O'Malley (2005), which consists of a framework containing the following six stages: 1) identifying the initial research questions; 2) identifying relevant studies; 3) selecting studies; 4) charting and collating the necessary data; 5) summarizing and reporting findings; and 6) enabling consultation (optional).

1. Identifying the initial research questions

This study will be based on mapping the existing work in relation to the application of representation technology to the education for sustainable development with the aim of emphasizing its various benefits to students. Additional aims are to facilitate an understanding of the influence of representation technology on students' learning outcomes and to contribute to improving their learning experience. Therefore, the research questions are as follows;

1) What representation technologies are used in the education for sustainable development?
2) What teaching and learning approaches are used in this context?
3) What are the effects of representation technology on students' learning?

2. Identifying relevant studies

Key concepts and search terms were developed based on the research questions in order to identify the relevant literature with the aim of achieving a comprehensive and feasible study. The key search terms that provided a clear path for this scoping review are shown in Table 1.

Table 1 Key search terms

Search terms
('Representation Technology' OR 'Education Technology' OR 'Digital Technology') AND ('Sustainable Development' OR 'Education for Sustainable Development) AND ('Learning Environment')

The search strategy for identifying the relevant literature was applied to the electronic database of ScienceDirect. This strategy was based on the inclusion of three criteria. Firstly, studies from 2016 to 2020 were chosen as contemporary sources because the research of ESD reached one of its peaks in 2016 (Grosseck et al., 2019) after the establishment of a global action programme (GAP) by the United Nations Educational, Scientific and Cultural Organization (UNESCO) to promote ESD in 2015. Moreover, Rowley and Slack (2004) define contemporary sources as those that were published in the previous five to seven years. Secondly, only studies in the English language were included due to the cost and time involved in translating foreign languages. Thirdly, only original research and peer-reviewed journal articles were included. The inclusion criteria are listed in Table 2.

Table 2 Inclusion criteria

Criteria	Inclusion
Time period	2016 to 2020
Language	English
Type of article	Original research, published in a peer-reviewed journal

3. Identifying relevant studies

The key search terms yielded 1100 articles and those related to organization, policy, or industry development were excluded based on a review of the abstracts. Moreover, several studies were excluded due to the low-level reference to the research questions. 19 of the full-text articles obtained (n=121) were deemed to be

appropriate for analysis based on the inclusion criteria and research questions. The process of selecting these studies is illustrated in Figure 1.

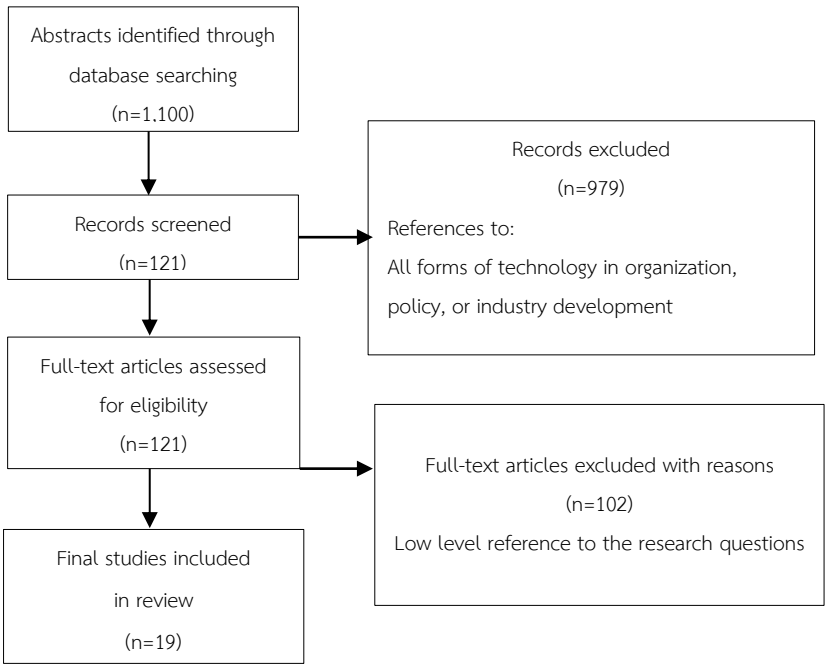

Figure 1 Flow diagram for study selection

4. Collating the selected data

The selected data was collated by author, year, location of study and study design, and a brief comment on the conclusions, limitations or recommendations of each study was also included (see Table 3).

5. Summarizing and reporting the findings

The findings were summarized and reported as shown in Section 3 and divided into four parts based on the research questions.

Results

This scoping review included the following 19 studies: 7 in Europe (2 in Germany, 1 in the United Kingdom, 1 in Spain, 1 in Greece, 1 in the European Union and 1 in Sweden); 3 involving multiple countries (1 in Italy, United Kingdom and Norway; 1 in the United Kingdom, Australia, South Korea and Colombia; 1 in the United States and Germany); 4 in North America (3 in the United States and 1 in Canada); 2 in Asia (China and Japan); 2 in Oceania (New Zealand and Australia); and 1 in Egypt.

1. What representation technologies are used in education for sustainable development?

1.1 3D representations and design studios

Design studios (or multimedia labs) that include 2D and 3D technology are used for the design and implementation of green sustainability. Students are required to propose the 3D modelling or forecast the environmental impact using a multi-agent simulation model in a real ecosystem (7, 8).

1.2 Dynamic representations of virtual reality (VR) and digital games

Technology that can engage students in a simulated, immersed, or scenario learning environment is frequently used in ESD. These resources include virtual field trips and scenario games that allow them to play a role in the community based on the storyline (1, 4, 13). Furthermore, digital games are becoming integrated with practical business events, such as supply chain management (2, 3, 18).

1.3 Dynamic representations of mobile applications and digital platforms

Mobile applications are used to deliver teaching content and for discussions (5, 6). In addition, a quick response (QR) code is a tool to link learning materials with websites and applications (17). Various kinds of digital platforms, such as cyberlearning, virtual libraries and learning management systems, are also utilized in many studies to create user-generated content and collaborative learning environments, with the objective of problem-solving or gaining a deeper understanding of the concept of sustainability (9, 10, 11, 12, 14, 15, 16, 19).

Table 3 Studies Included in the scoping review

(Study number) Author details, Year, Location	Use of representation technologies	Research design	Outcomes
(1) Schott, 2017, New Zealand	VR and digital game: 1. VR-based fieldtrip is applied for learning about climate change (illusion of a 3D space). 2. Digital game of “Second Life” source version is selected to create a virtual island.	N= 91 undergraduate tourism students. - Experimental and qualitative measures. - Assignment of a group project for fictional tourism consultants and government and individual reflective essays.	Shows advantages of virtual field trips compared to physical field trips, such as knowledge, vulnerability and a holistic and complex experience.
(2) Zarte and Pechmann, 2019, Germany	Digital game: Business game is used for teaching sustainable product service system. The game of “Christmas Production” is applied to provide a game environment.	Concept paper Three main tasks: firstly, prepare the ERP system PSS in a start-up firm. Secondly, plan and implement the ERP system processes. Thirdly, provide recommendations for the firm to increase its sustainable performance.	Example of extended version of the PSS business game is presented.

(Study number) Author details, Year, Location	Use of representation technologies	Research design	Outcomes
(3) Perini, Luglietti, Margoudi, Oliveira and Taisch, 2017, Italy, UKand Norway	Digital game: Digital game and real-time system are applied for learning about sustainable manufacturing. A lifecycle assessment (LCA) game is developed based on an online application.	N=265 university students serve as users. - Game-based learning approach. - The main task of the game is to link with ISO 14044, which includes the objectives of an inventory analysis, product lifecycle, environmental load and impact assessment.	Digital game presents the benefits of providing proactive feedback on learners' actions, reality, variety and interdisciplinarity learning environment, especially the high interaction when collaborating to complete different tasks.
(4) Chan, Chan, Agnes, 2020, China	Digital game: Scenario game is used for ecotourism education. The game simulates an indigenous community where participants can play a role based on the storyline.	N=66 undergraduate students. - Quasi-experiment and survey. - Game-based learning approach and real-world example. - Survey applied to examine students' learning outcomes.	- Discussion is an effective component of a game-based learning approach. - Scenario game participants show a significant attitudinal change compared to the discussion group. Notably, players' self-efficacy increases when the game provides more variety of options.
(5) Winfree, Goldacre, Sherkat, Graham, Mendoza and Miller, 2017, Australia	Mobile application: Mobile application for learning sustainability, energy efficiency, and carbon mitigation.	N=3 teachers and 1 senior level trade education representative. - Qualitative method and engagement approach. Interviews were conducted to understand the use of mobile devices for teaching and learning.	reality are emerging methods for increasing the connection between knowledge and industrial activities.
(6) Andrachuk, Marschke, Hings and Armitage, 2019, Canada	Mobile application: Smartphone application	- Systematic scoping review - Community- and citizen-based. - To examine the use of smartphone technologies for community and citizen science environmental monitoring.	Stimulating app-based discussions has the positive effect of engaging users when applied to teaching or learning due to the direct feedback from users. For example, users of birding apps sought bird species and generated relevant information. iNaturalist and eBird are the popular apps for community and citizen science.

(Study number) Author details, Year, Location	Use of representation technologies	Research design	Outcomes
(7) Dabaieh, Lashin, Elbably, 2017, Egypt	3D and design studio: 1. Design studio is used for teaching green sustainable design in architectural higher education. 2. The components of design studio include 2D drawings, 3D models and an urban living lab.	N=3 different test cell models - Explanatory analytical and descriptive approach. - Experience-based learning environment - Students need to submit a final project designed as a proposal using 2D and 3D modelling.	- The design studio not only assists students to apply principles in a practical project design, but also to think creatively. - Although experience-based learning has the benefit of connecting theory and practice, 53% of 54 respondents stated that it was not necessary to be familiar with local building materials or local culture.
(8) Klimova, Rondeau, Andersson, Porras, Rybin and Zaslavsky, 2016, European Union	3D: WebQuest, 3D model and video are used in environmental protection and sustainability degree programmes.	Research report	The use of WebQuest and a 3D model tool supports a virtual environment, which is a significant cognitive advantage and facilitates an understanding of inter-related ecological issues. Undergraduate and postgraduate students showed a significant improvement in their learning of theoretical concepts by video.
(9) Raoufi, Park, Khan, Haapala, Psenka, Jackson and Kim, 2019, US	Digital platform: Cyberlearning platform is used for sustainable product design. CooL:SLiCE platform is created so that students can visualize and analyze the effect of product design.	Pilot study n=5 postgraduate students and 1 undergraduate student. - Constructionism learning approach. - The task of designing and considering the sustainability of a virtual prototype of a drone.	CooL:SLiCE platform provides users with a deeper understanding of the concept of sustainability by visualizing a product and presenting information of its carbon footprint, evaluating its environmental impact and cost of manufacture. A visualization module also shows the advantage of communicating ideas within the team.

(Study number) Author details, Year, Location	Use of representation technologies	Research design	Outcomes
(10) Hardin, Bhargava, Bothner, Browne, Kusano, Golrokhian, and Agrawal, 2016, US	Digital platform: Cyberlearning platform is used for sustainability cases creation. A Gala platform is developed so that users can exchange, update and revise information of sustainability cases. Moreover, formats of podcasts, videos, blogs, infographics and maps are available for publishing cases on a Gala platform.	Pilot study of undergraduate and postgraduate students, n=40 - Quantitative assessments and qualitative survey - A case-based approach was applied for problem-driven, solution-orientated and experiential learning tool. - Students need to create sustainability cases to be used for course content.	Students show an in-depth understanding of knowledge and another learning outcome was improved test scores. Communication, analytical content and professional networking skills are also practiced in the creation of the case. Moreover, students showed a positive learning experience using this approach and felt they could control the learning pace. This case-based approach through a cyberlearning platform is a good example of classroom flipping and the ability to link experiential learning inside and outside the classroom.
(11) Wersun, Dean, Mills, Perkiss, Acosta, Anastasiadis and Mesicek, 2019, UK, Australia, South Korea and Colombia	Digital platforms: 1. A collective awareness platform is used to understand companies' environmental, social and governance performance. 2. WikiRate is used for cultivating student knowledge, skills and attitudes and developing a sustainability mindset.	N=1575 undergraduate and postgraduate. Online survey and coding themes. - Collaborative and participatory approach. - Students need to collaborate in a WikiRate project to generate a case.	Students show extended knowledge, skills and attitude as follows: 1) knowledge of CSR concepts, disclosure practices and how CSR affects the company; 2) Research skills, analytical and critical thinking, decision-making and translation skills; 3) attitude toward responsibility for global issues and consumer or personal sustainability. The use of WikiRate is shown to have an impact on students' sustainability behaviour, as well as their perspective of collaboration in this project.

(Study number) Author details, Year, Location	Use of representation technologies	Research design	Outcomes
(12) Mora, Pujol-López, Mendoza-Tello and Morales-Morales, 2020, Spain	Digital platform: A virtual collaborative library is designed to learn about sustainable development.	Paper Concept - Problem based learning (PBL) method. - Students can create their own virtual library and sharing material.	The aim of this activity is to teach students about sustainable development and cultivate their self-learning, communication and problem-solving skills in real life.
(13) Schneider and Schaal, 2018, Germany	Digital game: A location-based smartphone game is applied for the education of sustainable development and biodiversity. A Geogame is developed for nature conservationists, environmental psychologists and environmental education practitioners as a framing narrative	N=59 vocational college students. - Pre-post-design with the intervention of two different game formats: treasure hunt and Geogame. - Location-based outdoor tasks. - Students participate in a school trip in which interventions are embedded for environmental education.	The 3- and 5-day interventions both show the positive effect of fostering the connection to nature. The inclusion of nature in self (INS) significantly increases the connection. However, personal references are not significant in both interventions. No significant difference in the results of applying the treasure hunt and Geogame.
(14) Kuribayashi, Hayashi and Akaike, 2018, Japan	Digital platform: A public platform is used to develop a foresight approach with sustainable development goals (SDGs). Future public platform (FPP) is to be established, with applications of scenario and gamification elements in foresight.	Paper Concept - A Delphi survey is conducted every five years. - Users can discover the scenarios of sustainable development in the short-, mid and long-term future.	The aim of an FPP is to provide the public with accountable and transparent sustainable development information as stakeholders.
(15) Caniglia, John, Bellina, Lang, Wiek, Cohmer and Laubichler, 2018, US and Germany	Digital platform: Video conferencing tools, learning management systems, online publications and workspaces are used for transnational collaboration in sustainable development.	Pilot project - Student-centred and project-based approach. - Students collaborate in problem and solution-orientated research projects for sustainability in different urban contexts.	Transnational collaborative, intercultural and professional competencies for sustainability are essential factors to consider for future curriculum reform.

(Study number) Author details, Year, Location	Use of representation technologies	Research design	Outcomes
(16) Pearce, Grafman, College and Legg, 2019, US	Digital platform: 1. A networking platform is applied to build an understanding of collaboration in entrepreneurship and sustainable development.	Teachers can use OSN to construct the teaching content and discover opportunities to collaborate.	Using OSN for sustainable development is beneficial for service-learning collaboration and knowledge infrastructure.
(17) Kalogiannakis and Papadakis, 2017, Greece	Mobile application: Quick response (QR) codes are used for environmental education. OR codes are linked to websites with relevant learning material.	N=24 control group and 26 experimental group. Mobile learning and didactic approach. The intervention uses QR codes in outdoor and indoor activities.	The results of the experimental group were significantly different from those of the control group, who show increased environmental knowledge and high learning satisfaction. This study is limited in terms of its ability to convey the exact information of activities and questions for students.
(18) Mercer, Kythreotis, Robinson, Stolte, George and Haywood, 2017, UK	Digital game: A game is applied to promote sustainable behaviour. The Gummy bear supply chain (GBSC) game is developed to evaluate the product impact.	N=57 university students. - Questionnaire. - Constructionist approach and student-led creation pedagogy. Students need to create the content of the game.	Students feel greater responsibility for the local community. Moreover, based on the questionnaire results, using a game as a tool has a positive effect on learning about sustainability.
(19) Chin and Jacobsson, 2016, Sweden	Digital platform: A public platform is used to provide ESD. A mobile-first technical platform, TheGoals.org, is created to support users in learning.	Project report - Engaging and problem-solving pedagogies. - Users can share their ideas of solutions of SDGs on the platform.	Collective intelligence to solve problems related to sustainable development can be attained through this platform.

2. What teaching and learning approaches are used in this context?

The studies in the scoping review present the general use of a group project for final evaluation based on student-centred learning approach (1, 7, 9, 11, 15, 19). The main learning objectives in the teaching content were

digital game-based learning with the design of practical content, such as sustainable performance management, ISO and product lifecycles (2, 3, 4, 13, 18), while the community-based learning approach was applied to create an experience-based environment for students (6, 13, 7). The design of a case-based method was used to create the learning content to construct students' knowledge or concept of sustainable development (10, 11, 18, 19).

3. What are the effects of representation technology on student learning?

Most studies use technology to improve students' engagement with learning and higher-order thinking, such as problem-solving (10, 12, 15, 19) and interdisciplinary thinking (3, 4, 6, 18). VR technology can enable students to develop their cognitive skills and receive a holistic and complex learning experience by providing an immersive learning environment (1). Digital games and platforms commonly provide benefits, such as real-time feedback, effective communication, networking collaboration and intercultural competencies (3, 4, 6, 9, 10, 11, 12, 15, 18).

Discussion

This section contains a further discussion of the current knowledge of the benefits of using representation technology in the education for sustainable development. Kirkpatrick's four levels of learning evaluation model is applied to analyze the effect of these technologies on students' learning (Smidt et al., 2009).

1. VR, simulation, digital games and a collaborative network

A virtual field trip was applied in one study and compared with a physical field trip to highlight the advantages of a holistic and complex environment (1). This implementation also illustrated the importance of using VR technology during the COVID-19 pandemic, which has dramatically changed the teaching and learning environment. Educators must rethink the delivery of face-to-face classes and link them to an outdoor environment with a new type of distance field trips (Quay et al., 2020) and VR technology may become a new visual narrative style to deliver these courses. Digital games with VR or simulations have been shown in various studies to provide students with an action-orientated experience, which indicates a trend in ESD (1, 2, 3, 4, 13, 18). Schott (2017) applies VR and digital games to create an experiential learning environment, which becomes a primary tool to extend the learning content outside the classroom so that students can experience the different challenges of climate change without actually travelling. The interaction of VR and digital games has been proved to be beneficial for increasing students' awareness and understanding of environmental issues. Chan et al.'s (2020) focused on exploring the effectiveness of using a scenario-based simulation game in the education of ecotourism. The game involves building a simulated story of an indigenous community and students must play a role in this community and make decisions that affect its sustainable development. The integration of simulation and the digital game substantially increases students' knowledge of sustainability and self-efficacy compared to a discussion session teaching method. Using games in education that involves the application of experience-based learning, such as ESD, can provide students with opportunities to participate in particular events linked to ESD goals (Chatzifotiou et al., 2007). The adoption of digital platforms and the significance of network collaboration were mentioned in most of the reviewed studies (9, 10, 11, 12, 14, 15, 16, 19). Digital platforms do not only play a role in learning management, but also in building a professional network, such as a connection between lecturers, students and local communities

or other educational institutions. This finding can be used to establish cooperation in projects between different universities.

2. Learning experience

The learning evaluation model proposed by Kirkpatrick and Kirkpatrick (2006) consists of four elements, namely, reaction, learning, behavior and results. This model was used in the scoping review in this study to provide an overview of the effect of representation technologies on students' learning, as shown in Table 4.

Table 4 Overview of the effect of representation technologies on students' learning

Outcome	Number of Studies
Level 1: Reaction	(5, 6, 7, 13, 14, 17)
Level 2: Learning	(3, 4, 7, 8, 9, 10, 12)
Level 3: Behavior	(10, 12)
Level 4: Results	(18)

Firstly, students were seen to be highly engaged and satisfied with learning based on the use of representation technology. However, it was indicated in one study that the students failed to understand the importance of learning the local culture before creating a green sustainable design. This points to a need to convey and introduce the concept of sustainable management in the course so that to enable students can perceive its necessity. Secondly, besides learning theoretical concepts, the enhancement of their problem-solving and creative thinking skills has a positive effect on students' learning and this also improves their cognitive knowledge of ecological self-efficiency. Thirdly, it was found in one study that students' self-learning of sustainable development is cultivated using a collaborative virtual library. This finding may be considered to be an effective tool for increasing students' autonomy in a virtual learning environment. Fourthly, learning using the constructionist approach results in a change of behavior among students due to increased responsibility in the local community. This finding indicates that the constructionist approach may be an effective pedagogy to use when applying representation technology to the learning of sustainability.

Conclusion

The key advantages of using representation technology for ESD and the effects on students' learning were identified in this scoping review. ESD requires a learner-centred and action-orientated approach to inspire students to change their knowledge, values and attitudes in ESD (Rieckmann, 2017). Representation technology increases educators' opportunities to deliver effective teaching content to students in the form of virtual trips, scenario games and cyberlearning platforms. These formats greatly improve collaboration between environmental issues and higher education, which has a positive effect on students' awareness of real-world sustainable issues. The limitation of the study is its focus on students' perspective. The barriers to applying representation technology to classes from the teachers' perspective also need to be considered as a factor that influences the effectiveness of teaching and learning. Teachers' competency for implementing technology into their teaching approach should be developed (Cortes, 2019). Hence, it is suggested that future researchers should investigate the barriers to the successful

application of representation technology from teachers' perspective. Moreover, the different perceptions of learning using representation technology based on gender can also be considered in future research in order to create the ultimate learning environment.

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