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ORIGINAL RESEARCH

3D Multiuser Virtual Environments and Environmental Education: The Virtual Island of the Mediterranean Monk Seal

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Abstract
The study presents the results from a project in which a 3D multi-user virtual environment was used for informing students on issues related to the protection of the Mediterranean monk seal. The target group was 326, 10–12-years old students divided into three groups. The first one was taught using printed material, the second used a web-based application, and the third used the virtual environment. Data were collected by means of evaluation sheets and three questionnaires for recording students' views and attitudes. The third group of students had better learning outcomes compared to the first, but the results were inconclusive compared to the second. Then again, the MUVE had a notable impact on students' attitudes toward seals compared to the other tools. As for attitudes toward eco problems, the outcomes were better only compared to the first group. Moreover, fun and an increased motivation for learning were evident in the third group but co-existed with significant problems related to the use of the virtual environment. The findings point to the need for further examination of the use of multi-user virtual environments for raising the awareness of environmental issues.

Keywords 3D multi-user virtual environments · Environmental education · Mediterranean monk seal · Primary school students

1 Introduction

As active and well-informed citizens we are expected to understand and participate in the resolution of important environmental issues since they are vital not only for our future well-being but also for the future of our planet. Such issues that seek an immediate solution are the alarming loss of biodiversity and the conservation of species that became endangered due to human activities. Environmental education (EE) can play an important role in raising the public's awareness of environmental issues (including the protection of species threatened with extinction). That is because, through EE, one can acquire knowledge,

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skills, values, experiences, and the determination to act for solving environmental problems (Stevenson 2007).

A species threatened with extinction and of interest to Greeks is the Mediterranean monk seal (Monachus-monachus). Nowadays, Greece's seas host almost half of this species worldwide—diminishing—population. Alas, in formal educational settings, all courses in the Greek curriculum for primary and secondary education considered, there are no more than a couple of paragraphs related to this animal. There are organizations (exclusively non-governmental) which systematically try to educate the public on issues related to this marine mammal, but they do so in informal or non-formal educational settings. Also, the bulk of the available educational resources are—somehow—limited to printed material and websites.

Contemporary educational practices try to take advantage of technologies which promote self-motivated and autonomous learning, foster critical and reflective thinking, and allow learners to seek and share information (Dabbagh and Kitsantas 2012). The evolution of 3D multi-user virtual environments (MUVEs), a sub-genre of virtual reality (VR), has outlined novel means that can be exploited in education. Research on the use of VR/MUVEs in diverse educational settings and subjects is quite extensive and has demonstrated that the educational benefits are considerable (e.g., Merchant et al. 2014). The same applies to EE, because virtual environments, in addition to helping the learners to acquire knowledge, have a positive impact on attitudes, values, and skills, which are considered important in EE (Quinn and Lyons 2013).

Taking into account that: (a) innovative methods are needed for raising students' awareness of environmental issues and, more specifically, on issues related to the Mediterranean monk seal and (b) MUVEs have an interesting educational potential, a project, that was based on the results of a previous pilot study (Fokides et al. 2017), was designed and implemented in order to study exactly this. The research objective was two-fold: (a) to compare the learning outcomes with other teaching tools and (b) to examine whether there is a change in students' attitudes either toward the Mediterranean monk seals or toward eco problems, again in comparison with other teaching tools. Students' views regarding the use of MUVEs were also considered important. The rationale, methodology, and the results of this project are presented and analyzed in the coming sections.

2 Environmental Education, Education for the Conservation of Species, and the Mediterranean Monk Seal

In short, EE is the sum of organized efforts to inform the learners on how the natural environments function and to help them develop behaviors that will enable them to treat the ecosystems in a sustainable manner. EE is a multi-disciplinary educational field in which sciences such as Geography, Chemistry, and Physics, meet the social sciences and humanities, while its main topic (the environment) is certainly one of the most complex learning subjects (Fauville et al. 2014). Given that concerns regarding major environmental issues, such as the climate change, are growing steadily and receive quite a lot of publicity in the mass media, the interest in EE has also been growing strongly over the years (AGEDI 2016).

The general idea is that, through EE, one can reach a deeper understanding of the need to (a) balance protection and development (Tisdell 2013) (b) solve current problems and (c) avoid new ones (Buckler and Creech 2014). Due to the above, the objectives of EE are not limited to knowledge acquisition. Indeed, more important objectives are the individuals to (a) be aware and sensitive to the environment and its problems (b) change their attitudes and be motivated to actively participate in environmental protection (c) develop skills for identifying environmental problems, and (d) to work toward the resolution of environmental problems (UNESCO 1978). Consequently, in recent years, besides trying to determine how to foster the development of positive attitudes and behaviors toward the environment, much of the research in EE focused on investigating the processes that will enable everyone to develop the capacity to (a) think critically, ethically, and creatively when assessing environmental situations (b) make informed decisions, and (c) act in ways that sustain the environment (Wals et al. 2014).

EE can take place in formal settings but also in non-formal and informal ones, such as programs offered at national parks (Miller et al. 2013). Regardless of the settings, there is a consensus in the literature that individuals benefit significantly when participating in EE activities (Hill 2013). Although in the European Union, EE is compulsory in primary and secondary education, it is implemented differently in each member state. For example, in Sweden, there is a range of specialized environmental study courses (Skolverket 2011), in Denmark, an interdisciplinary approach is taken, while in other countries it is embedded in science or geography curricula (Fauville et al. 2014). Sadly, in Greece, EE is limited to good intentions and objectives articulated to the Greek program of study for primary and secondary education, as it exists only as an activity undertaken by individual educators on a voluntary basis (Flogaiti 2005).

The protection of endangered species belongs to the broader issue of wildlife and biodiversity conservation, which, in turn, is one of the key environmental issues. As expected, a part of EE is dedicated to educating the public on such matters. Indeed, EE is regarded as an essential tool in the effort of safeguarding the planet's biodiversity (Jacobson et al. 2015). That is because it expands one's knowledge level on ecology, promotes positive attitudes toward the protection of the environment (Ehrhardt and Witham 1992), and because it supports the development of positive attitudes toward wildlife (Ballouard et al. 2011). Even though accurate information and the long-term retention of that information are important to quality wildlife conservation educational programs (Jacobson et al. 2015), it is important to stress that the protection of endangered species relies heavily on the attitudes of the public (Dickman 2010), because protecting certain species requires human intervention (Prokop and Fančovičová 2013). What is also important to stress is that such educational programs play a vital role in influencing the attitudes and behaviors not only of adults but of children too (Crudge et al. 2016).

Coming to Greece's endangered species two of them receive a great deal of media attention, the loggerhead sea turtle (Caretta-caretta) and the Mediterranean monk seal (Monachus-monachus) because both are present in Greece's seas. The latter is probably the world's rarest pinniped species (Karamanlidis and Dendrinos 2015). It is estimated that around 700 individuals survive; there are three small colonies in the Archipelago of Madeira, in Cabo Blanco Peninsula, and along the Moroccan and Algerian Mediterranean coast, while almost half of the total population can be found in the Ionian and Aegean Seas in Greece and fewer along the Mediterranean coasts of Turkey. Mainly humans, but also natural hazards, significantly reduced this mammal's population; deliberate killing by professional fishermen, accidental entanglement in fishing gear and strangulation, overfishing and illegal fishing, environmental pollution, expansion of the human activities to its natural habitat, extreme weather phenomena that threaten the newborns, and mortality due to epidemic diseases or from naturally occurring bio-toxins, are among the most common reasons (Murphy et al. 2012).

In Greece, MOm/The Hellenic Society for the Study and Protection of the Monk seal (https://www.mom.gr/mom) is a non-governmental, non-profit environmental organization actively involved in the conservation of this species. The Alonissos National Marine Park (https://alonissos.gr/en/marine-park/overview.html) and the National Marine Park of Zakynthos (https://www.nmp-zak.org/en) are also dedicated to this cause. These organizations are also greatly involved in raising the public's awareness of the seal's protection. This is done by using conventional means (e.g., through commercials on TV, radio, and the Internet, leaflets, brochures, and posters). In addition, there are training courses on selected groups of people associated with the sea (e.g., how to respond to emergencies where seals need help) (Notarbartolo di Sciara et al. 2009). In informal/non-formal settings, the above organizations implement several EE programs, but these are mainly based on printed material (e.g., textbooks and workbooks). Digital material (e.g., websites and eco-games), project toolkits, in-classroom activities, and activities that require the physical presence of the learner to a marine or a national park, are also available.

3 3D Multi-user Virtual Environments

Pan et al. (2006), defined VR as a technology in which graphics generated by computers and other devices immerse the user in an interactive, three-dimensional (3D), virtual world.Mikropoulos and Natsis (2011), focusing on the educational uses of VR, defined such environments as ones that are based on specific pedagogical models that incorporate or designate one or more subjects and provide the user with experiences that otherwise could not be experienced in the real world, leading to specific learning outcomes. VR is widely used in Mathematics, Physics, Architecture, and, in general, in fields pertaining to the study of natural phenomena (e.g., Freina and Ott 2015). A number of VR's features render it an interesting educational tool. For example, the 3D representation of the objects and the environment, facilitate learning by providing rich and realistic experiences to users (Harrington 2012). The game-like characteristics of VR applications lead to increased levels of fun and enjoyment when using them, and, in turn, these lead to motivation to learn (McLellan 2004) and to actual knowledge acquisition (Faiola et al. 2013). VR allows users to enter a mental state in which they act and feel as being "present" in the virtual environment and this has an impact on the learning outcomes (Bulu 2012). MUVEs, as the term implies, allow the simultaneous co-existence of multiple users at the same simulation. Therefore, the users can interact not only with the virtual objects but with other users as well. Social interactions, peer feedback, and collaboration between users within a MUVE have a positive impact on the learning process (Zheng and Newgarden 2011).

The affordances of MUVEs offer the means to implement contemporary pedagogical strategies. For example, the situated learning theory contends that the learning of skills and capacities cannot be abstracted from the context in which they are situated (Brown et al. 1989). Students should be engaged in activities that address authentic problems and help them to develop scientific reasoning preferably through discussions. MUVEs, are well suited for such learning by mimicking/simulating scientific phenomena or the context in which the targeted skills and practices are embedded (Dalgarno and Lee 2010). Moreover, complex tasks (e.g., an experiment) can be executed with just a few clicks while maintaining the features relevant to the task/problem visually prominent, thus, supporting novice learners (Kamarainen et al. 2015). Constructivism posits that knowledge is constructed rather than transmitted, that the learners generate their own interpretation and understanding of the world as they make connections between new and old information, and that active participation is central to the learning process (Ertmer and Newby 2013). Furthermore, constructivist views endorse an exploratory approach to learning, an increased control of the learners over their learning process, and collaboration either between peers or between peers and experts. MUVEs permit, by default, the free exploration of the virtual environment and communication between users. Thus, students can work together, explore the virtual environment, and collaboratively try to make meaning of the phenomena they encounter, resulting in improved content learning (Dalgarno and Lee 2010). As technology allows us to simulate scientific phenomena, simulation-based learning takes advantage of this. The simulated phenomena can be accurate representations of their real-world counterparts, or simplified ones, so as the focus to be on particular aspects; in any case, simulations can be far more complex than what is possible to realize in a real-world classroom (Rutten et al. 2012). Needless to say, that such simulations can be implemented in MUVEs. Not only that but as spatial and temporal scales can be altered, the virtual world can enhance one's understanding of processes which would otherwise be hard to grasp (Kamarainen et al. 2015).

The research on the use of VR/MUVEs in the context of EE, though not extensive, is quite diverse, as such applications were used for simulating ecosystems or environmental problems, having as an objective to offer information that may affect an individual's views for the real environment or to create the appropriate conditions for cultivating the desired environmental behaviors. For example, marine (Tarng et al. 2008), forest, and lake (Metcalf et al. 2018) ecosystems were simulated. MUVEs were also used for simulating problems in an urban environment (Quinn and Lyons 2013). Environmental sustainability (Dillahunt et al. 2008), the problems resulting from the over-exploitation of natural resources (Jacobson et al. 2009), waste management (Castronovo et al. 2018), water conservation (Hsu et al. 2018), and industrial ecology and environmental management (Eckelman et al. 2011), were the themes in other applications. Some studies exploited advanced features of VR/MUVEs. For example, in an application, the user assumed the role of a ranger and interacted (through dialogue boxes, open-ended text responses, and interactive tasks) with non-playable characters (NPCs) representing a bird-watcher, an environmental scientist, and a veterinarian (Gehlbach et al. 2015). In other cases, immersive virtual environments were used. This type of VR applications can, quite effectively, mimic unmediated sensory experiences through the use of specialized equipment (e.g., VR headsets). Such applications allowed, for example, participants to inhabit the bodies of animals (Ahn et al. 2016) or to experience, first-hand, the effects of climate change (Markowitz et al. 2018).

Most of the studies reported encouraging results (e.g., Schott 2017), high engagement in the virtual environment (e.g., Metcalf et al. 2018), learning gains (e.g., Markowitz et al. 2018), improved conceptual understanding (e.g., Neulight et al. 2007), more complex causal reasoning about non-obvious causes (e.g., Grotzer et al. 2013), increased interest and learning motivation (e.g., Tarng et al. 2008), development of environmentally responsible attitudes (Metcalf et al. 2018), and behavioral/attitudinal changes (e.g., Dillahunt et al. 2008; Hsu et al. 2018). For promoting the perception of environmental problems, personal experiences are recommended as an effective approach (Larson and Redman 2014). In this respect, the driving force of VR/MUVEs applications' effectiveness in the context of EE, is probably their vividness and realism (Bailey et al. 2016). In turn, their realism results in sensory-rich experiences (Ahn et al. 2016), as well as to the senses of immersion and "presence" to the virtual environment (Ahn et al. 2016; Markowitz et al. 2018). The illusion of presence increases the users' attention and engagement (Ahn et al. 2016), allowing a heightened interconnection either with nature or the environmental problem (Gehlbach et al. 2015). Additionally, Markowitz et al. (2018) suggested that the above mechanism has a cumulative effect; the more the users explored a virtual world, the more they demonstrated conceptual changes and knowledge gains.

Although specific animals such as dolphins (Cai et al. 2013) and wolves (Schaller et al. 2009) were the themes in some VR/MUVEs applications, it has to be stressed that, in the literature, there is only a handful of studies in which a VR/MUVEs application had as a theme an endangered animal and this was not always done in the context of an EE project (e.g., Allison and Hodges 2000).

4 Methods

On the basis of what was presented in the preceding sections, it was considered an interesting endeavor to examine the use of MUVEs in the context of an EE project for the conservation of endangered species. Since the Mediterranean monk seal is a species threatened with extinction and also present in Greece, it was selected as the MUVE's theme. As it will be further elaborated in the coming section, the target group was primary school students. Given that data were to be collected from whole classes, a quasi-experimental design was applied, with one experimental and two control groups. The project's main objective was to examine whether MUVEs have a more positive impact on students' knowledge on issues related to the protection of endangered species, compared to the impact of other teaching tools, such as printed material and web-pages. MUVEs' impact on students' attitudes toward the seals and toward eco problems, as well as students' views regarding the use of MUVEs during their teaching, were also considered worth examining. Thus, the following hypotheses were tested:

- **H1** The use of MUVEs yields better learning outcomes compared to the use of printed material or web-pages.
- **H2** The retention of knowledge is also better.
- **H3** Students develop more positive attitudes toward seals when they are taught using MUVEs, rather than when they are taught using printed material or web-pages.
- **H4** Students also develop more positive attitudes toward eco problems when they are taught using MUVEs.
- **H5** Students find MUVEs easy to use.
- **H6** Students enjoy learning with MUVEs more than learning with printed material or web-pages.
- **H7** MUVEs provide more incentives for learning compared to printed material and web-pages.
- **H8** Students perceive MUVEs as a more useful teaching tool compared to printed material or web-pages.
- **H9**The perceived impact on students' learning is also greater in MUVEs than in printed material or web-pages.

4.1 Participants and Duration

Fifth and sixth-grade primary school students (ages 10–12) were the project's target group. That is because at these grades the Greek primary school curriculum of study includes (a few) units related to environmental issues. The project was implemented in public schools located in Athens, Greece. In order to achieve an "accessible", "ordinary", and "typical" sample (Creswell and Creswell 2017), a set of selection criteria was applied to the schools that expressed an interest to participate: (a) their students to have never before been taught subjects related to the Mediterranean monk seal and to the conservation of endangered species (b) students' grades to reflect the spread of ability in a typical Greek fifth or sixth-grade, and (c) the ratio of boys and girls to be close to that of a typical Greek public primary school. As a result, a total of 365 students were recruited, coming from eighteen fifth and sixth-grade classes of seven primary schools. One of the three instructional methods presented in the "Procedure" section was randomly assigned to each class, resulting in the formation of three groups of a—more or less—equal size.

Prior to the beginning of the project and for ensuring a uniform, unswerving, and strict implementation of the project's procedures and methods, the teachers of the participating classes were gathered and briefed. Each instructional method was presented—in detail—to them, followed by teaching examples. Students' parents were also gathered and briefed about the project and their written consent for their children's participation was obtained.

As it was not conducted simultaneously to all schools, the project lasted for about four months, from early January to mid-May 2018, with each class attending six two-hour sessions (two sessions per week). It has to be noted that organizational problems had to be resolved prior to the beginning of the project. For example, quite a lot of school headmasters and teachers were, initially, reluctant to allocate more teaching hours for the project. The schools' timetables proved to be quite inflexible in re-arranging the courses so as the project's sessions to fit in. The computer labs also proved to be a major problem; their availability was limited (as they were used from other teachers as well) and all of them had outdated computers not able to handle 3D applications. Although the project was able to provide more than twenty laptops for solving the above problem, these had to be constantly moved from one school to another.

4.2 Materials

Since MOm, the Alonissos National Marine Park, the National Marine Park of Zakynthos, as well as other websites, have a wealth of resources (e.g., texts, videos, animations, photos, charts, diagrams, etc.) and activities readily and freely available, it was decided to use them. The material was edited and re-organized into six teaching units/sessions: (a) the habitat of the Mediterranean monk seal (b) behavior (diet/predation and reproduction/development), and (c) interactions with humans (pollution, other threats, and conservation). The next step was to develop the virtual world. For that matter, a MUVE developed using Opensimulator (https://opensimulator.org/) for a previous pilot project with the same theme (Fokides et al. 2017), provided the foundation for the new application. On the basis of the feedback received from students and peers during the pilot project, it became evident that certain parts had to be re-worked, but the outline was kept intact. The virtual world (actually a fictional island) represented an important place for the seal's protection (Fig. 1a–c). On this island, students were able to visit various areas which provided information on the biology and ecology of the species, so as to be able to identify the threats and risks the seal faces, to assess the anthropogenic factors that hinder its survival, and to understand the complex issues and interactions involved.

The virtual island was split into two distinct areas. One area was semi-urban; a number of buildings there (e.g., pier, biology lab, and exhibition kiosks) contained the bulk of the cognitive material and usually served as students' starting point. The other region

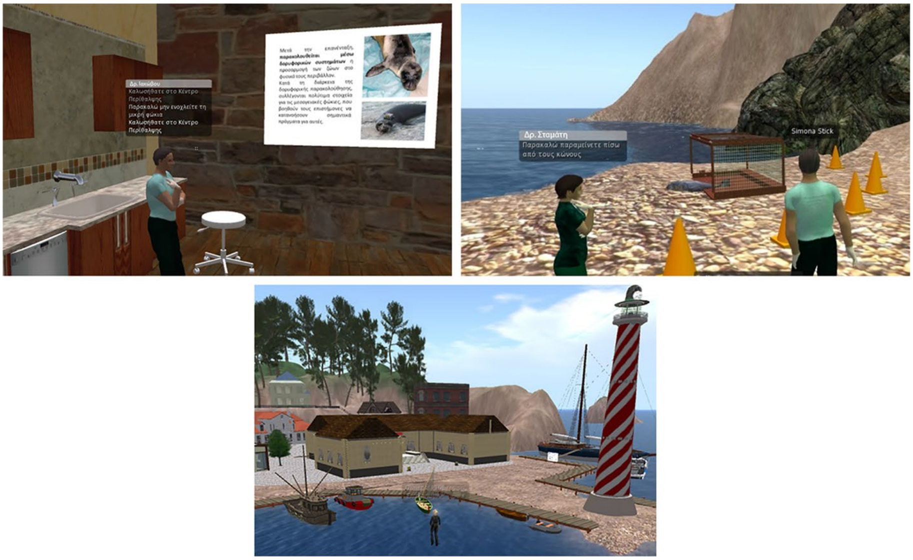

Fig. 1 Screenshots from the MUVE

represented the habitat of the species (e.g., undersea area, beaches, and caves). In this area, hazards due to human activity were simulated (e.g., entanglement in fishing nets, environmental pollution). There was also a rehabilitation area and a space for the outdoors observation of the species. All the above served as the "study" areas of the virtual island.

Besides simple programming scripts that implemented basic interactions (e.g., controls for the media screens that presented the cognitive material, opening of doors or boxes, and seals' animations), "smart" NPCs were added. The NPCs were programmed so as to (a) follow pre-defined paths (b) converse with each other on a regular basis, and (c) perform actions that simulated a phenomenon or a situation (e.g., returning a rescued seal to its natural environment). In addition, key NPCs (i.e., the marine biologists/veterinarians, some fishermen, and some tourists) could (a) respond to a set of pre-defined questions and (b) ask a set of pre-defined questions and, depending on students' answers, responded or acted accordingly.

Instead of just prompting students to study the learning material, it was considered far more effective to engage them in in-world activities and tasks, which were assigned to them by NPCs. In a way, students were forced to search for the relevant material or view a simulated phenomenon (which was sometimes placed in a different area of the virtual island), study it, make connections, and apply critical thinking for finding the solution to the problem at hand or for successfully completing a task. Safeguarding mechanisms were placed for preventing students to complete a task by chance or without actually studying. For example, depending on the task/activity, timers prevented immediate responses, certain media screens had to be flagged as clicked, and certain areas had to be flagged as visited. Following the same line of thought, another key feature that was added was the simulated experiments. For instance, on an interactive map, students could alter the space allocated for seals or the food available to them and see a rough estimation of the seals' population over time. The "smart" NPCs, the activities/

tasks, the experiments, and the media screens had a reset/restart feature that allowed students to replay or reenact them at will.

Finally, six short acts were implemented using NPCs (one for each session's starting point). The purpose of these acts was students to encounter a phenomenon, a problem, or a situation that needed to be addressed and get directly involved. For example, at the beginning of Session 5 (interactions with humans-other threats), a dead seal entangled in fishing nets has drifted ashore near the pier. People are gathered and discuss what to do to avoid such incidents in the future, while the fishermen are upset because their nets were destroyed and they are losing money. A marine biologist steps in and asks students to follow him to a nearby isolated beach to discuss things in private. On their way there, students meet a couple of tourists who take selfies close to a seal's nesting place. Upon completion of the application, a small group of students tested it; on the basis of their comments, minor adjustments were made.

For reasons further elaborated in the "Procedure" section, a handbook was written that included all of the MUVE's learning material (texts, photos, charts, and diagrams) presented exactly as in the virtual world. Workarounds were used to bypass the limitations of paper and effectively transfer the MUVE's interactive content on this medium. For example, screenshots represented the various areas of the virtual island. The videos were transliterated into narration (text) and image sequences. As for the simulated experiments, these were also presented with images and text, in the form of short problems which students had to solve. Finally, the six introductory acts, as well as any other case where NPCs interacted with the students (e.g., activities and tasks), were transcribed into comics storylines, using screenshots from the MUVE, images, text, and diagrams. Given that students were to use the MUVE for six sessions, the handbook was also organized into six teaching units.

Following the same logic, a website was developed. Provided that in web pages multimedia features can be embedded, it was relatively easier to transform the MUVE's interactive content into web pages. For instance, the simulated experiments were exactly the same, as the MUVE's programming scripts could be embedded in a web page's HTML code. The six introductory acts were converted into videos using screen capturing software. The various areas of the virtual island were converted into a series of hyperlinked images/pages and the same applied for the tasks that the NPCs assigned to students. The website was later packed into a self-contained application, consisting of a single, installable bundle including all the web-pages and necessary files. Therefore, the website could be locally executed to any computer as a stand-alone application without the need for an Internet connection. Lastly, a workbook was written, including worksheets and in-classroom activities inspired by Mom's educational material. The workbook was used by all students, regardless of the tool they used (see "Procedure" section).

4.3 Procedure

As presented in a preceding section, MUVEs provide the means to implement the principles of constructivism and situated learning, as well as simulation-based learning/teaching methods. Moreover, in the teaching of EE and science courses, it is advised students to work in groups, preferably small (Harlen and Qualter 2014). Bybee's 5E (Bybee et al. 2006) is an instructional model that fits to the above. Consequently, it was followed, though its stages were slightly modified so as to suit the study's needs:

- The "Engage" stage excites students' interest, gets them personally involved in the lesson, and sets the groundwork for the upcoming activities. As already mentioned, in the virtual island students encountered a situation (simulated with the use of NPCs) which provided the necessary stimulus.
- In the "Explore" stage students explore ideas through activities and the "Explain" stage provides students with an opportunity to communicate what they have learned. These stages were merged and took place in the "study" areas of the virtual island. The students studied the relevant material (presented by NPCs, media, and data screens), performed the in-world experiments, activities, and tasks, recorded their views (on paper), discussed them (using the MUVEs' voice chat or instant messaging services), re-assessed their views, and recorded their final collective opinion/view/understanding on the situation/problem they encountered.
- The "Extend" stage allows students to further explore the implications of what they have learned. The purpose of the "Evaluation" stage is to determine how much learning has taken place. Both stages were also merged and took place outside the virtual world. The students presented their recorded views (from the previous stages) to the whole class, engaged in discussions, worked on the worksheets (in groups), performed the in-classroom activities, and engaged—once more—in discussions. The assessment was also done collaboratively through group discussions and presentation of ideas and views.

It has to be noted that:

- During all stages, the teachers acted as facilitators of the process by starting or joining in students' discussions, by drawing their attention to important aspects of their work, and by providing guidelines (but without enforcing their views).
- Each student used his/her own laptop. For every four laptops, one acted as a server and the other three were connected to that. Although Opensimulator can serve more than a hundred simultaneous users, the above setting was considered more appropriate since (a) it allowed a small group of four students to be simultaneously present to the virtual world, act as a team, and collaborate (b) connection problems were avoided, and (c) problems related to the coordination of too many students were also avoided.
- Most of the time, students were free to explore the virtual island. Furthermore, since most simulated scenarios, experiments, and media presentations had a reset/re-run function, students could study them from multiple perspectives, focus on certain details, and revisit them at any time.
- In order to proactively deal with problems related to the use of MUVEs, students practiced themselves during a two-hour session (prior to the beginning of the project) by using a small virtual world developed for this reason.

As already mentioned, in order to compare the results that the MUVE had, two more groups of students were formed. One used the printed material and the other one used the web application. The procedure that was followed to these groups was identical to the one followed in the MUVE group. Thus, a total of three groups of students participated in the study who were taught the same subject, using the same teaching method, and for the same period of time. Their only difference was the teaching tool that each group used.

4.4 Instruments

For data collection purposes, a total of four evaluation sheets were devised (pre-test, tests 1 and 2, and delayed post-test). Each test consisted of closed (yes–no, multiple choice, fill-in-the-blanks, etc.) and open-ended questions. Less than half of the questions in these tests checked knowledge acquisition. The majority of the questions checked whether students were able to associate different pieces of information/knowledge, make informed decisions, and apply what they have learned to new situations. The pre-test was administered prior to the beginning of the project; its purpose was to check whether all groups of students had the same initial knowledge level regarding the Mediterranean monk seal and the problems related to this species. The first test was administered half-way through the project (including questions related to the content of sessions 1–3), while the second test was administered immediately after the last session (including questions related to the content of sessions 4–6). The delayed post-test was administered three weeks after the end of all sessions (including questions from all sessions); its purpose was to check the retention of knowledge.

For measuring the impact that the MUVE, the printed material, and the web-pages had on students' attitudes toward seals, it was considered more appropriate to use a scale developed for a specific animal rather than a scale designed for measuring a generalized attitude toward animals. One such scale is the Toad Attitude Questionnaire (TAQ) (Tomažič 2011) which was developed employing Kellert's typology (scientistic, negativistic, and moralistic) (Kellert 1985). It consists of twenty-five statements in a five-point Likert type scale (ranging from totally disagree to totally agree). One item had to be excluded because it could not fit ("Toads are of value as they eat mosquitoes and other bugs") and the rest were re-worded by replacing the word "toad(s)" with "seal(s)". The revised TAQ was administered twice, once prior to the beginning of the project (together with the pre-test) and once after the end of the project (together with the delayed post-test).

For measuring students' attitudes toward eco problems, the New Ecological Paradigm scale (NEP) (Dunlap et al. 2000) was used. NEP is considered a reliable and valid tool for measuring environmental views and it is extensively used in EE. NEP is built upon the idea that differences in behavior or attitudes can be explained by underlying values or worldviews (Anderson 2012). It consists of fifteen statements and respondents are asked to indicate their strength of agreement to them in a five-point Likert-type scale (worded strongly agree, agree, unsure, disagree, strongly disagree). The NEP was administered twice, together with TAQ.

As for measuring students' views regarding the three teaching tools, the Learning Experience Questionnaire (LEQ) was used, which is a modular questionnaire developed for measuring several factors that shape the learning experience (Fokides et al. 2019). Out of the initial sixteen factors, five were selected for the present study, corresponding to H5-H9, namely, perceived ease of use (six items), enjoyment (six items), motivation (six items), perceived usefulness (four items), and perceived knowledge improvement (five items). The questionnaire was administered immediately after the last session (together with the final test). The above questionnaires and scales are presented in the "Appendix".

5 Results Analysis

After excluding from the analysis students who were absent in more than one session, the final sample size was reduced to 326 participants, divided into three groups of almost equal size (Group1 = teaching with the printed material, Group2 = teaching with the web

Table 1 Means and standard deviations per group and per evaluation sheet

	Group					
	Group1 (N = 108)		Group2 (N = 109)		Group3 (N = 109)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Pre-test (max = 46)	17.78	3.94	19.12	5.12	18.55	3.88
TAQ initial (max = 120)	82.23	10.18	81.40	9.33	80.04	9.52
NEP initial (max = 75)	42.02	7.22	40.65	6.51	41.50	6.07
Test 1 (max = 40)	24.02	6.17	26.05	5.95	27.14	6.48
Test 2 (max = 50)	35.12	7.41	38.18	8.02	41.16	7.77
Delayed post-test (max = 48)	33.33	5.47	34.68	4.73	36.62	5.99
TAQ final (max = 120)	96.42	9.77	99.81	9.51	105.36	9.33
NEP final (max = 75)	61.05	5.53	62.25	6.41	63.92	5.71

Table 2 Means and standard deviations per group and per LEQ's factors

	Group					
	Group1 (N = 108)		Group2 (N = 109)		Group3 (N = 109)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Perceived ease of use (max = 30)	N/A	N/A	25.45	4.57	13.14	5.78
Enjoyment (max = 30)	19.50	3.54	23.21	3.20	26.22	3.71
Motivation (max = 30)	18.50	4.11	21.22	3.99	23.58	3.18
Perceived usefulness (max = 20)	15.67	3.00	16.14	2.76	15.35	2.81
Perceived impact on knowledge (max = 25)	17.78	3.44	19.04	3.15	20.46	4.11

Note. N/A = not applicable

application, and Group3 = teaching with the MUVE). The scores in all the evaluation sheets were computed on the basis of the number of correct answers. Total scores on both NEP and TAQ scales and on each of the LEQ's factors were also calculated (Tables 1, 2). Moreover, on these scales, a reliability analysis was run using Cronbach's alpha. It was found that for the initial NEP the reliability score was 0.88 and for the final NEP it was 0.90, exceeding DeVellis's (2003) guidelines (>0.70). For the initial TAQ the reliability scores of all its constructs were between 0.76 and 0.88 and the overall score was 0.82. For the final TAQ the reliability scores of all its constructs were between 0.77 and 0.84 and the overall score was 0.81. As for the LEQ, the reliability scores of all its constructs was between 0.82 and 0.91 and the overall score was 0.91.

In order to determine whether the scores of the three groups had any statistically significant differences, one-way ANOVA tests were conducted. The sample size was considered more than adequate for inferential statistical testing (such as one-way ANOVA), given that for three groups with $N_{total} = 326$, a significance level of 0.05, and an effect size of 0.20, the power value was 0.90, which was considered good (Cohen 1988). Before proceeding with the tests, it was checked whether the assumptions for ANOVA testing were met. It was found that (a) one group had one student less than the other two, but this was considered a negligible deviation from the assumptions of an equal number of participants to all groups (b) there were no outliers (c) the data were normally distributed, as assessed by the Shapiro–Wilk test and Q-Q plots, and (d) the homogeneity of variance was not violated, as assessed by Levene's test. Given that all the assumptions were satisfied, the tests were conducted (Table 3), followed by post-hoc comparisons on all possible pairwise contrasts in cases where statistically significant differences were noted (Table 4).

Taken together, the above results suggested that:

- Given that there were no statistically significant differences in the pre-test, the initial TAQ, and the initial NEP, it is safe to assume that any differences noted to the rest of the results can be attributed to the different medium each group used.
- H1 can be accepted with reservations. While Group3 outperformed Group1 in both tests, outperformed Group2 only in the second (and the effect size was small). Thus, it can be concluded that when a MUVE was used, the learning outcomes were better compared to the use of printed material. On the other hand, when compared to the use of web-pages, the results were inconclusive, though marginally better.
- H2 can be accepted since, in the delayed post-test, Group3 outperformed the other groups. Therefore, the use of a MUVE resulted in a better retention of knowledge compared to printed material and web-pages.
- H3 can be accepted because Group3 had significantly higher scores in the final TAQ questionnaire compared to the other groups. It is worth noting that the difference in students' positive attitudes toward seals was large when comparing the MUVE with the printed material and medium-sized when comparing the MUVE with the web-pages application.
- Only the first leg of H4 can be accepted since, in the final NEP, Group3 outperformed Group1 and had equally good results with Group2. Therefore, the students who used the MUVE formed more positive attitudes toward eco problems compared to the ones who used the printed material (medium sized difference), but there was no difference compared to the ones who used the web-pages.
- H5 has to be rejected. It is very clear that students in Group3 found that the MUVE was hard to use and students in Group2 considered the web-pages very easy to use.
- H6 and H7 can be accepted. Students in Group3 were clearly more motivated and had more fun compared to students in groups 1 and 2.

Table 3 One-way ANOVA results

Tests and scales	*F*	*Sig*	LEQ	*F*	*Sig*
Pre-test	$F(2, 323) = 2.59$	$p = .077$	Perceived ease of use	$F(1, 216) = 304.23$	$p < .001$*
TAQ initial	$F(2, 323) = 1.42$	$p = .244$	Enjoyment	$F(2, 323) = 100.92$	$p < .001$*
NEP initial	$F(2, 323) = 1.19$	$p = .307$	Motivation	$F(2, 323) = 49.02$	$p < .001$*
Test 1	$F(2, 323) = 7.06$	$p = .001$*	Perceived usefulness	$F(2, 323) = 2.11$	$p = .123$
Test 2	$F(2, 323) = 16.53$	$p < .001$*	Perceived impact on knowledge	$F(2, 323) = 15.14$	$p < .001$*
Delayed post-test	$F(2, 323) = 10.10$	$p < .001$*			
TAQ final	$F(2, 323) = 24.31$	$p < .001$*			
NEP final	$F(2, 323) = 6.49$	$p = .002$*			

Table 4 Post-hoc results and effect sizes

Tests and scales	Pair	Sig	Group	Effect size (Cohen' s *d*)	LEQ	Pair	Sig	Group	Effect size (Cohen' s *d*)
Test 1	1–2	$p = .043^*$	2	0.33 (small)	Perceived ease of use	1–2	N/A	N/A	N/A
	1–3	$p = .001^*$	3	0.49 (small)		1–3	N/A	N/A	N/A
	2–3	$p = .398$	–	–		2–3	$p < .001^*$	2	2.36 (large)
Test 2	1–2	$p = .011^*$	2	0.40 (small)	Enjoyment	1–2	$p < .001^*$	2	1.10 (large)
	1–3	$p < .001^*$	3	0.80 (large)		1–3	$p < .001^*$	3	1.85 (large)
	2–3	$p = .013^*$	3	0.38 (small)		2–3	$p < .001^*$	3	0.87 (large)
Delayed post-test	1–2	$p = .160$	–	–	Motivation	1–2	$p < .001^*$	2	0.67 (medium)
	1–3	$p < .001^*$	3	0.57 (medium)		1–3	$p < .001^*$	3	1.38 (large)
	2–3	$p = .023^*$	3	0.36 (small)		2–3	$p < .001^*$	3	0.65 (medium)
TAQ final	1–2	$p = .025^*$	2	0.35 (small)	Perceived impact on knowledge	1–2	$p = .027^*$	2	0.38 (small)
	1–3	$p < .001^*$	3	0.94 (large)		1–3	$p < .001^*$	3	0.71 (medium)
	2–3	$p < .001^*$	3	0.59 (medium)		2–3	$p = .010^*$	3	0.39 (small)
NEP final	1–2	$p = .292$	–	–					
	1–3	$p = .001^*$	3	0.51 (medium)					
	2–3	$p = .093$	–	–					

Notes. N/A = not applicable; * = statistically significant difference; in the "Group" column the number indicates the group that had better results

- H8 has to be rejected. Given that there was no statistically significant difference regarding the usefulness of the medium, it can be concluded that the printed material, the web-pages, and the MUVE were considered equally useful.
- H9 can be accepted. Students thought that the MUVE had a greater impact on their knowledge compared to students who used the printed material and the web-pages (though the effect size, in this case, was small).

6 Discussion

A successful EE project builds upon two pillars knowledge and attitudes. The results indicated that, as far as the former is concerned, the MUVE produced statistically significant learning gains and improved conceptual understanding compared to the printed material. Although the findings were somehow inconclusive when comparing the MUVE with the web-pages, the results are—more or less—similar to the findings of previous studies (e.g., Grotzer et al. 2013; Neulight et al. 2007). The results in the long-term retention of knowledge were clearly in favor of the MUVE. Since others indicated that the retention of knowledge is important to wildlife conservation educational programs (e.g., Jacobson et al. 2015), it can be concluded that, regarding knowledge, the MUVE can be viewed as an effective tool.

As far as attitudes are concerned, the study examined attitudinal changes in two levels toward seals and toward the environment as a whole. It was found that the MUVE had a significant impact on students' attitudes toward seals, clearly surpassing the other tools. Given that the research on the use of MUVEs for changing the users' attitudes toward endangered species is almost non-existent, this finding, though important, cannot be connected with previous research. Coming to the attitudes toward the environment or toward eco problems, the MUVE and the web-pages produced equally good results, with the MUVE having an advantage over the printed material. This finding is quite interesting considering that (a) attitudes toward specific animals are easier to impact than general environmental attitudes (Kim et al. 2011) (b) general environmental attitudes need to be continuously reinforced (Beaumont 2001), and (c) the study's subject was seals and not the environmental problems in general.

Thus, an important issue to contemplate is the value of the observed attitudinal changes, given that the link between knowledge, attitudes, behavioral intentions, and actual behaviors is not that clear. Some support the view that improved environmental knowledge and attitudes are not reliable predictors of actual pro-environmental behaviors (Hughes 2013). On the other hand, the theory of planned behavior (Ajzen 1991), supports the view that one's previous knowledge or experiences form salient beliefs upon which attitudes are based; attitudes together with motivations to action form behavioral intentions; these are likely to be translated into actual behaviors if opportunities of carrying them out are given. In order to facilitate this chain of transformations in real life and in the context of EE projects for the conservation of endangered species (a) an interpretative approach is preferred over passive provision of information (Ham 2007) (b) the first-hand experience of animals can help (Kuo 2002) (c) examples of the desired attitudes and behaviors that are easy to implement are required (Ballantyne et al. 2007) (d) experts that act as role models have an impact (Apps et al. 2015), and (e) the emotional involvement of the learner can also help (Ballantyne et al. 2007).

It appears that the MUVE proved to be a medium able either to provide or simulate all the above. It has to be reminded that the MUVE was a rather multifaceted simulation of the seal's habitat and that it was developed having in mind the main concepts of situated learning, constructivism, and simulation-based learning. The fact that inside the MUVE the students (a) were engaged in tasks which addressed real problems and (b) they encountered the simulated equivalents of real phenomena/situations, probably helped them to develop a better understanding of the context in which the knowledge they acquired was applied/situated (Brown et al. 1989; Dalgarno and Lee 2010). The collaborative nature of the tasks that students had to complete, the encouragement of in-world discussions, and the freedom to explore and to repeat the simulated acts and experiments, probably had a positive impact on content learning as constructivism postulates (Dalgarno and Lee 2010). On the basis of notions originating from the simulation-based learning theory (Rutten et al. 2012), the MUVE intended to provide rich and as-realistic-as-possible experiences (Harrington 2012); thus, it can be supported that students had the virtual analog of first-hand experiences. Furthermore, the NPCs (with the exception of the fishermen) acted as role models and presented the desired attitudes and behaviors, once again embedding these in the context in which they apply.

The results in LEQ might provide some additional insights into why the MUVE proved to be a better teaching tool. Though all tools were considered equally useful, the students thought that the MUVE had a greater impact on their learning compared to the other tools. The preceding paragraph offers a number of plausible explanations for this outcome. Among the five factors that were examined, fun/enjoyment was the one in which the MUVE excelled. Also, as it was evident in the results in LEQ, the students who used the MUVE were strongly motivated to learn. The link between the enjoyment users feel when using VR/MUVEs applications and learning was established in previous studies (e.g., Faiola et al. 2013; Fokides and Atsikpasi 2018). There is also a strong link between enjoyment and motivation to learn (Fokides and Atsikpasi 2018; McLellan 2004) as well as between motivation and actual learning (Fokides and Atsikpasi 2018). Therefore, one can infer that the combination of elevated enjoyment and motivation to learn resulted in the MUVE's group increased learning gains and improved conceptual understanding. Unfortunately, the results concerning the MUVE's easiness of use were disappointing, indicating that students faced significant problems when using the application (although they had a practicing session prior to the beginning of the project). This factor plays a key role in the quality of experience VR/MUVEs applications provide (Lee et al. 2010), affecting enjoyment, motivation, and the learning outcomes (Fokides and Atsikpasi 2018). Given the above, it is safe to assume that it acted as a mitigator of the otherwise good results that students in the MUVE group had.

6.1 A Critical View of the Results

While the statistically significant differences between the three groups point to the logical (and valid) conclusion that the MUVE was a better tool for raising students' awareness of endangered species (to a varying degree depending on which tool it was compared to), a second more stringent reading of the results, may lead one to conclude that the "WOW!" factor is somehow missing. Indeed, a number of interesting observations arise when viewing the results in Table 1 from a different perspective. First, the scores in the pre-test, all groups considered, were disturbingly low; most students did not know much about seals. A striking improvement to all groups was noted in the delayed post-test (ranging from

81 to 97%). Moreover, the difference between the MUVE and the web-pages groups was small, and both were closely followed by the printed material, given that there was no difference between groups 1 and 2 and there was a medium-sized difference between groups 1 and 3. Consequently, in terms of knowledge acquisition, all tools produced good results. Coming to the results in TAQ, it is evident that all groups had quite high scores in the initial TAQ, meaning that all students already had positive feelings toward seals. Given that, the improvement was far less impressive (ranging from 17 to 32%). Though it was the only case in which the MUVE group had a clear advantage over the other groups, the results in the printed material group were also more than pleasing. Finally, the results in NEP were similar to the results in the pre/post-tests. The difference between the initial and the final NEP (in all groups) was remarkable, indicating a 45–54% positive change in students' views and attitudes toward eco problems. Once again, both the web-pages and the MUVE proved to be equally influential, whereas the 9% difference between the printed material and the MUVE, although enough to result in a medium-sized effect, was not that impressive.

Given that the differences between the three groups were measurable but not that prominent and considering all the time and effort needed for developing any type of MUVE, one might ask a rather provocative question: "Did it worth the trouble?" A skeptic might argue that it is better to stick to already well-received and effective tools, rather than use elitist ones which do not provide a considerable added value and require above the average hardware in order to take full advantage of their features and affordances. Adopting an eco-friendly (and education-friendly) point-of-view, one might counterargue that even the slightest conceptual or attitudinal positive change—especially in younger generations—is crucial if we are to succeed in saving the endangered species or the environment. The debate is certainly not an easy one to settle, as it belongs to a broader—and ongoing—discussion for the educational value of diverse ICT tools.

6.2 Contribution to Research and Implications for Practice

The Mediterranean monk seal was selected as the MUVE's theme as it is an endangered species present in Greece's seas. It was presumed that students already knew quite a lot and had positive feelings toward this animal due to the publicity it receives in the mass media. The former assumption was disproved due to the findings in the pre-test, while the latter was confirmed as the scores in the initial TAQ were high. Thus, the study provides a—rather general—idea of students' views, feelings, and knowledge for seals. Given that how children's attitudes toward animals are influenced can play a vital role in the success of EE programs for raising awareness of endangered species, research on this matter is vital. The problem is that such attitudinal studies focused either on animals that are charismatic like dolphins (Barney et al. 2005) or on animals that people fear or dislike such as bats and spiders (Prokop and Tunnicliffe 2008). Research on the attitudes toward specific endangered species is rather limited (e.g., Kwan et al. 2017). Thus, the present study contributes to the relevant literature as it (a) utilized a teaching tool (MUVEs) that it is not commonly used in EE (b) examined a species that does not fall in the above categories, and (c) quantified the influence of three different teaching tools on students' knowledge, views, and attitudes.

The study's findings have implications for the experts involved in the development of VR/MUVEs. Enjoyment received an exceptionally high score in the MUVE group and the importance of this finding has already been discussed in a preceding section. Thus, developers can focus on features that have the potential to increase the sense of enjoyment even more. One way to achieve this is by adding game-like features, as these facilitate both enjoyment and motivation (Faiola et al. 2013; McLellan 2004; Kozlov and Johansen 2010). The MUVEs' realism is also a feature that can be improved even further since it also affects enjoyment (Fokides and Atsikpasi 2018). Then again, caution is advised, because to achieve increased realism means to extensively use detailed 3D objects, which, in turn, results in complex applications that require advanced computers in order to run smoothly. The MUVE failed miserably in its easiness of use. Given that this had a negative impact on students' learning experience, as presented earlier, software developers need to find more "natural" methods for implementing user-application interactions, probably by using devices for immersive VR (e.g., head-mounted displays).

Also, the findings have implications for education, at least in formal settings. The organizational problems that were encountered are indicators of the inadequacies of the conventional curricula of study. Since, in the classes' timetables no teaching hours were allocated in advance for initiatives that require more than one teaching hour per session, lessons had to be skipped and courses had to be rescheduled. The teachers' objections to the above were strong and—up to a certain degree—justified; trying to insert two two-hour sessions per week in an already oversaturated timetable was troublesome, even if it was a temporary deviation from the classes' routine. It is quite logical to state that the feasibility of projects with extended duration is questionable. Alas, such problems hinder the introduction of EE or VR/MUVEs (which by their own right are time-consuming when introduced in classrooms) in everyday teaching. Education administrators and policymakers have to reconsider how the curriculum in primary and secondary education is structured and come up with solutions that encourage the use of contemporary teaching methods instead of thwarting them.

6.3 Limitations and Future Work

While the results were thought-provoking, there are certain limitations to the study that bear mentioning. The sample, although more than sufficient for statistical analysis, could have been larger and a wider age range could have been included. Therefore, there are some reservations regarding the generalizability of the results. The number of sessions was small; organizational problems limited the duration of the study. Though multiple aspects of students' performance and views were recorded, no data were collected regarding the teachers' views or how well they were able to implement each teaching method.

Further studies will help to identify similarities or differences to the findings of the present study. For example, the target group can be students of all ages, so as to determine the suitable content (and the right difficulty level) for each age group and at what age a greater impact on knowledge and attitudes is to be expected. Other endangered species and environmental issues can be examined. Additional research tools can also be utilized; observations and interviews with students and teachers will allow an in-depth understanding of the pros and cons of each teaching tool. For that matter, devices (e.g., tablets) and technologies (e.g., immersive VR) can be used and compare the results.

7 Conclusion

Within the framework laid by a previous pilot study, a project was implemented for examining the impact of MUVEs on students' knowledge and attitudes toward issues related to the protection of endangered species. As far as knowledge is concerned, the findings demonstrated that the MUVE had an advantage over web-pages and printed material. As far as attitudes toward the Mediterranean monk seals are concerned, the MUVE instigated a considerable positive change compared to both the printed material and the web-pages. On the other hand, the differences in attitudes toward eco problems were prominent only when the MUVE was compared with the printed material. Nevertheless, and despite the study's limitations, the experimental data that were obtained support the view that MUVEs offer an interesting alternative method for raising student's awareness of endangered species and of environmental issues. Then again, a lot more can be done in order to improve their effectiveness; there is still a long way ahead before their full potential and their impact on EE and on pedagogy, in general, is fully realized.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix

The revised Toad Attitude Questionnaire (Tomažič 2011).

Scientistic

1. I would like to learn about different species of seals.
2. I would like to learn about the environments where seals live.
3. I would like to read about seals.
4. I would like to know how seals eat, smell and hear.
5. I would like to know how seals develop.
6. I would like to study seals in nature.
7. I get bored when the teacher is talking about seals. (reversed)
8. Fishermen kill too many seals each year.
9. I could observe seals for a long time.

Negativistic

10. When I am on the beach, I do not have a special wish to meet a seal. (reversed)
11. I would rather see a model of a seal than a live one. (reversed)
12. Seals are disgusting animals. (reversed)
13. I would rather see a movie about seals than watch them in nature. (reversed)
14. I would like to hold a seal in my arms.
15. I am afraid of seals. (reversed)
16. I would like to have a seal as a pet.
17. Seals are ugly. (reversed)

Moralistic

18. We don't need to protect the Aegean Sea, because seals living there will move elsewhere. (reversed)
19. It would be for the best if all seals were killed. (reversed)
20. Seals need to have rights too.
21. I wouldn't like to hunt seals.
22. Hunting seals for fun is cruel.
23. Keeping seals in captivity is cruel.
24. Seals are very important in nature.

25. Toads are of value as they eat mosquitoes and other bugs. (excluded)

New Ecological Paradigm scale (Dunlap et al. 2000).

1. We are approaching the limit of the number of people the Earth can support.
2. Humans have the right to modify the natural environment to suit their needs.
3. When humans interfere with nature it often produces disastrous consequences.
4. Human ingenuity will ensure that we do not make the Earth unlivable.
5. Humans are seriously abusing the environment.
6. The Earth has plenty of natural resources if we just learn how to develop them.
7. Plants and animals have as much right as humans to exist.
8. The balance of nature is strong enough to cope with the impacts of modern industrial nations.
9. Despite our special abilities, humans are still subject to the laws of nature.
10. The so-called "ecological crisis" facing humankind has been greatly exaggerated.
11. The Earth is like a spaceship with very limited room and resources.
12. Humans were meant to rule over the rest of nature.
13. The balance of nature is very delicate and easily upset.
14. Humans will eventually learn enough about how nature works to be able to control it.
15. If things continue on their present course, we will soon experience a major ecological catastrophe.

The Learning Experience Questionnaire-selected factors (Fokides et al. in press).
Perceived ease of use (not applicable for printed material).

1. I think it was easy to learn how to use the application.
2. I found the application unnecessarily complex. (reversed)
3. I would imagine that most people would learn to use this application very quickly.
4. I needed to learn a lot of things before I could get going with this application. (reversed)
5. I felt that I needed help from someone else to use the application because it was not easy for me to use it. (reversed)
6. It was easy for me to become skillful at using the application.
Enjoyment
7. I think the application/printed material was fun to use/read.
8. I felt bored while using/reading the application/printed material. (reversed)
9. I enjoyed using/reading the application/printed material.
10. I really enjoyed studying with this application/printed material.
11. It felt good to successfully complete the tasks in this application/printed material.
12. I felt frustrated. (reversed)
Motivation
13. This application/printed material did not hold my attention. (reversed)
14. The application/printed material was interesting and got my attention. (reversed)
15. When using/reading the application/printed material, I did not have the impulse to learn more about the subject. (reversed)
16. The application/printed material did not motivate me to learn. (reversed)
17. This application/printed material had things that stimulated my curiosity.
18. The amount of repetition in this application/printed material caused me to get bored. (reversed)

Perceived usefulness

19. I feel that this application/printed material eased the way I learn.
20. This application/printed material was a much easier way to learn compared to the usual teaching.
21. Why use this application/printed material? There are easier ways to learn what I want to learn. (reversed)
22. The application/printed material can make learning more interesting.

Perceived knowledge improvement

23. I felt that the application/printed material increased my knowledge.
24. I felt that I caught the basic ideas of the subject I was taught.
25. I will definitely try to apply the knowledge I learned.
26. There were explanations and examples of how to use the knowledge I acquired.
27. The presentation of the learning material conveyed the impression that its content is worth knowing.

References

Abu Dhabi Global Environmental Data Initiative (AGEDI). (2016). *Eye on environmental education.* Retrieved from https://www.unenvironment.org/explore-topics/education-environment/why-does-educationand-environment-matter/eye-environmental. Accessed 25 April 2019.

Ahn, S. J., Bostick, J., Ogle, E., Nowak, K. L., McGillicuddy, K. T., & Bailenson, J. N. (2016). Experiencing nature: Embodying animals in immersive virtual environments increases inclusion of nature in self and involvement with nature. *Journal of Computer-Mediated Communication, 21*(6), 399–419. https://doi.org/10.1111/jcc4.12173.

Ajzen, I. (1991). The theory of planned behavior. *Behavior and Human Decision Processes, 50*, 179–211. https://doi.org/10.1016/0749-5978(91)90020-T.

Allison, D., & Hodges, L. F. (2000). Virtual reality for education. In *Proceedings of the ACM symposium on virtual reality software and technology*, 60–165. NY: ACM Press. https://doi.org/10.1145/502390.502420

Anderson, M. W. (2012). New Ecological Paradigm (NEP) scale. *The Berskshire encyclopedia of sustainability: Measurements, indicators, and research methods for sustainability* (pp. 260–262).

Apps, K., Dimmock, K., & Lloyd, D. (2015). Scuba divers and the grey nurse shark: Beliefs, knowledge and behavior. *Human Dimensions of Wildlife, 20*, 425–439. https://doi.org/10.1080/10871209.2015.1037028.

Bailey, J. O., Bailenson, J. N., & Casasanto, D. (2016). When does virtual embodiment change our minds? *Presence: Teleoperators and Virtual Environments*, *25*(3), 222–233. https://doi.org/10.1162/PRES_a_00263

Ballantyne, R., Packer, J., Hughes, K., & Dierking, L. (2007). Conservation learning in wildlife tourism settings: Lessons from research in zoos and aquariums. *Environmental Education Research, 13*, 367–383. https://doi.org/10.1080/13504620701430604.

Ballouard, J. M., Brischoux, F., & Bonnet, X. (2011). Children prioritize virtual exotic biodiversity over local biodiversity. *PLoS ONE, 6*(8), e23152. https://doi.org/10.1371/journal.pone.0023152.

Barney, E. C., Mintzes, J. J., & Yen, C.-F. (2005). Assessing knowledge, attitudes, and behavior toward charismatic megafauna: the case of dolphins. *Journal of Environmental Education*. https://doi.org/10.3200/JOEE.36.2.41-55

Beaumont, N. (2001). Ecotourism and the conservation ethic: Recruiting the uninitiated or preaching to the converted? *Journal of Sustainable Tourism, 9*, 317–341.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42. https://doi.org/10.3102/0013189X018001032.

Buckler, C., & Creech, H. (2014). *Shaping the future we want: UN decade of education for sustainable development; final report*. Paris: UNESCO.

Bulu, S. T. (2012). Place presence, social presence, co-presence, and satisfaction in virtual worlds. *Computers & Education, 58*(1), 154–161. https://doi.org/10.1016/j.compedu.2011.08.024.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., et al. (2006). *The BSCS 5E instructional model: Origins and effectiveness* (Vol. 5, pp. 88–98). Colorado Springs, CO: BSCS.

Cai, Y., Chia, N. K., Thalmann, D., Kee, N. K., Zheng, J., & Thalmann, N. M. (2013). Design and development of a virtual dolphinarium for children with autism. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, 21*(2), 208–217. https://doi.org/10.1109/TNSRE.2013.2240700.

Castronovo, F., Yilmaz, S., Rao, A., Condori, W., Jr., Monga, K., & Gooranorimi, H. (2018). Board 63: development of a virtual reality educational game for waste management: Attack of the recyclops. In *Proceedings of the 2018 ASEE annual conference & exposition*.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). NJ: Lawrence Erlbaum.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: qualitative, quantitative, and mixed methods approaches*. London: Sage

Crudge, B., O'Connor, D., Hunt, M., Davis, E. O., & Browne-Nunez, C. (2016). Groundwork for effective conservation education: An example of in situ and ex situ collaboration in South East Asia. *International Zoo Sourcebook, 50*, 34–48.

Dabbagh, N., & Kitsantas, A. (2012). Personal learning environments, social media, and self-regulated learning: a natural formula for connecting formal and informal learning. *The Internet and Higher Education, 15*(1), 3–8. https://doi.org/10.1016/j.iheduc.2011.06.002.

Dalgarno, B., & Lee, M. J. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology, 41*(1), 10–32.

DeVellis, R. F. (2003). *Scale development: Theory and applications* (2nd ed.). Newbury Park, CA: Sage.

Dickman, A. J. (2010). Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict. *Animal Conservation, 13*, 458–466. https://doi.org/10.1016/j.iheduc.2011.06.002.

Dillahunt, T., Becker, G., Mankoff, J., & Kraut, R. (2008). Motivating environmentally sustainable behavior changes with a virtual polar bear. *Proceedings of the Pervasive 2008 Workshop, 8*, 58–62.

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). New trends in measuring environmental attitudes: measuring endorsement of the new ecological paradigm: a revised NEP scale. *Journal of Social Issues, 56*(3), 425–442. https://doi.org/10.1111/0022-4537.00176.

Eckelman, M. J., Lifset, R. J., Yessios, I., & Panko, K. (2011). Teaching industrial ecology and environmental management in second life. *Journal of Cleaner Production, 19*, 1273–1278. https://doi.org/10.1016/j.jclepro.2011.01.008.

Ehrhardt, N. M., & Witham, R. (1992). Analysis of growth of the green sea turtle (*Chelonia mydas*) in the western central Atlantic. *Bulletin of Marine Science, 50*(2), 275–281.

Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly, 26*(2), 43–71. https://doi.org/10.1002/piq.21143.

Faiola, A., Newlon, C., Pfaff, M., & Smyslova, O. (2013). Correlating the effects of flow and telepresence in virtual worlds: Enhancing our understanding of user behavior in game-based learning. *Computers in Human Behavior, 29*(3), 1113–1121. https://doi.org/10.1016/j.chb.2012.10.003.

Fauville, G., Lantz-Andersson, A., & Säljö, R. (2014). ICT tools in environmental education: Reviewing two newcomers to schools. *Environmental Education Research, 20*(2), 248–283. https://doi.org/10.1080/13504622.2013.775220.

Flogaiti, E. (2005). *Εκπαίδευση για το περιβάλλον και τηναειφορία [Education for the environment and sustainable development]*. Αθήνα: Ελληνικά Γράμματα.

Fokides, E., & Atsikpasi, P. (2018). Development of a model for explaining the learning outcomes when using 3D virtual environments in informal learning settings. *Education and Information Technologies, 25*(3), 2265–2287. https://doi.org/10.1007/s10639-018-9719-1.

Fokides, E., Chachlaki, F., & Liarakou, G. (2017). MUVES and Environmental Education. The paradigm of the Mediterranean monk seal's island. In *Proceedings of the 5th Panhellenic Conference for the Integration and Use of ICT in the Educational Process* (pp. 492–503). Athens, Greece: School of Pedagogical and Technological Education.

Fokides, E., Kaimara, P., Deliyiannis, I., & Atsikpasi, P. (2019). Development of a scale for measuring the learning experience in serious games. Preliminary results. In *Proceedings of the digital culture & audiovisual challenges international conference*. Corfu, Greece: Ionian University.

Freina, L., & Ott, M. (2015). A literature review on immersive virtual reality in education: state of the art and perspectives. In *Proceedings of the International Scientific Conference eLearning and Software for Education* (Vol. 1, p. 133). Carol I, National Defence University.

Gehlbach, H., Marietta, G., King, A. M., Karutz, C., Bailenson, J. N., & Dede, C. (2015). Many ways to walk a mile in another's moccasins: Type of social perspective taking and its effect on negotiation outcomes. *Computers in Human Behavior, 52*, 523–532. https://doi.org/10.1016/j.chb.2014.12.035.

Grotzer, T. A., Kamarainen, A., Tutwiler, M. S., Metcalf, S., & Dede, C. (2013). Learning to reason about ecosystems dynamics over time: The challenges of an event-based causal focus. *BioScience, 63*(4), 288–296. https://doi.org/10.1525/bio.2013.63.4.9.

Ham, S. (2007). Can interpretation really make a difference? Answers to four questions from cognitive and behavioral psychology. In *Proceedings of the interpreting world heritage conference* (pp. 25–29), Vancouver, Canada.

Harlen, W., & Qualter, A. (2014). *The teaching of science in primary schools* (6th ed.). London: Routledge.

Harrington, M. C. (2012). The virtual trillium trail and the empirical effects of freedom and fidelity on discovery-based learning. *Virtual Reality, 16*(2), 105–120. https://doi.org/10.1007/s10055-011-0189-7.

Hill, A. (2013). The place of experience and the experience of place: Intersections between sustainability education and outdoor learning. *Australian Journal of Environmental Education, 29*(1), 18–32. https://doi.org/10.1017/aee.2013.13.

Hsu, W. C., Tseng, C. M., & Kang, S. C. (2018). Using exaggerated feedback in a virtual reality environment to enhance behavior intention of water-conservation. *Journal of Educational Technology & Society, 21*(4), 187–203.

Hughes, K. (2013). Measuring the impact of viewing wildlife: Do positive intentions equate to longterm changes in conservation behavior? *Journal of Sustainable Tourism, 21*, 42–59.

Jacobson, A. R., Militello, R., & Baveye, P. C. (2009). Development of computer-assisted virtual field trips to support multidisciplinary learning. *Computers & Education, 52*(3), 571–580. https://doi.org/10.1016/j.compedu.2008.11.007.

Jacobson, S. K., McDuff, M. D., & Monroe, M. C. (2015). *Conservation education and outreach techniques*. Oxford: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198716686.001.0001.

Kamarainen, A., Metcalf, S., Grotzer, T., & Dede, C. J. (2015). Exploring ecosystems from the inside: How immersion in a multi-user virtual environment supports epistemologically grounded practices in ecosystem science instruction. *Journal of Science Education and Technology, 24*(2), 148–167. https://doi.org/10.1007/s10956-014-9531-7.

Karamanlidis, A., & Dendrinos, P. (2015). Monachus monachus. *The IUCN Red List of Threatened Species, 2015*, e.T13653A45227543. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T13653A45227543.en.

Kellert, S. R. (1985). Attitudes toward animals: Age-related development among children. *Advances in Animal Welfare Science,1984*, 43–60. https://doi.org/10.1007/978-94-009-4998-0_3.

Kim, A.-K., Airey, D., & Szivas, E. (2011). The multiple assessment of interpretation effectiveness: Promoting visitors' environmental attitudes and behavior. *Journal of Travel Research, 50*, 321–334. https://doi.org/10.1177/0047287510362786.

Kozlov, M. D., & Johansen, M. K. (2010). Real behavior in virtual environments: Psychology experiments in a simple virtual-reality paradigm using video games. *Cyberpsychology, Behavior, and Social Networking, 13*(6), 711–714. https://doi.org/10.1089/cyber.2009.0310.

Kuo, I.-L. (2002). The effectiveness of environmental interpretation at resource-sensitive tourism destinations. *International Journal of Tourism Research, 4*, 87–101. https://doi.org/10.1002/jtr.362.

Kwan, B. K., Cheung, J. H., Law, A. C., Cheung, S. G., & Shin, P. K. (2017). Conservation education program for threatened Asian horseshoe crabs: A step towards reducing community apathy to environmental conservation. *Journal for Nature Conservation, 35*, 53–65. https://doi.org/10.1016/j.jnc.2016.12.002.

Larson, K. L., & Redman, E. N. (2014). Water education for sustainability: Criteria and recommendations. *Society & Natural Resources, 27*(11), 1213–1222. https://doi.org/10.1080/08941920.2014.933932.

Lee, E. A. L., Wong, K. W., & Fung, C. C. (2010). How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach. *Computers & Education, 55*(4), 1424–1442. https://doi.org/10.1016/j.compedu.2010.06.006.

Markowitz, D. M., Laha, R., Perone, B. P., Pea, R. D., & Bailenson, J. N. (2018). Immersive virtual reality field trips facilitate learning about climate change. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2018.02364

McLellan, H. (2004). Virtual realites. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology*. Mahwah, NJ: Erlbaum.

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education, 70*, 29–40. https://doi.org/10.1016/j.compedu.2013.07.033.

Metcalf, S. J., Kamarainen, A. M., Torres, E., Grotzer, T. A., & Dede, C. (2018). EcoMUVE: A case study on the affordances of MUVEs in ecosystem science education. In J. Y. Qian (Ed.), *Integrating Multi-User Virtual Environments in Modern Classrooms* (pp. 1–25). Hershey, PA: IGI Global.
Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education, 56*(3), 769–780. https://doi.org/10.1016/j.compedu.2010.10.020.
Miller, L. J., Zeigler-Hill, V., Mellen, J., Koeppel, J., Greer, T., & Kuczaj, S. (2013). Dolphin shows and interaction programs: Benefits for conservation education? *Zoo Biology, 32*(1), 45–53.
Murphy, S., Spradlin, T. R., Mackey, B., McVee, J., Androukaki, E., Tounta, E., et al. (2012). Age estimation, growth and age-related mortality of Mediterranean monk seals Monachus monachus. *Endangered Species Research, 16*(2), 149–163. https://doi.org/10.3354/esr00392.
Neulight, N., Kafai, Y. B., Kao, L., Foley, B., & Galas, C. (2007). Children's participation in a virtual epidemic in the science classroom: Making connections to natural infectious diseases. *Journal of Science Education and Technology, 16*, 47–58. https://doi.org/10.1007/s10956-006-9029-z.
Notarbartolo di Sciara, G., Adamantopoulou, S., Androukaki, E., Dendrinos, P., Karamanlidis, A. A., Paravas, V., et al. (2009). *National strategy and action plan for the conservation of the Mediterranean monk seal in Greece, 2009–2015. Report on evaluating the past and structuring the future*. Paper prepared as part of the LIFE-Nature Project: MOFI:Monk Seal and Fisheries: Mitigating the conflict in Greek Seas. Athens, Greece: Hellenic Society for the Study and Protection of the Mediterranean monk seal (MOm).
Pan, Z., Cheok, A. D., Yang, H., Zhu, J., & Shi, J. (2006). Virtual reality and mixed reality for virtual learning environments. *Computers & Graphics, 30*(1), 20–28. https://doi.org/10.1016/j.cag.2005.10.004.
Prokop, P., & Tunnicliffe, S. D. (2008). "Disgusting" animals: Primary school children's attitudes and myths of bats and spiders. *EURASIA Journal of Mathematics, Science & Technology Education, 4*(2), 87–97. https://doi.org/10.12973/ejmste/75309
Prokop, P., & Fančovičová, J. (2013). Does colour matter? The influence of animal warning coloration on human emotions and willingness to protect them. *Animal Conservation, 16*(4), 458–466. https://doi.org/10.1111/acv.12014.
Prokop, P., & Tunnicliffe, S. D. (2010). Effects of having pets at home on children's attitudes toward popular and unpopular animals. *Anthrozoös, 23*, 21–35. https://doi.org/10.2752/175303710X12627079939107.
Quinn, F., & Lyons, T. (2013). Educating for sustainability in virtual worlds: Does the virtual have value? *Strand 9 Environmental, Health andOutdoor Science Education, 118.*
Rutten, N., Van Joolingen, W. R., & Van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education, 58*(1), 136–153. https://doi.org/10.1016/j.compedu.2011.07.017.
Schaller, D. T., Goldman, K. H., Spickelmier, G., Allison-Bunnell, S., & Koepfler, J. (2009). *Learning in the wild: What Wolfquest taught developers and game players*. Museums and the Web, 2009.
Schott, C. (2017). Virtual fieldtrips and climate change education for tourism students. *Journal of Hospitality, Leisure, Sport & Tourism Education, 21*, 13–22. https://doi.org/10.1016/j.jhlste.2017.05.002.
Skolverket,. (2011). *Läroplan för grundskolan, förskoleklassen ochfritidshemmet [Curriculum for elementary school, preschool class and recreation center]*. Stockholm: Skolverket.
Stevenson, R. B. (2007). Schooling and environmental education: Contradictions in purpose and practice. *Environmental Education Research, 13*(2), 139–153. https://doi.org/10.1080/13504620701295726.
Tarng, W., Change, M. Y., Ou, K. L., Chang, Y. W., & Liou, H. H. (2008). The development of a virtual marine museum for educational applications. *Journal of Educational Technology Systems, 37*(1), 39–59. https://doi.org/10.2190/ET.37.1.d.
Tisdell, C. (2013). Ecotourism experiences promoting conservation and changing economic values: the case of Mon Repos turtles. In R. Ballantyne & J. Packer (Eds.), *International handbook on ecotourism* (pp. 382–393). Northampton, Massachusetts: Edward Elgar Publishing Inc.
Tomažič, I. (2011). Reported experiences enhance favourable attitudes toward toads. *Eurasia Journal of Mathematics, Science & Technology Education, 7*(4), 253–262. https://doi.org/10.12973/ejmste/75207.
United Nations Educational, Scientific, and Cultural Organization (UNESCO). (1978). *Intergovernmental conference on environmental education, final report*. Paris: UNESCO.
Wals, A. E., Brody, M., Dillon, J., & Stevenson, R. B. (2014). Convergence between science and environmental education. *Science,344*(6184), 583–584.
Zheng, D., & Newgarden, K. (2011). Rethinking language learning: Virtual worlds as a catalyst for change. *International Journal of Learning and Media, 3*(2), 13–36. https://doi.org/10.1162/ijlm_a_00067.