The effect of virtual reality technology and education on sustainable behavior: a comparative quasi-experimental study

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Abstract

Purpose – Sustainability is one of the global challenges, individuals and businesses need to change their behavior and consumption patterns to move towards sustainable development. This is not possible without planning for education and related knowledge transfer. On the other hand, disruptive technologies such as virtual reality (VR) have revolutionized the field of education. The purpose of this study is to evaluate the effect of holding traditional training courses and VR-based training courses on sustainable behavior.

Design/methodology/approach – It is a quasi-experimental study, in which pretest-posttest design and control group are used. The statistical population includes students of one of the Iranian universities. A total of 105 students were randomly divided into two experimental groups and one control group (35 students in each group). Experimental group 1 underwent a training course using VR and Experimental group 2 received a traditional training course. At first, a pre-test was performed and after completing the eight-session period (two 1-h sessions per week), the post-test was conducted again for the groups.

Findings – The results of analysis of variance test show that there was a significant difference between the mean scores of sustainable behaviors in the post-test phase in the two experimental groups and the control group. Using Tukey's test, it was found that the scores of sustainable behavior were different among three groups in pairs. That is, holding a training course as well as using VR has been effective on sustainable behavior. Environmental policymakers and planners can use technologies such as VR to teach environmental issues to create a culture of sustainability and sustainable development, in addition to training and educational courses.

Originality/value – Contribution of this study shows that the use of VR can be effective in learning sustainable behavior. Also, holding training courses is a way to change the consumption pattern and behavior of people to maintain the environment and sustainability.

Keywords Sustainable behavior, Virtual reality, Education, Quasi-experimental study, Behavior, Virtual and augment reality

Paper type Research paper

Introduction

Today, the issue of sustainability has become one of the concerns of different societies (Scurati *et al.*, 2021). The sustainable development goals, set by the United Nations for 2030, include three main economic, social and environmental dimensions that address how natural resources are used and distributed fairly (Griggs *et al.*, 2013). Natural resource

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mismanagement is a major part of the environmental problems facing the contemporary world (Baxter and Pelletier, 2020). Production of harmful substances and wastes for the environment is one of the problems of human societies and it is predicted that the production of wastes would increase from about 3.5 million tons in 2010 to about 6 million tons by 2025 (Hoornweg *et al.*, 2013).

Consumers and citizens, by changing their lifestyles and consumption patterns, need to attempt reducing the production of harmful substances to the environment (Lubowiecki-Vikuk *et al.*, 2021). To prevent damage to the environment, paying due attention to the sustainable behavior of people and taking care of natural resources that are slowly regenerated would be necessary (Ebersbach and Brandenburger, 2020). Given the importance of sustainability, the analysis of sustainable behavior and identifying the factors affecting it has been the concern of many researchers. In their study, Blizzard and Klotz (2012) used a systematic review method to provide a framework for designing sustainable systems. Chi *et al.* (2020) provided a framework for the sustainable behaviors of shared-bicycle users. They considered environmental stimuli such as government laws and social ethics and internal stimuli such as perceived competence, and perceived dependence as factors influencing sustainable behavior in the sharing economy. In another study, Liu (2021) examined the behavior of tourists and accordingly showed that sustainable behavior is related to environmental impacts and environment development.

In general, the factors affecting human behavior and in particular sustainable behavior are very complex (Gifford and Nilsson, 2014). Given the extent of sustainability, to exert a radical transformation and to change the consumption pattern, it would be necessary to educate citizens, improve the experts' knowledge and ultimately support the change of behavior toward sustainable consumption habits (Scurati *et al.*, 2021). In line with the ten-year United Nations policy being already set by 2030 for education for sustainable development (ESD), many training centers around the world have included courses related to sustainable development (Hsiao and Su, 2021). Accordingly, the discussion of education and learning in the field of sustainability is very important, but despite many studies done in this field, there are yet many obstacles in establishing the concept of environmental development and sustainable behavior (Liu, 2021).

In some former studies, the relationship between education, learning and the concept of sustainability has been addressed. In their study, Klug and Niemand (2021) evaluated a lifestyle called precycling, which was characterized by the prevention of pre-production waste. They believed that the precycling lifestyle was a part of sustainable consumption and shall not be included in the curriculum of schools and universities. Studies have also shown the effect of learning – in the form of a written factor such as short stories – on sustainable behavior. The results of the Ebersbach and Brandenburger's (2020) study showed the positive effect of short stories on children's sustainable behavior. In her study, Manning (2009) examined the psychological dimensions of learning sustainable behavior. She believed that there were three types of barriers to sustainable behavior; first, the physical barriers that exist in the real world, such as financial and infrastructural barriers; second, cultural and social barriers including imitating the behavior of others in relation to the environment; and third, individual and psychological barriers as to how to break the habit and lack of knowledge about a new behavior. Fostering sustainable behavior among children, young people and adults is one of the missions of education (Ebersbach and Brandenburger, 2020).

Given the importance of training in the field of sustainability and the environment, however, the current financial crisis and economic conditions have reduced investment in on-the-job training, and further this lack of training may lead to harmful behaviors and lack

of knowledge transfer (Mirauda *et al.*, 2020). Accordingly, the use of virtual technologies is important. The use of new technologies such as virtual reality (VR) is essential to maintain the enthusiasm of the next generation and to teach them advanced systems (Salah *et al.*, 2019). Coskun *et al.* (2015) believed that the challenge for organizations and individuals to change behavior and achieve sustainability goals is lack of training and choosing the appropriate tools to implement them.

In this regard, VR technology as a virtual technology has been highly regarded by academic and educational institutions. VR-based training systems can be used to identify and experience products, become familiar with complex systems and simulate different environments (Taxén and Naeve, 2002). Merchant *et al.* (2014) showed VR as a good tool for improving the quality of education. VR, owing to its high flexibility, is an acceptable tool for creating sustainable behavior (Scurati *et al.*, 2021). Given the potential of VR technology in the field of education and also the importance of sustainability, assessment of the impact of VR on sustainable behavior has been empirically identified as a research gap, which needs to be carefully examined. Therefore, in this study we seek to evaluate the impact of training courses on sustainable behavior and VR-based learning and to compare the two methods with each other. Accordingly, the research questions are:

RQ1. What effect does the training course have on sustainable behavior?

RQ2. What effect does the use of VR have on sustainable behavior learning?

RQ3. Which traditional methods of training or VR technology have a greater impact on sustainable behavior?

Contribution of this study shows that the use of VR can be effective in learning sustainable behavior. Also, holding training courses is a way to change the consumption pattern and behavior of people in order to maintain the environment and sustainability. The results of this study are useful for environmental policymakers, managers of companies and educational institutions to invest in the use of virtual technologies in teaching sustainable behavior and pay attention to corporate social responsibility (CSR). In the second section, the literature of sustainability and the use of VR are discussed. In the third section, the methodology used in this study, the study groups and research tools are described. In the fourth section, the results of the experiments are presented. In the fifth section, in addition to analyzing the research findings, theoretical considerations, practical suggestions and existing limitations are explained, and finally in the last section, the final conclusion of the study is presented.

Literature review

Virtual reality and education

Although the concept of VR has changed a lot of its original concept, real-world simulation has always inspired researchers and artists (Jones, 2000). VR is the use of computer and a human–computer interface to simulate the real world and create a three-dimensional world (Bryson, 1996). VR, as a disruptive technology, is predicted to have effects on human life such as the internet and smartphones (Rosedale, 2017). The VR developers should consider the cultural and local dimensions of people in designing this technology (Zeng *et al.*, 2022). Bevan *et al.* (2019) showed that viewer's role, interaction visual and audio aspects are features of VR experiences. Interaction between users and virtual objects such as user control, user activity level, information retrieval method and feedback affects how VR experiences are designed (Sutcliffe *et al.*, 2019). VR technology can influence people's decision-making process and behavior through the ability to travel through time and space,

create symbolic content, evaluate future strategies and deliver long-term results (Scurati *et al.*, 2021). Zeng *et al.* (2022) believed that VR technology could stimulate tourists' cultural dissemination manner. They showed VR is innovative and valuable tool for tourism marketing. With the advent of the 5G mobile network, a suitable platform will be created for the effectiveness of VR technology in educating and promoting students' learning motivation (Hsiao and Su, 2021).

Many studies have mentioned the use of VR in education. One area where VR can be used is scientific visualization. For example, a virtual wind tunnel was designed at NASA Research Center. Using this program, scientists can manipulate the amount of virtual smoke and airflow around the space shuttle (Mazuryk and Gervautz, 1996). In another study, Shin *et al.* (2002) presented a virtual web-based laboratory system in which VR technology was used to teach process systems engineering. Using virtual technology, they tried to overcome temporal, spatial and safety and resource problems. In their study, Merchant *et al.* (2014) reviewed 67 articles related to VR and reported the positive impact of this technology on educational programs and its greater effectiveness. Due to the ability of 3D imaging, VR technology can be used to analyze the anatomy of the body by physicians and students (Pensieri and Pennacchini, 2014).

The use of VR in engineering concepts training might be effective in increasing student interaction and saving training time; besides, it is possible to repeat an experiment without equipment depreciation and with high security (Zhao and Lucas, 2015). The use of VR technology is compatible with classic and proven learning models such as experimental learning and situational learning, because the user can experience different situations in a virtual environment (Li *et al.*, 2018). Salah *et al.* (2019) used a VR-based training method to teach the reconfigurable manufacturing system. The results of their study showed that the proposed method had a better performance than the traditional training methods in terms of user perception and satisfaction, number of errors and completion time.

Narciso *et al.* (2019) have shown that the use of VR is an innovative way to train firefighters and to reduce operational risks. After analyzing 99 articles, Kavanagh *et al.* (2017) categorized the motivation for using VR into intrinsic and pedagogical factors. Intrinsic factors include increased enjoyment, and motivation and pedagogical factors include play-based learning and participation. Weech *et al.* (2019) found a negative relationship between presence and cybersickness in VR and showed that factors such as navigation control and display factors play a mediating role in this regard. Manea-Tonis *et al.* (2020) used extended reality to assess the impact of virtual technology on people's social lives and work. They found that students' virtual experiences had direct impact on their culture and learning. Tilhou and Taylor's (2020) study showed that VR brings better educational experiences for students and confirmed the learning and motivational achievements of this technology. Cai *et al.* (2021) evaluated the effect of virtual reality technology on the spoken English learning training. The results of their study showed that the spoken English learning was affected by cognitive style and VR technology. Huang *et al.* (2021) systematically reviewed VR and augmented reality (AR) technologies in language learning studies and showed that students were the main users of AR/VR technologies. The benefits of these technologies also include improving students' language learning, increasing motivation and having a positive understanding of the use of technology.

Paszkiewicz *et al.* (2021) presented a methodology for implementing VR in education for industry 4.0. They believed that the virtual environment would improve students' knowledge and skills. Also, using VR-based training courses reduces costs and increases employee safety and efficiency. New concepts such as learning factories refer to the use of new technologies in the field of education and are considered as a change in the field of

education and have created real environments in the education process. In this regard, VR is a good tool for effective training of students and trainers (Abidi *et al.*, 2012). VR enhances users' cognitive ability and increases attractiveness due to different visual, audio and even touch capabilities (Paszkiewicz *et al.*, 2021). According to the issues raised in this study, VR is used in the training course and it is assumed that VR is a suitable tool for the transfer of concepts and knowledge.

Virtual reality and sustainability

VR technology has been considered in the field of management and environment since the 1990s. For example, studies have shown that the use of 3D visualization in the tourism industry reduces carbon footprint (Dewailly, 1999). As we entered the 21st century, advances in virtual technologies led to the digital transformation of education. Disruptive technologies have also led to changes in the field of education and research in the field of sustainability (Abad-Segura *et al.*, 2020). Nicholson-Cole (2005) predicted that in the future, VR imaging is used to predict weather based on people's preferences. Summerville *et al.* (2005) presented a model based on four factors of "values", "awareness", "trial", "evaluation" and "uptake", and claimed that this framework is for using VR to encourage sustainable behavior. Jamei *et al.* (2017) explained some of the benefits of using VR in smart city design, including the ability to evaluate design ideas in real time and in 3D, effective communication between stakeholders, academics and professional associations, saving time and test costs and promoted participatory planning.

In their study, Mirauda *et al.* (2020) developed a VR-based training tool that was able to train workers on how to accurately measure open-channel flows. Their experimental results showed that VR Lab reduced the time and cost of control activities, increased users' knowledge of hydraulic equipment and improved decision-making processes; besides, Abad-Segura *et al.* (2020) noted the importance of sustainability of educational technologies in the field of higher education. Kamari *et al.* (2021) evaluated building information modeling and enabled VR technology among civil and architectural engineers. They showed that the use of VR can be useful in the conceptual stage because it can eliminate additional costs and errors in the later stages of construction. Also, this technology is a useful tool for greater efficiency and sustainability in future design.

In their study, Scurati *et al.* (2021) provided a framework of VR experiences related to sustainable behavior as in Figure 1. Three spheres have been mentioned in this framework. Emotional sphere is related to how we perceive environmental issues, so VR can motivate us to promote sustainable behavior. Logical sphere is related to information, education and understanding of phenomena. It refers to the way people think in dealing with environmental issues. Practical sphere is related to the evaluation and comparison of measures and strategies to deal with environmental issues. These three spheres are shown in the form of dark circles in Figure 1. In this framework, the dimension of VR training is mentioned in the form of logical space and it is associated with improving the knowledge and skills of individuals.

Jolink and Niesten (2021) also proposed VR technology as an experimental approach to the study of sustainable behavior due to its ability to produce immersive environments. Based on the issues raised in this study, it is assumed that training courses and the use of VR technology can affect the sustainable behavior of people. According to previous studies, it has been found that many studies have examined the use of VR in the field of education and also the dimensions of VR use in sustainable behaviors have been studied. However, what is identified as a research gap in this field is the lack of practical study and the real test to examine the impact of VR on sustainable behavior. The use of experimental methods is

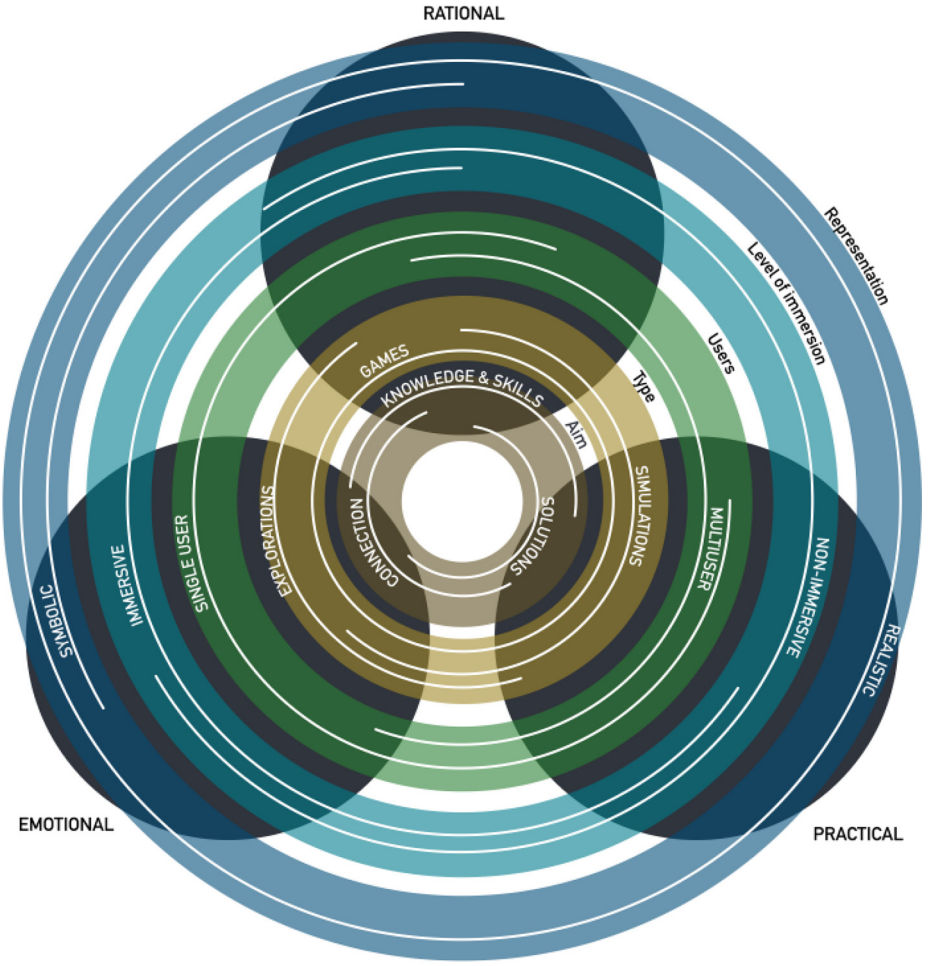

Figure 1.
Virtual reality experiences to support sustainable behaviors

Source: Scurati *et al.* (2021, p. 5)

one of the validated research methods. Here, there has been no study to evaluate the impact of this technology on learning the environmental behavior of individuals in the real environment. Also, comparing the impact of this technology with the traditional educational method is another difference of our study with previous studies that can be considered in educational policies.

Methodology

In this study, pretest-posttest design and control group were used to evaluate the impact of training and VR on sustainable behavior.

Participants

The statistical population of the study was students of one of the Iranian Universities. The reason for choosing students was their interest and power of learning and social participation. In this regard, 110 students were invited to participate in this research project, of which 105 agreed to participate in this study. Accordingly, the participation rate was 95.5%. Using convenience sampling, 105 students were selected and randomly divided into three groups. Participants' level of education ranged from bachelor's student to PhD student. The choice of method was random for controlling exogenous variables because it might affect the outcome and the dependent variable of this study.

Research design

Participants were divided into three groups. Then, for the first and second groups, a 4-h training course on sustainable development and the environment was held every week for four weeks. The first group of classes, in addition to teaching the content, also used VR technology. The second group classes were held in person and traditionally in the form of a lecture by the teacher. The third group was the control group. The control group included people who have not participated in the training course. During the experiment, these people were randomly assigned to this group. Therefore, they were very similar to the participants of the experimental group. The control group is important in the testing process because the results of other groups are compared with this group. In this study, students in the control group did not participate in training classes and the test results of other groups were compared with them. Pre-test and post-test were used for all three groups. The research design is shown in Table 1.

Research tool

Although the main focus of sustainable development is on the protection of natural resources and the environment, the protection of human resources such as society, culture and welfare of the people are as important as the protection of ecosystems (Tapia-Fonllem *et al.*, 2013). Based on this, Tapia-Fonllem *et al.* (2013) provided a comprehensive framework including four dimensions of pro-ecological, frugal, altruistic and equitable actions to evaluate sustainable behavior. In this study, a questionnaire was designed based on the four dimensions (Appendix). The questionnaire consisted of 48 questions, of which three were related to demographic information and 45 were related to sustainable behavior. The initial questionnaire was modified according to the opinion of seven University professors with a background in sustainable development studies, so the face validity was verified. To evaluate the reliability of the questionnaire, Cronbach's alpha coefficient was used, which was equal to 0.81, 0.79, 0.83 and 0.80 for the four parts of the questionnaire, which are acceptable values.

Data analysis

Data were analyzed using descriptive statistics, *t*-test, analysis of variance (ANOVA) and Tukey's test in SPSS-20 software.

	Measurements		
	Pre-intervention	Intervention	Post-intervention
Experimental group 1	E_1	T_1	E'_1
Experimental group 2	E_2	T_2	E'_2
Control group	C_1	–	C'_2

Table 1.
Research design

Results

Demographic information of the participants is shown in Table 2. About 58% of the participants were female and 66% of them were undergraduate students.

After randomly dividing the participants into three groups, a pretest was taken and the ANOVA result ($F = 3.429$, $p = 0.116 < 0.05$) showed that there was no significant difference between the pre-test results of the three groups. Then, two experimental groups participated in training courses for four weeks. At the end of the training courses, a post-test was taken. Table 3 shows the pre-test and post-test information for experimental group 1 (E1). According to the t-values and $p < 0.05$, it is clear that the post-test results are significantly different from the pre-test for the first group. This means that all dimensions of sustainable behavior have been influenced by VR-based education and VR technology has been effective on sustainable behavior. Thus, the null hypothesis is rejected:

H0. There is no significant difference between the post-test and pre-test results of group E1.

H1. There is a significant difference between the post-test and pre-test results of group E1.

Table 4 shows the pre-test and post-test information for the second experimental group (E2). Values of t and $p < 0.05$ indicate that there is a significant difference between the post-test and pre-test results of this group. This means that holding a traditional training course has been effective on the sustainable behavior of participants. Thus, the null hypothesis is rejected:

Table 2. Descriptive statistics of students' characteristics ($N = 105$)

Demographic character	Frequency (n)	(%)
Age		
<20	22	21
20–25	57	54
25–30	18	17
>30	8	8
Educational level		
Bachelor's student	69	66
Master's student	31	29
PhD student	5	5
Gender		
Male	44	42
Female	61	58

Table 3. Difference in pre-post intervention for VR

Variables	Pre-intervention	Post-intervention	t	Sig.
Pro-ecological behavior	2.141 ± 0.432	4.372 ± 0.481	5.263	0.000
Frugal actions	1.493 ± 0.525	4.225 ± 0.529	7.179	0.000
Altruistic behaviors	2.636 ± 0.549	3.906 ± 0.663	4.392	0.001
Equitable behaviors	1.541 ± 1.583	3.632 ± 0.416	3.212	0.001
Sustainable behavior	1.951 ± 0.436	4.047 ± 0.417	4.255	0.001

H0. There is no significant difference between the post-test and pre-test results of group E2.

H1. There is a significant difference between the post-test and pre-test results of group E2.

The pre-test and post-test changes regarding the four dimensions of sustainable behavior are separately shown in Figures 2–5. As can be seen, the changes related to Experimental group 1, i.e. the use of VR technology, were more than the other two groups.

ANOVA test was used to compare the test results between the three groups. The results of ANOVA test are shown in Table 5. According to the F-value and $p < 0.05$, it is clear that at least two groups have significant differences with each other and require post hoc comparisons. Thus, the null hypothesis is rejected:

H0. The post-test results of the groups are equal ($\mu_1 = \mu_2 = \mu_3$).

H1. At least there is a significant difference between the post-test results of the two groups.

Tukey's test was used to determine the differences between the groups (Chiu *et al.*, 2019). The results of Tukey's test are shown in Table 6. Based on the obtained values, it is clear that there is a significant difference between the three groups in pairs. This means that the training course has been effective on sustainable behavior and also the use of VR technology has had a greater impact on sustainable behavior than the traditional training course.

Variables	Pre-intervention	Post-intervention	t	Sig.
Pro-ecological behavior	1.841 ± 0.872	3.112 ± 0.611	3.871	0.003
Frugal actions	2.391 ± 0.925	3.005 ± 1.019	4.390	0.000
Altruistic behaviors	2.246 ± 0.389	3.229 ± 0.823	6.892	0.002
Equitable behaviors	1.961 ± 0.183	2.842 ± 0.736	3.212	0.001
Sustainable behavior	2.101 ± 0.536	3.057 ± 0.937	3.993	0.001

Table 4.
Difference in pre-post intervention for traditional training

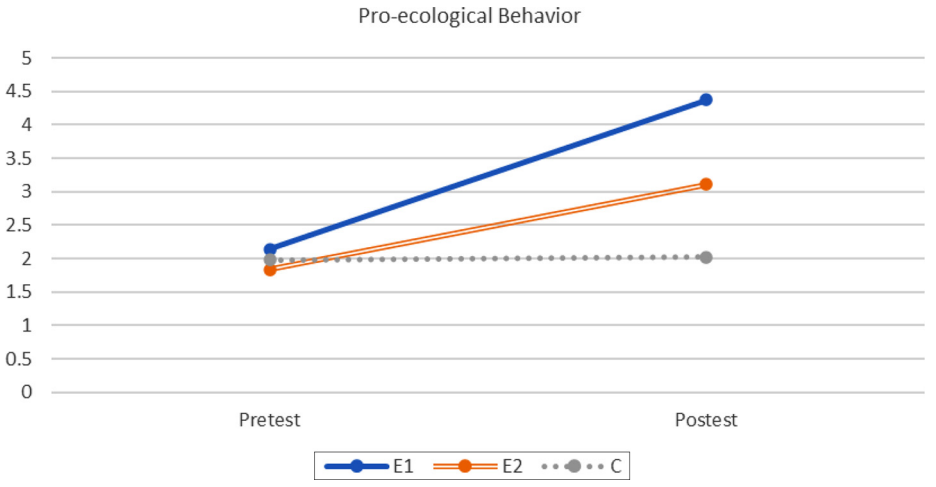

Figure 2.
Evolution of pro-ecological behavior

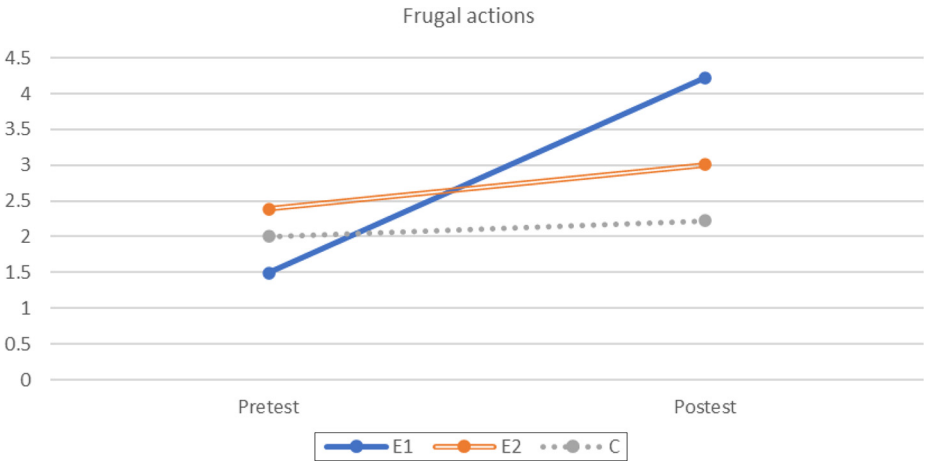

Figure 3.
Evolution of frugal actions

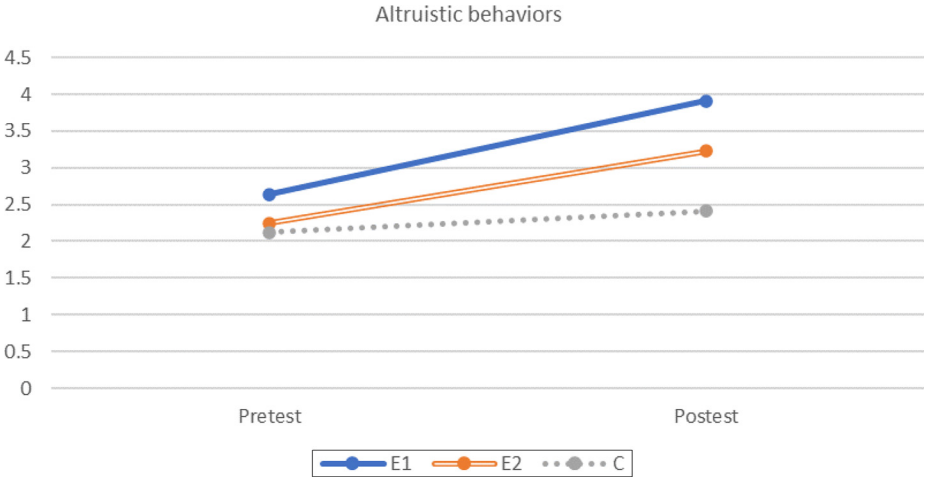

Figure 4.
Evolution of altruistic behaviors

Discussion

The more awareness of sustainable development, the more sustainable behavior will be promoted and the behavioral pattern of individuals will change (Yamane and Kaneko, 2020). Therefore, education is a good way to promote sustainable behavior and improve consumption patterns. Also, The UN put ESD on its agenda in its 10-year policy in 2019 (Hsiao and Su, 2021). Ebersbach and Brandenburger (2020) in their studies pointed out the importance of training and learning in sustainability; Jolink and Niesten (2021) and Scurati *et al.* (2021) applied VR in the field of sustainability, but the distinguishing feature of this study was evaluating the impact of both traditional teaching methods and VR on sustainable behavior in an experimental study and comparing the two approaches. The results showed that to achieve sustainable development and environmental protection, we must pay attention to the field of education and new educational technologies. VR

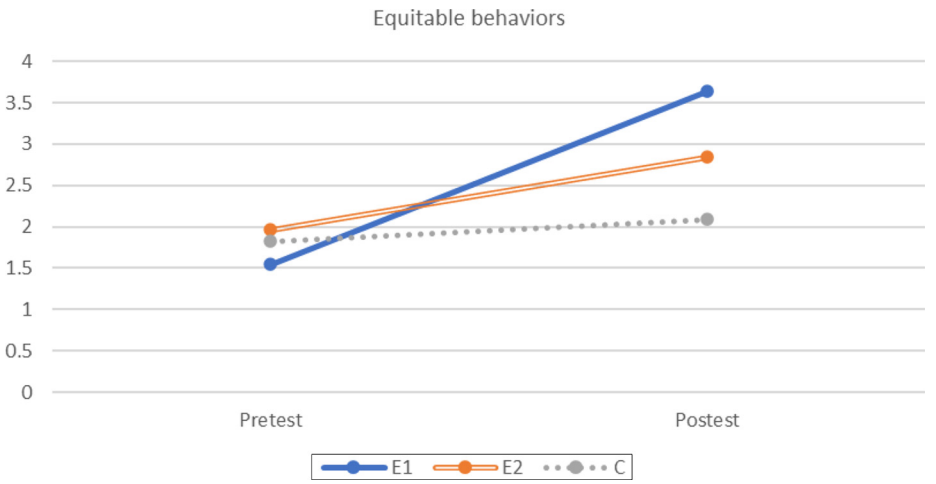

Figure 5.
Evolution of equitable behaviors

Variables	Mean square value	Degree of freedom	*F*-value	Sig.
Between groups	575.762	2	8.076	0.001
Within groups	71.293	102		
Total		104		

Table 5.
Summary of ANOVA of sustainability behavior

i j	E'_1	E'_2	C'_2
E'_1	–	–	–
E'_2	0.001	–	–
C'_2	0.000	0.012	–

Table 6.
Different scenarios using Tukey's test

technology also has a greater impact on learning sustainable behavior than traditional teaching methods. The results of this research are theoretically and practically debatable.

Theoretical implication

In response to *RQ1*, it was found that there has been a difference between post-test and pre-test of the second group of experiments ($t = 3.933$, $p = 0.001 < 0.05$). Also, according to Tukey's test, there has been a significant difference between post-test of experimental groups and control group; thus, it can be claimed that holding training courses would affect individuals' sustainable behavior. Based on this, it can be said that education is one of the factors affecting the sustainable behavior of people. Changing consumption patterns requires educating citizens and improving their knowledge (Scurati *et al.*, 2021). In this study, four dimensions of sustainable behavior were evaluated. Pro-ecological behavior refers to targeted behaviors to protect natural resources and the environment (Corral-Verdugo *et al.*, 2010) and include activities such as recycling, energy storage, soil conservation and water conservation. The results of the study ($t = 3.871$, $p = 0.003 < 0.05$) showed that pro-ecological behavior is changed

under the influence of education. In this regard, Klug and Niemand (2021) believed that the precycling pattern is part of sustainable consumption, he pointed out that this behavior was teachable. Similarly, Mirauda *et al.* (2020) found the effect of training experts in water conservation. The second dimension was frugal behaviors, which was opposed to consumerism. The results ($t = 4.390$, $p = 0.000 < 0.05$) showed that frugal behaviors had a significant change after the training course. Iwata (2002) showed that the factors of consumerist psychology might be changed under the influence of environmental information. Also, Albert (2019) showed the relationship between frugal innovation and sustainability. Altruistic behaviors are concerned with increasing the well-being of others (Tapia-Fonllem *et al.*, 2013). According to the research results ($t = 6.892$, $p = 0.002 < 0.05$), by participating in training courses this motivational state is enhanced. In this regard, Marchetti *et al.* (2021) showed that the primary school children can become altruistic by using the educational course. The fourth dimension was equitable behaviors. The concept of sustainable development is based on justice between different generations. Sustainable development seeks to strike a balance between the interests of today's generation and the achievements of the next generation. The results of the research ($t = 3.212$, $p = 0.001 < 0.05$) showed that the training course can promote equitable behavior. Based on an experimental experiment, Sadker and Sadker (1992) showed the effect of equity training program on students' behavior.

In response to *RQ2*, it can be said that VR technology is an effective tool in teaching sustainable behavior. Compared to the pre-test, the post-test results of the first experimental group ($t = 4.255$, $p = 0.001 < 0.05$) has shown a significant difference. As a result, advances in virtual learning technology such as VR can be considered as the effective factors in changing consumption patterns and protecting the environment. A comparison done of our findings to the findings of earlier studies revealed that Paszkiewicz *et al.* (2021) believed that VR technology had a great impact on people's learning due to its different audio, video and simulation capabilities. Also, Abidi *et al.* (2012) mentioned the concept of learning factory and the use of disruptive technologies such as VR in student education. Banos *et al.* (2006) believed that persuasive technologies like VR can affect people's emotions and thus can change their attitudes. Also, the use of persuasive technology has an effect on energy consumption (Chiu *et al.*, 2019). Lee *et al.* (2020) showed that VR quality factors strongly affect users' psychological perception. Another study confirmed that the use of VR is effective in improving cognitive training in children (Zhao *et al.*, 2021). Scurati *et al.*'s (2021) study also discussed the transfer of knowledge and teaching VR experiences in relation to sustainable behavior in a logical dimension.

To answer *RQ3*, the result of Tukey's test showed that holding a VR-based training course had a greater impact on sustainable behavior than traditional training. Accordingly, the priority of using new educational technologies over traditional methods is approved in the field of sustainability. This finding is due to the fact that VR has advantages over traditional education, such as cost reduction, risk reduction, reproducibility, high control over training procedures and the possibility of self-learning (Bhagat *et al.*, 2016; de Visser *et al.*, 2011). Our results are consistent with a previous study, where Tilhou and Taylor (2020) believed that VR technology brings better educational experiences for students and confirmed the motivational factors of people using this technology. Summerville *et al.* (2005) also noted the importance of using VR in motivating people for sustainable environmental behavior. Such a result was in line with the findings of Tilhou and Taylor (2020) and Summerville *et al.* (2005).

Managerial implication

According to the results of research on the importance of holding training courses in the field of sustainability, it is suggested that environmental policymakers hold training classes

for citizens to familiarize people with environmentally harmful behaviors, how to use natural resources and the concept of sustainable development. Sustainable behavior change among people at different ages is possible through education (Ebersbach and Brandenburger, 2020). Also, considering that the participants of this study were selected from among the students, so including the course on sustainable development and holding related workshops has an important impact on the formation of sustainable behavior of the young generation of society. Manea-Tonis *et al.* (2020) also showed that virtual technologies have an impact on students' culture and learning. Klug and Niemand (2021) believed that the subject of precycling should be considered as educational and academic courses. Another result of the study showed that the use of virtual educational technology such as VR has a significant effect on sustainable behavior and is more effective in learning than traditional classes. Therefore, managers of organizations in line with CSR and environmental policymakers in cooperation with knowledge-based companies active in the field of information technology and VR are suggested to design specialized software in the field of environment so that in addition to specialized training of employees, ordinary people can be able to improve their knowledge using this technology. Also, more effective learning is enabled with the simulation done in this technology. VRLab can reduce the time and cost of operational activities and increase users' knowledge (Mirauda *et al.*, 2020). Due to the corona pandemic, the formation of face-to-face classes has encountered health problems, so the use of virtual technologies in holding training classes is a suitable solution under these conditions. Also, Abad-Segura *et al.* (2020) pointed out the importance of sustainability issues in higher education and universities. According to the research results, it is suggested that the topics of university courses in Iran be reviewed based on education related to sustainable development and teach students courses related to environment and sustainability at different stages.

Limitation and future studies

Considering that the training course in this study was for four weeks, the effect of factors such as educational environment factors and individual factors was not considered, so in future studies, the effect of these factors on sustainable behavior can be evaluated. In this study, participants were selected among young people and students. For future research, it is suggested to evaluate the training course and the use of VR for middle-aged and elderly people and compare the results with this study. Also, in evaluating the research variables, accurate statistical methods were used, which is considered as a research limitation, so for future research, the use of uncertain methods such as fuzzy logic is suggested because it is closer to reality. Another limitation of the research is the selection of Iranians. Considering that Iran is a developing country and is ranked 59th in the field of sustainable development (Sachs *et al.*, 2020), it is recommended to evaluate and compare training courses in a developed country.

Conclusion

Protecting the environment and natural resources and paying attention to sustainable development is one of the concerns of communities. Citizens of society as well as companies need to learn about the right behavior appropriate to the concept of sustainability and attention to their social responsibility. Regarding *RQ1*, the results showed that holding training courses is effective on learning sustainable behavior in people. Also, in *RQ2*, it was found that VR educational technology is effective on sustainable behavior. The results related to *RQ3* showed that classes based on VR technology had a greater effect than holding traditional training classes on learning sustainable behavior among participants. The results of this study

showed that holding training courses and especially the use of virtual technologies in education are suitable strategies for learning sustainable behavior. Due to the economic constraints, holding face-to-face training is usually faced with challenges, and also holding these classes in the corona pandemic conditions is problematic. Therefore, managers and politicians in the field of environment can invest in software design and use of virtual education hardware to conduct training courses related to sustainable development for citizens and experts in this field. In this way, they can pave the way for the formation of sustainable behavior in individuals and also consider social responsibility.

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Appendix. The research questionnaire

Code	No.	Q.	Scale				
Demographic character	1	Please specify your Gender	Male			Female	
	2	Please specify your age	Below 20	20-25	25-30	Above 30	
	3	Please specify your education level	Bachelor's student		Master's student		PhD student
			Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
Pro-ecological Behavior	4	I wait for the full load of the washing machine					
	5	I drive on freeways below 100km / h					
	6	I collect and recycle usable papers					
	7	I throw the empty bottles in the recycling bin					
	8	I am aware of environmental destructive behaviors					
	9	I use convenience foods					
	10	I use products with refillable packages					
	11	I use seasonal products					
	12	I use a clothes dryer					
	13	I am interested in and study environmental issues					
	14	I discuss environmental challenges with my friends					
	15	I kill pests with insecticides					
	16	I turn off the cooling system when leaving the place					
	17	I'm looking for a way to recycle goods					
	18	I encourage friends and relatives to recycle					
	19	I save fuel by walking and cycling					
Frugal Actions	20	If the old models are usable, I will not buy new equipment and devices					
	21	I still use my old clothes					
	22	I am not used to buying jewelry					
	23	I do not buy or maintain several pairs of shoes					
	24	I do not store too much food					
	25	I do not spend much of my income on luxuries					
	26	I often eat homemade food					
	27	I prefer walking to driving in short distances					
	28	I use usable notebooks and papers					
	29	I like the contentment life style					
Altruistic Behaviors	30	I donate my clothes to the poor					
	31	I help the needy and the deprived of the society					
	32	I participate in voluntary activities such as the Red Crescent					
	33	I go to see patients and help them					
	34	I help the elderly and the physically disabled					
	35	I help people find their way and address					
	36	I donate to charities and fundraisers					
	37	I donate blood to patients regularly					
	38	I help and cooperate with my colleagues					
Equitable Behaviors	39	Women should have the same rights as their husbands at home					
	40	In the workplace, employers and managers must treat their subordinates fairly					
	41	Children at home should have the right to decide and comment					
	42	Poor people should also benefit from medical and health services					
	43	In my family, men and women are all involved in household chores					
	44	In society, the workplace and the university, racial discrimination makes no sense					
	45	I treat rich and poor alike					
	46	At university, students and professors are equally important					
	47	The right to education and advancement for girls and boys should be equal					
	48	Natural resources must be evenly distributed throughout the community					