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RESEARCH ARTICLE

Critical thinking in environmental education through digital games among students

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ABSTRACT

In recent years, we have come aware of the importance of digital games-based learning environments among young learners. In order to produce a sustainable environmental education that is interactive, persuasive, and action-oriented, it should be interactive and persuasive. This article explains the insights gathered during the teaching of cognitive knowledge, engaging students emotionally through the demonstration of the consequences of destructive environmental behavior in this article. Many studies show that knowledge acquisition in digital games has a significant impact on collaborative learning compared to individual digital game playing. This method study has been examined among 50 students in a high school in environmental education trend in Jaffa-Tel Aviv, who played a game individually (n = 50), in a collaborative group (n = 40) and in a control group (n = 38). During the designed digital games, the students were asked to complete an open-ended questionnaire to identify their thinking skills. A higher level of attitude learning was observed from games compared to traditional pedagogical methods and pro-environmental behavior was achieved. It is important to continue evaluating the effectiveness of digital games as a learning tool and to identify best practices for their design and implementation in educational settings.

Keywords: environmental education; digital games; game developer; pro-environmental behavior; eco-awareness

1. Introduction

Nowadays, one of the most significant challenges for EE (environmental education) is strengthening professional development for teachers, including pro-environmental attitudes and behaviors. According to Woodhouse and Knapp, environmental and cultural preservation and degradation are addressed through sustainable development education and by focusing on the study of the ecological and cultural integrity of places people inhabit[1]. The ability to understand, listen to one another and live in harmony with one's local environment is essential to the sustainability of culture and the local economy[2].

A combination of relevant technological knowledge and education is required for both workplace and education requirements. An effective teacher's role in facilitating student achievement in the use of technology and technology competence concludes an essential requirement.

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A game-based learning approach is becoming increasingly popular among educators looking for tools for online environments. Learning through play and being exposed to the digital world, in which students already play video games outside of class, is one of the most effective ways for students to learn. One's effective involvement in society depends on one's digital skills, which are related to one's educational level. The aim of this study is to examine how online game generators can be used to create educational games that enhance high-order thinking skills in junior high school students.

This research was conducted as part of a program to promote higher order thinking skills through the incorporation of game generators into learning. The most important concern in this case is that playing computer games takes up (wastes) time that could be spent on schoolwork, free study, or exercise[3]. Furthermore, games promote scientific problem solving which are intrinsically motivating which are therefore suitable for Environmental Studies. Many prior studies using educational games showed that collaborative efforts are more beneficial in learning compared to individual efforts[4], while some studies contradict due to the fact learning outcomes can be influenced by the design of the educational game, including the inclusion of collaborative features and in collaborative settings, some individuals might not contribute fully, relying on others to do the work[5].

This has not been studied in attitudinal learning using environmental education games. A qualitative approach was used in this study to provide an effective pedagogical tool. Students' contributions to game creation were identified by analyzing the documentation.

The findings indicate students' skills and performance have been improved in three main areas: (a) thinking skills and cognitive functioning; (b) performance and behavioral aspects; and (c) emotional aspects. Yet, students with learning disabilities can benefit from online game generators as tools to improve their learning skills, according to the study of Wijers et al.[6]. Teenagers are fascinated with digital eco-games, so they spend a lot of time playing. In fact, these games exhaust both their minds and their bodies as they require a lot of nerve energy and mental focus[7,8]. Teenagers who were exposed to various features of digital eco-games had a tendency to be intrinsically motivated by these eco-games. Even so, digital games play a crucial role in enhancing motivation and immersion in gameplay, especially when they are carefully designed to meet the interests and needs of learners[9]. There is a greater level of anxiety associated with this type of game due to two factors: first, how much time the child spends playing it, and second factor-game characteristics.

Digital games-based learning and attitude change

It has been found that the attitudes of individuals influence environmental decisions in a variety of ways. Attitudes have also been directly linked to behavioral change in a number of studies. Attitudes have been directly related to behavioral change. Furthermore, it is interesting to mention that in addition to broad areas of knowledge (knowledge of issues, knowledge of actions strategies = cognitions) in relation to environmental education, the importance of values, ethics, attitudes and behaviors in pedagogic conditions, thus giving the teaching of environmental education a perspective not always found in other fields[8,10]. Additionally, social learning influences attitudes through interaction with other participants[11]. Due to the fact that many people are eco-aware, but cannot control pro-environmental behaviors, intentions have not been translated into actions. Teaching pro-environmental behavior in the classroom through digital games can serve as a powerful tool for encouraging environmentally conscious behavior among young people. However, educators do not often use games since they consider them too time-consuming and there are not enough devices to accommodate all students. On the other hand, games foster players' knowledge of sustainability issues and make them think and highly motivated about sustainable development strategies.

Furthermore, games often encourage players to take actions that contradict their existing attitudes but

slightly match the target attitudes.

Digital games-based learning (DGBL) is more effective at attitudinal learning than traditional methods because learners are enabling to test their behaviors and see the consequences of non-environmental behavior immediately through the game environment. There is no doubt that digital games-based learning (DGBL) is more effective at changing attitudes[6,12], presented in **Table 1**.

Table 1. TPB measurement model assessment.

Index code	Construct/Indicator (survey items)	Individual (n = 40)		Collaborative (n = 50)		Loading
		Mean	SD	Mean	SD	
Attitude towards behavior (ATB)						
A3	It was an amazing and learning experience for every one as a team.	3.88	0.81	3.41	1.08	0.77
A4	Our team has enjoyed taking part in the development of a digital game.	3.75	1.05	3.05	1.02	0.81
Social pressure (SOP)						
S1	I got stressed not to play for a while to learn more characteristics about the game.	3.58	1.12	2.85	1.40	0.4
S2	My verbal expression has been enriched, and I have acquired new tools in research, in communication that I wasn't aware before.	3.4	1.01	2.55	1.2	0.27
Perceived behavioral control (PBC)						
B2	It is entirely up to me to decide whether to play the game when not in use.	3.08	1.13	3.03	1.28	0.83
B3	When I leave a room, I am responsible for turning off the lights.	3.07	1.05	3.07	1.31	0.72
Behavioral intention (BI)						
BI1	I am interested to plan a flexible learning schedule.	3.75	0.82	3.33	1.1	0.77
BI2	Whenever I am not using my laptop, I intend to turn it off.	3.05	0.88	3.04	1.29	0.81

The game was developed for ESE and used in the two studies: weather changes and pollution in our environment (**Figures 2** and **3**), that included all the three elements of attitudinal learning besides simplifying social learning. Concerning collaboration, when two or more people collaborate, they can collaborate and construct together knowledge while trying to solve an environmental issue. In comparison with individual efforts, collaboration is crucial to promote inquiry learning, problem solving, and critical thinking, as well as enabling students to explain their reasoning. Collaboration in games can be distinguished by two types: (1) team members are able to engage in the virtual space and interact on multi-player multi-modal display screens[4].

Collaboration can also happen virtually in an online game when players are represented within the game. (2) team members engage in the real space to take decisions, while taking turns to operate the mouse to perform actions on the game screen that the team agrees upon[6,13].

Using the theory of planned behavior (TPB) explains that three types of considerations guide any human behavior: (a) an attitude toward a behavior that is influenced by beliefs about its likely consequences (behavioral beliefs) that generates a positive or negative attitude toward the behavior; (b) Perceived social pressure is caused by normative expectations of others; (c) Behavioral control beliefs are beliefs that make us perceive that we have control over how we behave (control beliefs) that arouse to perceived behavioral control (PBC)[14] (**Figure 1**). It was also examined how participants perceived their learning experience during collaborative and individual games (**Tables 2** and **3**).

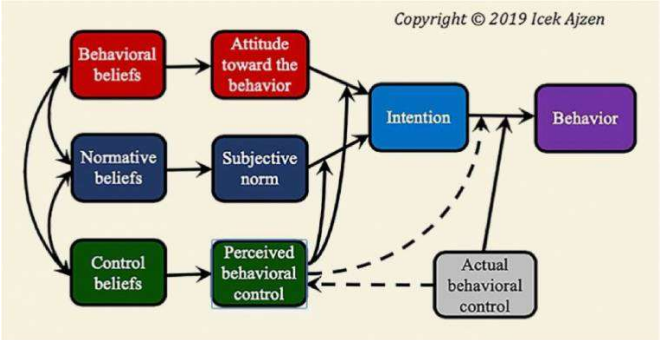

Figure 1. Graphical depiction of the theory of planned behavior[14] model of attitude towards behavior.

Table 2. TPB measurement model assessment (game players vs control group).

Index code	Construct/Indicator (survey items)	Game (n = 90)		Control (n = 38)		Loading
		Mean	SD	Mean	SD	
Attitude towards behavior (ATB)						
A3	It was an amazing and learning experience for every one as a team.	3.96	0.45	3.82	0.90	0.55
A4	We have enjoyed taking part in to develop a digital game.	3.98	0.54	3.91	0.85	0.96
Social pressure (SOP)						
S1	I got stressed not to play for a while to learn more characteristics about the game.	3.28	0.73	2.68	1.15	0.95
S2	My verbal expression has been enriched, and I have acquired new tools while playing such as communication that I wasn't aware before.	3.60	0.90	3.83	0.86	0.43
Perceived behavioral control (PBC)						
B2	Whether or not I choose to continue playing the game when it is not in use is entirely up to me.	3.05	1.06	3.85	0.85	0.81
B3	When I leave a room, I am responsible for turning off the lights.	3.79	0.96	3.18	1.04	0.68
Behavioral intention (BI)						
BI1	I am interested to plan a flexible learning schedule.	4.00	0.66	3.83	0.82	0.84
BI2	Whenever I am not using my laptop, I intend to turn it off.	3.73	0.72	3.98	0.74	0.86
Attitude towards behavior (ATB)						
A3	It was an amazing and learning experience for every one as a team.	4.76	0.45	3.22	0.90	0.55
A4	We have enjoyed taking part in to develop a digital game.	3.98	0.54	3.51	0.85	0.96
Social pressure (SOP)						
S1	I got stressed not to play for a while to learn more characteristics about the game.	3.28	1.03	2.68	1.15	0.95
S2	My verbal expression has been enriched, and I have acquired new tools while playing such as communication that I wasn't aware before.	3.60	0.89	3.83	0.86	0.43
Perceived behavioral control (PBC)						
B2	Whether or not, I choose to continue playing the game when it is not in use is entirely up to me.	3.15	1.06	3.85	0.85	0.81
B3	When I leave a room, I am responsible for turning off the lights.	3.09	1.08	3.71	1.04	0.68
Behavioral intention (BI)						
BI1	I am active socially about environmental sustainability in my neighborhood.	3.96	0.86	3.83	0.82	0.84
BI2	Whenever I am not using my laptop, I intend to turn it off.	3.83	0.72	4.03	0.24	0.86

Table 3. TPB model—Reliability values.

Constructs	No. of items	Composite reliability	Average variance extracted (AVE)
Attitude towards behavior (ATB)	2	0.75*	0.57*
Social pressure (SOP)	2	0.61	0.42*
Perceived behavioral control (PBC)	2	0.81*	0.68*
Behavioral intention (INT)	2	0.83*	0.71*

*Correlation is significant at the 0.05 level.

Multi-Group Analysis was performed to test any differences based on TPB (Theory of Planned Behavior between the game players and control group. Behavior intentions were significantly influenced by attitude towards behavior for those who played the game compared to those who did not play (**Table 3**).

The scheme presents that attitudes and social pressure can moderate the effect of perceived behavioral control (PBC) on intention to predict behavior.

There are three types of behaviors (behavioral beliefs) that produce favorable or unfavorable attitudes toward the behavior (ATB): beliefs about the normative expectations of others (normative beliefs) that cause perceived social pressure (SOP) or subjective norms, and beliefs about whether factors facilitate or impede behavior performance (control beliefs) that lead to perceived behavioral control (PBC).

2. Materials and methods

The purpose of this case study was to test the influences of digital games (when played collaboratively and individually) in promoting pro-environmental attitudes and behaviors, using parts of the theories of planned behavior (TPB)[14].

The objective of this study was to examine any differences between collaborative players and individual players in attitudinal and behavioral learning from a game anticipated for Environmental Studies (EVS) between collaborative game players and individual game players, and between game players and a control group. Participants' perceptions of their learning experience during collaborative and individual games were also examined. Furthermore, a comparative analysis of software environments for teaching the participants by simulation modeling (user-friendly graphical interface-Any logic, Simio simulation software, Arena simulation environment) has been implemented. The software had provided a comprehensive set of tools and features that meet the requirements of simulation modeling or VR/AR design.

An open-source web framework for building VR experiences by using HTML and JavaScript, makes it accessible for students familiar with web development. Yet, participants had to solve the problem on the subject of technical mechanics in using "Scratch" in virtual and augmented reality through the U IN GAME website. The use of scratch enables to create solutions to problems using computers, to study information, to invent and implement algorithms, and to write programs according to the specific topic (**Figure 2**).

Figure 2. "GLOBE plant spreading" is a strategy game for 2 players (https://www.uingame.co.il/scratch-plants).

3. Participants

Using traditional methods of instruction, this research consists methods study that investigated the teaching of Environmental Studies at a high school in Israel. At the first stage, using the theory of planned behavior and the attitude learning instrument, we investigated the efficiency of digital games in influencing pro-environmental behaviors when played collaboratively (n = 40) and individually (n = 50). Secondly, the effectiveness of games in Environmental Studies (EVS) was tested by comparing all game players (n = 50) with a control group (n = 38) that did not play the game. Furthermore, EVS must include all three components of attitude to be effective in producing pro-environmental behavior. This study's quantitative findings were supported by an interview analysis that shed light on game play experience and its influence on attitudes and behaviors.

4. Research questions

- What is the most effective way to influence pro-environmental behaviors through digital games?
- Do digital games work better when played collaboratively or individually?
- How did students perceive their game play experience?

5. Hypothesis

H1: Collaborative players' behavioral intentions are influenced by attitude toward behavior (ATB), social learning for social pressure after three weeks of game play.

H2: Influence of PBC (perceived behavioral control) on INT (behavioral intentions) after three weeks of game play is greater for collaborative players comparing to control players.

H3: Influence of SOP (social pressure) on AFF (affective learning) after three weeks of game play is greater for collaborative players comparing to control players.

6. Game context and activity

One of the most impressive points described by researchers and game developers is to transform and to integrate educational environmental content in game-based contexts, into a fun and engaging activity to learn. Games are developed using a variety of programming languages depending on the platform (console, computer, or mobile) and the scope of the game. Teacher-student materials will be hosted on the U IN GAME website.

This site is approved by the Ministry of Education of Israel for teaching game programming.

Teachers guide their students during the activity:

- They facilitate collaborative work and consult in the game's relevancy to the environmental science issues.
- Teachers do not have to be game developers; they have received a game kit.
- Students develop digital literacy skills through games based on one of these:
- Prior knowledge in game programing.

A kit specially created for environmental contexts guide students step by step to create games in this case clouds identification concerning weather crisis and pollution in our environment (**Figure 3**).

Figure 3. Cloud types Action game. Two players game for students to learn to recognize clouds and their features.

How to get started in game development in several steps

Instructions to start the game:

Step 1: Learn to write code.

The students were exposed to understand the most popular languages (C++, Java, Html5, and Java Script). In addition to writing scalable and robust code, these professionals possess the necessary technical abilities to build these games.

Step 2: Design a small game.

The students' developers have to design their first game by presenting the coding skills they've learned (building a game from scratch) and it is recommended starting with a small JavaScript game as a portfolio once they've finished.

Step 3: Create a game design portfolio (**Figure 4**).

A portfolio is used by students to show people their best and most relevant game designs when they ask for samples. You should ensure your portfolio reflects the field of game design that you're interested in, whether that be level design, systems design, interface design, or another discipline.

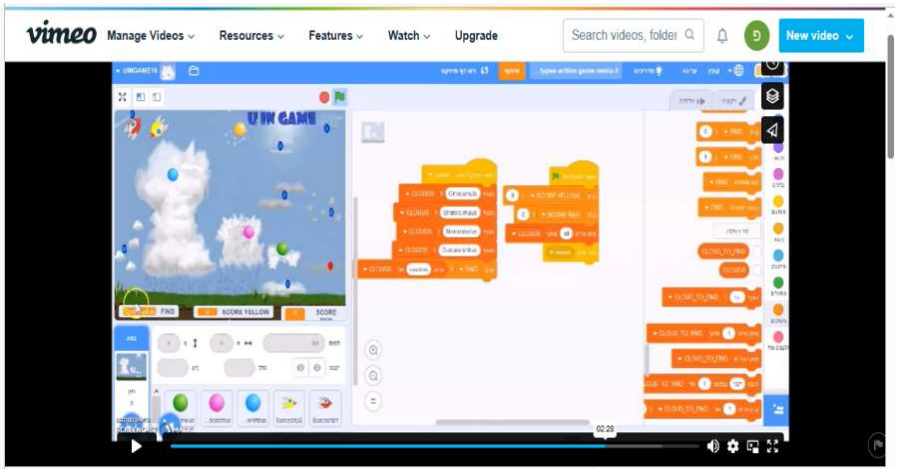

Figure 4. How to create a 4.th cloud in the GLOBE cloud types game on Vimeo.

7. Results

Individual vs Collaborative A3, A4 are index survey items in the TPB survey, related to attitude towards behavior (ATB), S1 and S2 for social pressure (SOP), and B2 and B3 for perceived behavioral control (PBC).

ATB, SOP and PBC explain the behavioral intentions (BI) after four weeks of playing the game. I1 and I4 are indicator survey items for BI (behavior intentions).

With the TPB, individual and collaborative game players' data were combined (n = 90) and compared with the control group's data (n = 38) in order to investigate pro-environmental behaviors on the part of game players and the control group. The sample size, item reliability, internal composite reliability, construct validity, and discriminant validity were based on the measurement model.

A comparison of Spearman Correlation Coefficients for individual and collaborative tasks according to TPB Measurement Model Assessment is shown in **Table 1**.

In order to demonstrate the extent to which construct measures were converging, the average variance extracted (AVE) values were higher than the recommended value of 0.50.

Several pieces of evidences were collected: (1) Observations when participants played digital games such as weather changes and pollution in our environment, (2) Interviews conducted after the surveys and scorecards generated at the end of the game. Participants were selected for interviews based on their scores and gender. Five girls and five boys, each gender had one high scorer and one low scorer were selected from both individual and collaborative groups (n = 10). All interviews were stored on password-protected computers.

Results and validity

Using a variety of data, including surveys, interviews, and digital artifacts, to analyze and report on the study ensured data triangulation[6,9,13].

Multi-group analysis was performed to test any differences based on TPB (theory of planned behavior) between the game players and the control group.

Behavior intentions were significantly influenced by attitude towards behavior for those who played the game compared to those who did not play (**Table 4**).

Table 4. TPB measurement model results (game players vs control group).

Hypotheses	Path coefficients	Path coefficient difference (game vs control)	*p* value (game vs control)	Accept/reject hypotheses
H1	ATB > INT	0.82	0.00**	Accept
H2	PBC > INT	0.15	0.43	Reject
H3	SOP > AFF	0.51	0.17	Reject

ATB—Attitude towards behavior
INT—Behavioral intentions
AFF—Affective learning
PBC—Perceived behavioral control
SOP—Social pressure
**Correlation is significant at the 0.01 level.

Collaborative players read and discussed instructions in the game from beginning to end, expressed complete engagement, and discussed their strategies from the beginning. As they discuss minor decisions and laugh at mistakes, they read the instructions and information on the game screen. In social learning, when a member performs a wrong action by mistake, the other points it out to oppose it. Team members supported each other's efforts as a result of active communication, which improved information processing.

They have collaborated with other teams as well, to present a new compensation they had gained. The classroom was active due to discussions, and players have enjoyed. Furthermore, I have been revealed to analyze information from the game helped the players to change decisions by seeing the impact of their decisions instantly during the game. Participants have learned that human activities on nature were harmful "because it would have a strong impact on climate changes".

They were worried about environmental pollution (air pollution, soil pollution, water pollution and other

environmental hazards). Performing an action that was detrimental to the environment lowered scores, changed the color of the tree icon, changed the smiley faces from happy to sad, and resulted in other indicators showing a negative outcome. Monitoring these indicators constantly enables players to decide whether to continue with their actions or correct their mistakes immediately. Ultimately, due to the mentioned results, we can understand that only the first hypothesis has been accepted: (ATB > INT = 0.82 Path coefficient difference: Game vs Control). This result emphasizes that the game has shown cognitive learning and has emotionally overwhelmed participants, to be connecting them to reality. Collaboration was used to make decisions when environmental resources were depleted and actions were reversed to find friendly solutions and minimize the damages. On the other hand, individual players were totally engaged in the game although most of them played the game before reading the instructions thoroughly have showed frustration when their actions did not produce the desired results. During play, they looked at the monitors and tried reversing their actions.

The roles they played were taken seriously. In the classroom, there was minimal noise and little interaction. They have understood that wrong actions produced undesirable effects on the environment as was indicated by the monitors. By doing this stage, they were able to take corrective action as soon as possible.

We can summarize that according to our findings, both groups showed similar attitudes and behaviors, even though they strategized differently. Collaboration with team members, sharing knowledge, participating in joint actions, and reflecting on actions with each other increased the fun and learning experience. There was a serious commitment to the role played by each player and they relied on their own judgment and knowledge to succeed. Taking first-person perspectives immersed them in the game. Each participant mentioned different learning outcomes from the game, several learning outcomes were mentioned by participants, demonstrating that a single game can incorporate several lessons. All participants mentioned the harmful environmental effects of human-caused (anthropogenic) activities. Actually, the participants from the three groups are able to express their responsibility towards their near environment after being exposed to digital environmental games and pedagogy, depending on what is taught in Environmental Studies (EVS), and personal behavioral options.

8. Discussion and implications

This study has clearly presented that gaming as an industry has an economic gain that has been persistently increasing in different disciplines, especially in environmental education. Games cannot be considered as the only educational tool for ESE (Environmental Sustainability Education) due to the fact the use of games enhances learning when they are supervised and managed by instructors. Actually, when selecting a game for a class, instructors have to test if the game is adjusted to the objectives of the specific discipline. The purpose of using games is to keep the players focused on learning goals and avoid prompts that could lead to a more critical approach to sustainability issues. In this study, PBC (perceived behavioral control) facilitates SOP (social pressure) and ATB (attitude towards behavior). An impact on behavioral intentions for all game players combined that is statistically significant.

A quantitative analysis showed that perceived behavioral control (PBC) predicts behavior or an individual's perception of their ability to perform a given behavior, depending on the factors that may facilitate or delay it[14]. Regardless of how weather changes and pollution in our environment games were played, collaboratively or individually, since the game acted as objects-to-think-with, attitude towards behavior (ATB), social pressure (SOP) and perceived behavioral control (PBC) all influenced pro-environmental behavioral intentions (INT)[15]. These games have fostered players to believe and be motivated that players were actively engaged in successful pro-environmental behaviors within each game, which improved their perceived control (perceptions of external barriers to behavior) and self-efficacy (confidence in their ability to perform behaviors)[14,16].

Before playing these games, the presence of social pressure and pro-environmental behaviors were not achieved. Furthermore, at the first stage, participants believed that they did not have the ability to make a meaningful step. However, after playing, they believed that even small actions could have significant consequences on their environment.

According to Ajzen[14], PBC (perceived behavioral control) produces behavioral intentions that can anticipate actual behaviors. This indicates that "how weather changes and pollution in our environment" were positively influenced by individual and collaborative game players that promoted pro-environmental behavior. Considering the game players and the control group (who were exposed only to traditional instructional methods of EVS-Environmental Studies): according to game players, beliefs about the consequences of the behavior caused a favorable attitude toward the behavior and influenced behavioral intentions (pro-environmental behaviors (ATB)) significantly more than a control group.

Since this study had measured not only cognitive knowledge gain, but also affective, behavioral, and social learning from games, this could be a unique study for attitudinal learning from games. Furthermore, games were more effective in EVS-Environmental Studies than traditional methods according to the theory of planned behavior, although no differences were found in the prediction of behavioral intentions across the three groups.

The findings are useful for implementing attitude learning games in classes where there is a lack of technology facilities versus the number of students. Interviews have presented that all game players believed that fast-paced construction activities showed rapid development, before playing "how weather changes and pollution in our environment" games. However, these environmental games have shown the participants that loss of green cover, plant growth depended on abiotic environmental factors, and weather changes activities affect the environment and citizens' satisfaction. Both collaborative and individual game players have mentioned the effects of climate change, its causes, and how they can reverse its harmful effects. Therefore, the participants players have expressed their anxiety towards extreme precipitation events that can disturb plant growth, and make plants more vulnerable to flooding and soil erosion.

Players attempted to foster an eco-friendly lifestyle in each game; they were able to see the resulting results immediately, so that participants plan to adopt more eco-friendly practices in their everyday lives. It is important to mention that collaborative players felt a sense of insurance while learning together as beginners, while talking and thinking aloud, and hence had more fun[17]. There are times when one player misses a clue when using the game screen, so that discussions helped social learning[18]. Using the partner's expertise in information processing, we were able to strategize more effectively. As part of the team, members also provide verbal cues that guide the action and share the total working memory resources that are required for the task at hand[19,20].

9. Conclusions and future research

In this case study, digital technologies provide opportunities for enhancing teaching and learning and can improve the professional development (PD) of participants and educators too. Rather than accumulating knowledge, education focuses on what people do with that knowledge, and for that reason, attitudinal instruction should provide learners with experience of actions and consequences. This study emphasizes that gaming on environmental topics was shown to be a more effective way to influence pro-environmental behaviors than traditional EVS (Environmental Studies) training. Within a game, action can be taken visually, decisions can be made, actions can be performed virtually, and results can be seen and understood[9,21–24].

This is difficult to perform in traditional EVS (Environmental Studies) instruction. In both collaborative

and individual eco-games, attitudes were changed and pro-environmental behaviors were influenced by the game. According to the results, collaborative players are more likely to use social learning, while individual players are more likely to use perspective taking. While designing a game intentionally can help educators incorporate meaningful lessons into one game, all of them experienced attitudinal learning from the game covering different aspects, showing that it is possible to combine meaningful lessons into a game in an intentional manner. It can be cocluded that "how weather changes and pollution in our environment" games enhanced players' eco-awareness and saturated them in an authentic plot that allowed them to see the implications of their actions shortly.

It would be helpful to replicate the structural model based on the theory of planned behavior, as well as measures of attitude learning based on the attitudinal learning instrument in future research. Besides the need to assess prior attitudes, this study needs more information regarding attitudinal learning and behavioral intentions that would have been helpful for developing an assessment of attitudinal learning and behavioral intentions.

It would be interesting that games could be evaluated to determine their effectiveness in producing durable behaviors; longitudinal studies are needed that observe participants' behaviors rather than rely on self-reports. The use of computer games as a pedagogical tool for teaching students about the proper attitudes and behaviors toward the environment makes sense as these games become more popular.

After completing the program, the students were asked to fill out an open-ended questionnaire aimed at identifying how they used their thinking skills. According to the findings, students used higher-order thinking strategies such as decision-making, problem solving, reflection, investigation, and creativity during the program.

"Decision making" is the most significant found category. Study results show that game generators enable users to apply diverse thinking skills. Digital technologies that provide opportunities for enhancing teaching and learning can improve the professional development (PD) of educators.

After completing their professional development (PD) program for "Adapting the Education System to the 21st Century", 174 Israeli ICT leaders shared what they had learned about themselves as self-directed learners during the PD (professional development) program. Ultimately, we can conclude that games provide a transformative pedagogy that makes them more persuasive in ESE (Environmental Sustainability Education) than traditional instructional methods.

Author contributions

Conceptualization, FAH; methodology, AJLS; software, formal analysis, investigation, FAH; resources, VAG and AJLS; writing—original draft preparation, FAH; writing—review and editing, VAG and FAH; visualization, FAH; supervision and guidance, VAG and AJLS. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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Appendix

20 Items defining different types Of attitudes among 90 students

1. I have been enriched to plan new ideas about environmental sustainability. **Attitude towards behavior (ATB)-A1**.

2. The topic of environmental sustainability is very exciting and creative for me. **Attitude towards behavior (ATB)-A2**.

3. It was an amazing and learning experience for every one as a team. **Attitude towards behavior (ATB)-A3**.

4. We have enjoyed taking part in to develop a digital game. **Attitude towards behavior (ATB)-A4**.

5. I feel more expert about environmental sustainability. **Attitude towards behavior (ATB)-A5**.

6. I have learnt something new concerning to environmental sustainability. **Attitude towards behavior (ATB)-A6**.

7. Collaboration with team members, sharing knowledge, and reflecting on actions with each other increase learning experience. **Perceived behavioral control (PBC)-B1**.

8. My decision to stop playing the game when not in use is entirely my own. **Perceived behavioral control (PBC)-B2**.

9. I am responsible for turning off the lights when I leave a room. **Perceived behavioral control (PBC)-B3**.

10. As a person who is passionate about environmental sustainability, I am comfortable discussing it with others. **Perceived behavioral control (PBC)-B4**.

11. "How weather changes and pollution in our environment" games have upgraded players to eco-awareness where they immediately see the consequences of climate crisis into actions. **Perceived behavioral control (PBC)-B5**.

12. I got stressed not to play for a while to learn more characteristics about the game. **Social pressure (SOP)-S1**.

13. My verbal expression has been enriched, and I have acquired new tools while playing such as communication that I wasn't aware before. **Social pressure (SOP)-S2**.

14. It is very difficult for me not to leave the computer running after a while in order to save energy. **Social pressure (SOP)-S3**.

15. I connect with other people regarding environmental sustainability. **Social pressure (SOP)-S4**.

16. I intend to plan a flexible learning schedule. **Behavioral intention (BI)-I1**.

17. It is my intention to turn off my laptop when I am not using it. **Behavioral intention (BI)-I2**.

18. I feel I have developed an environmental responsibility while I have spent several hours while playing digital game. **Behavioral intention (BI)-I3**.

19. I feel enthusiastic to keep a less polluted environment. **Behavioral intention (BI)-I4**.

20. I am active socially about environmental sustainability in my neighborhood. **Behavioral intention (BI)-I5**.