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Digital Escape Rooms: A Resource for Environmental Education

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Abstract: Today's adolescents represent an elective target in addressing environmental challenges. Education is a key factor in achieving a sustainable future for them. However, formal education can represent a challenge when youths are its target, as they are considered the "interactive generation". Game-based learning, and, in particular, Digital Educational Escape Rooms (DERs), have emerged as innovative methods in education, with promising applications in environmental sustainability studies. In this study, we developed 14 Digital Escape Rooms using the Social Cognitive Theory of Bandura as a theoretical framework. These were focused on environmental education and we tested them on a sample of 411 students (aged 12–18 years; 158 female, 38.4%). A one-group quasi-experimental research design was adopted, carrying out a pre-test post-test analysis. Each participant completed assessments at two time points: before engaging in the escape rooms (T0) and after (T1). The assessment tools included the Goal Assessment Scale (GAS) and the Perceived Climate Self-Efficacy Scale. Our findings revealed no significant gender differences in goal achievement. However, at T0, females exhibited higher levels of perceived climate self-efficacy in both individual and collective dimensions. Instead, the Digital Escape Rooms appeared particularly effective in increasing self-efficacy among male participants. These results suggest that Digital Escape Rooms hold potential for enhancing environmental self-efficacy, although gender differences in baseline efficacy levels warrant further exploration.

Keywords: digital escape rooms; adolescence; pro-environmental behavior; gender differences; perceived climate self-efficacy

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1. Introduction

Environmental issues represent an urgent challenge for current and future generations [1]. These challenges include global warming, acid rain, ozone layer depletion, pollution, the destruction of natural resources, soil degradation and desertification, and loss of biodiversity (e.g., [2–4]). Today's youth—aged between 10 and 24 years—are a prime target for addressing environmental problems for many reasons. This age group comprises 1.8 billion people, accounting for a quarter of the world's population [5]. Young people are inheriting unprecedented environmental challenges that will significantly impact their lives [6].

Youth who are open to new experiences and change [7,8] are well-positioned to address environmental challenges: they actively seek information from a variety of sources, particularly the media and social networks, which increases their awareness of the impacts of climate change and other environmental threats [9]. Furthermore, this demographic is

increasingly recognized not as passive recipients of adult initiatives but as empowered actors capable of changing the community and demonstrating competent citizenship [10]. In particular, youth have taken an active role in decision-making, becoming important drivers of environmental behavior change [11], such as through the adoption of pro-environmental behavior (PEB). PEB can be promoted through the dissemination of pro-environmental knowledge that encourages more sustainable behaviors and lifestyles at home [12,13]. Presenting oneself as an example of PEB can influence the ability to model other people's behavior and thus influence the decision to adopt PEB in other subjects, among peers, in the family, and in communities [14,15]. In fact, people tend to engage in more PEB when they feel supported by others [16–18].

Another important prerequisite for PEB is self-efficacy, the belief in one's ability to make a difference, also known as self- and collective efficacy beliefs [19].

1.1. The Role of Self-Efficacy in Pro-Environmental Behavior

Bandura [20,21] assumes that self-efficacy exerts a considerable influence on the individual through four primary processes. Firstly, self-efficacy influences the way in which individuals approach thinking, goal setting and problem solving in relation to cognitive processes. Individuals with high self-efficacy visualize successful outcomes and pursue a problem-solving approach, whereas individuals with low self-efficacy focus on possible failures. Secondly, motivational processes are characterized by self-efficacy, which increases intrinsic motivation. It influences the efforts individuals are willing to make, their perseverance in the face of challenges and their resilience after setbacks. Thirdly, self-efficacy controls affective processes, as people with high self-efficacy are better able to deal with stress, fear and anxiety and see challenges as an opportunity rather than a threat. Finally, decision-making processes are also influenced by self-efficacy, as people with high self-efficacy are more likely to engage in challenging activities and environments, while people with low self-efficacy tend to avoid difficult tasks.

Research has shown that people with stronger self-efficacy beliefs are more likely to engage in PEB aimed at mitigating environmental challenges, such as reducing waste, conserving energy, or participating in sustainability initiatives [22–24]. Adopting PEB increases positive feelings, creating a virtual cycle: when people adopt PEB, they feel more efficacious, experience more positive feelings and tend to repeat PEB [25]. This is particularly important for the youth, who need to build resilience, as they are the ones who face the impact of the human footprint on the environment [15,25–27].

1.2. The Role of Education and Game-Based Learning in Pro-Environmental Behavior

Environmental education is a key factor in realizing a sustainable future [28]. Environmental education specifically aims to promote changes in attitudes and behaviors, encourage the adoption of PEBs (i.e., a person's conscious action to minimize impact on the natural world in the name of environmental protection), and develop a sense of ethical and social responsibility [29]. However, formal education on this topic is not without its challenges [30]. These include the prevalence of one-way communication models that fail to actively engage young people, a lack of critical pedagogy reflected in insufficient spaces for reflection and discussion about alternative lifestyles, and a lack of participatory opportunities that enable deeper learning (e.g., [31,32]). The difficulty of effectively linking content and pedagogy to young people's behavior changes suggests that environmental education should explore new approaches [33]. Aguaded-Gomez [34] coined the term "interactive generation" to describe today's generation, emphasizing their tendency to use new and less formal communication structures. In order to raise awareness of environmental and social challenges and prepare people to actively participate in seeking viable solutions, there is an urgent need to develop innovative educational tools. These tools should incorporate different perspectives and dimensions and combine different learning and teaching approaches, including non-formal ones.

The use of Game-Based Learning has emerged as an innovative pedagogical method that aims to overcome many of the traditional educational barriers and thus increase student engagement [29,35]. This approach involves a fundamental redesign of the teaching and learning experience through the use of games, creating a meaningful correspondence between game elements and learning objectives. The advantages of using games in education are manifold: they allow content to be adapted to different learning speeds, permit mistakes while providing immediate feedback, encourage creativity, and improve motivation and socialization [36]. Given these benefits, games have attracted great interest from both researchers and educators [37].

Educational escape rooms are currently one of the most studied pedagogical tools developed in the field of Game-Based Learning, and their application in environmental education is promising. Fotaris and Mastoras [38] emphasize the growing popularity of escape rooms in educational contexts, which is reflected in the increasing scientific attention [36]. Their digital implementation (Digital Escape Rooms, DERs) has become even more attractive since the pandemic [37]. DERs were originally developed for recreational use and to challenge players to work together to find clues, solve puzzles and complete tasks in order to "escape" from a scenario within a certain time [39]. They are usually conducted in groups in a cooperative manner and involve solving riddles or puzzles to escape a fictional situation [40,41].

While DERs are usually aimed at college and professional audiences [37], research on their effectiveness in addressing environmental problems—especially in youth and with regard to gender differences—is still scarce. Our work aims to fill this gap and explore the effectiveness of DERs when used as an environmental education tool to improve PEB in youth. Specifically, we are interested in assessing the effectiveness of DERs on perceived self-efficacy and collective efficacy, with particular attention to gender differences.

1.3. Current Study

This study is part of a larger project called "escapeTOlearn". The project was funded by the University of Torino as part of the 2021/2022 call for public engagement and is related to research activities on the sustainable use of resources. The overall project aims to experiment with an environmental education tool (DER) and involve students from the first to twelfth grade. The goal of this research is to better understand the effects of fruition of DERs dealing with the sustainable use of resources on the adoption of PEBs. A first hypothesis is that knowledge acquired by students who play with DERs designed in this project can affect their PEBs, promoting their adoption.

The Social Cognition theory of Bandura [20,21] was considered as a framework in designing DERs. According to this theory, four key sources contribute to the development and reinforcement of self-efficacy beliefs. First, mastery experiences are the most impactful source, as personal success in achieving goals strengthens self-efficacy, while repeated failures can undermine it, particularly if they occur before a strong sense of efficacy has formed. Second, vicarious experiences—observing others, especially peers or relatable role models, succeed—can enhance self-efficacy, particularly when the observer perceives the model as sharing similar abilities or background. Third, verbal persuasion from trusted individuals, such as positive encouragement or constructive feedback, can elevate self-efficacy, whereas negative feedback may diminish it. Finally, physiological and affective states also play a role, as positive emotional and physical conditions can bolster self-efficacy, while anxiety, fear, or excessive stress can weaken it, with individuals often interpreting their physical and emotional states as indicators of their competence in specific tasks. DERs were developed taking into account these four sources, because they promote:

- A mastery experience, as when students successfully complete tasks and overcome challenges posited by DERs, they reinforce their belief in their own abilities;
- A vicarious experience, because they were played collaboratively within small groups;
- Verbal persuasion thanks to automatic feedback given at the end of each task of the DER;

- Physiological states, because the immersive nature of these environments raises physiological arousal—such as increased heart rate, adrenaline, and heightened focus—through the use of time constraints and complex problem-solving tasks. In parallel, the affective responses are triggered in terms of positive emotions like satisfaction, pride, and excitement.

Gender differences were also taken into account, as the literature indicates that males and females perceive the environment differently and implement PEBs differently. For example, as described by Swim et al. [42], PEBs that focus on household behaviors, such as recycling or buying sustainable food, align more closely with traditional household roles. Consistent with the gender role conformity predicted by Social Role Theory, females were more likely than male to participate in the three household PEBs examined in the study by Hunter et al. [43] in 22 countries. Moreover, a study conducted by Li et al. [44] in China found that females tend to be the more environmentally friendly, generally caring more about the environment and performing more PEBs. In addition, data from a study by Correia et al. [45] showed that there is a gender difference in attention to communication about PEB: females are more attentive to PEB communication than males, provided they have the same attitudes and regardless of education level. Thus, another hypothesis is that the use of DERs in formal education can reduce the gap between females and males concerning attitudes towards the environment.

To test these hypotheses, a survey was conducted on individual goals and perceived self- and collective efficacy before (T0) and after the administration (T1) of DERs.

2. Materials and Methods

Fourteen different DERs were developed for the targeted age group (available at http://www.escapetolearn.unito.it/, accessed on 15 May 2024). The level of difficulty of the DERs was tailored to the educational level of the students [36]). The topics of the DERs are sustainable production and consumption (waste prevention and management) and the economic impact of environmental sustainability. Each DER was carefully designed to be self-sufficient: this is a crucial design feature, as it ensures that each DER contains all the essential knowledge and information that participants need to engage with and complete the activities independently. All DERs were implemented on the ThingLink platform, thus facilitating autonomous learning and promoting critical thinking among students. Additionally, the selection of topics for these DERs was a collaborative and thoughtful process. Before presenting them to the participants, we consulted extensively with the teachers at the participating schools. This collaboration was critical to ensure that the selected topics aligned with the current curriculum and educational needs of the participants and were tailored to the specific context of each school.

2.1. Participants

Four comprehensive schools in Piedmont (a region in north-western Italy) were involved in this project. The activity was part of the training activities approved by the school management. School principals were contacted by phone to present the project and organize interactive sessions in the schools. Although a total of 601 students participated in the general project, this study focused on 12- to 18-year-old students in secondary lower and upper schools, as they play an important role in the decision to implement PEBs. Our final sample consisted of 411 students (158 females, 253 males).

2.2. Measures

To analyze whether the developed DERs were effective in increasing efficacy (self- and collective) in taking measures to mitigate the impact on the environment (e.g., adopting PEBs), we used a questionnaire. The first part contained questions on the participants' motivation to participate in educational activities and their perceptions of self- and collective efficacy. The final part of the questionnaire included questions on demographic data, including gender and age. Parental permission was asked for filling out the survey.

The Goal Assessment Scale was used to measure the participants' motivation to participate in educational activities. The GAS is a method of scaling goals that is widely used as an outcome measure and is ideal for comparing outcomes between different groups with different abilities and needs [46]. It has also been used successfully in education [47,48]. People who set goals for themselves are more likely to achieve them than those who are given goals [49]. Unlike typical goal setting, where a goal is either achieved or not, the GAS process involves envisioning a range of possible outcomes for a given goal using a five-point scale: (1) baseline, (2) less than expected outcome, (3) expected outcome, (4) more than expected outcome, and (5) much more than expected outcome. In this study, participants were able to choose 1 to 3 options from a predefined list of ad hoc goals (see Table 1).

Table 1. Goals indicated in T0 by participants. Participants could enter 1 to 3 choices.

Goals	Male (n = 253)	Female (n = 158)
GAS_1 Doing something new	134	60
GAS_2 Knowing better what to do for the environment	114	95
GAS_3 Finding out what we can all do together to reduce our impact on the environment	103	85
GAS_4 Getting information about how to use environmental resources	110	68
GAS_5 Finding out what I can do to reduce my impact on the environment	117	51
GAS_6 Knowing about the impact humans have on the environment	56	56
GAS_7 Knowing what an Escape Room is	76	43

Note: GAS = goal attainment scale.

The perceived climate self-efficacy scale was used to assess the participants' perceptions of their self- and collective efficacy. The scale, developed by Doran and colleagues [50,51], consists of five items on perceived self-efficacy (SE) and five items on collective efficacy (CE). Respondents are asked to indicate the extent to which they agree with a number of statements. For example: "I trust that I can do my part to solve the climate crisis" or "I trust that we as young people can contribute to solving the climate crisis". The possible answers ranged from "strongly disagree" (coded as 1) to "disagree" (coded as 2), "neither agree nor disagree" (coded as 3), "agree" (coded as 4), and "strongly agree" (coded as 5). In this study, the Cronbach's alpha for self-efficacy was 0.76; the Cronbach's alpha for collective efficacy was 0.67.

Statistical analyses were performed using SPSS statistical software, version 28 (IBM, Armonk, NY, USA). Descriptive measures (frequencies, means ± SD) were calculated for all test variables. To assess the significance of differences between males and females, χ^2 tests were used. The eta value was calculated to estimate the effect size. The *t*-test was performed to assess the statistical significance of the goal, self- and collective efficacy in the T0 and T1. Correlation analysis was performed between self- and collective efficacy in T1 ($p < 0.05$ was considered significantly different). A simple linear regression was used to analyze which variables were the best predictors of self- and collective efficacy (scores were recorded as binary variables according to the average values of the cases). Self- and collective efficacy were considered as dependent variables, while motivation was used as an independent variable. Statistical significance was set at $p < 0.05$.

2.3. Ethical Considerations and Procedure

This research complies with the provisions of the Declaration of Helsinki [52], and all ethical guidelines required for the conduct of research involving human subjects were followed, including compliance with Italian legal requirements for the study and the rules of the Code of Ethics of the Order of Italian Psychologists. After approval by the Ethics Committee of the University of Turin (protocol number: 0230657), data were collected between May and October 2022 by researchers and research assistants who were trained for the project.

The process began with the obtaining of informed consent from each participant, followed by the completion of an ad hoc questionnaire to collect demographic data. Participants then completed all the questionnaires described above. This initial assessment (T0) took place before they engaged with the DERs. In a second phase, participants interacted with the DERs. After completing this activity, the questionnaires (T1) were administered again to assess any changes in their perceptions and attitudes. In each class, two or more tutors, who were part of the research team, instructed participants on how to use the DERs on the available devices (computers, cell phones, or tablets) and emphasized the importance of collaboration and data collection [37].

Participants were divided into small teams of no more than three to maximize participation and collaboration. This approach was intended to enhance the learning experience by encouraging interaction and collaborative problem solving among participants. Each questionnaire session, both T0 and T1, lasted approximately 10 min. The entire activity, including the introduction to the project and game modes, the questionnaire sessions, and the game time, was limited to a maximum of two school hours (approximately 90 min). The time spent with each class averaged 240 min and included the pre-game introduction phase, game time, and post-game debriefing time. The time spent on the game does not appear to be related to specific educational levels or content areas [37]. Since the disadvantages of using games educationally include the risk of potentially excessive competition and inadequate time management [53], we decided to make the game time flexible and to promote a positive game experience.

3. Results

In Figure 1, there is an example of DERs with a task to compile the waste (organic and non-organic), while in Figure 2 there is a photo with a group of participants.

Figure 1. Example of a task to be solved in a DER on waste recycling. The DER in question was about the correct placement of materials in the waste collection. The illustration says: "Organic waste not organic waste. Task: Assign the different materials and substances to the correct group".

Figure 2. A group of participants playing with a DER of EscapeTOlearn.

In T0, the participants indicated which goals they were pursuing with their participation in the activity. Overall, the majority of the participants indicated the goals "Doing something new", "Knowing better what to do for the environment", and "Finding out what we can all do together to reduce our impact on the environment". Male participants indicated "Doing something new", "Finding out what I cand do to reduce my impact on the environment", and "Knowing better what to do for the environment". Female participants indicated "Knowing better what to do for the environment", "Finding out what I can do to reduce my impact on the environment", and "Getting information about how to use environmental resources". Table 1 lists the objectives in order of frequency. It was also found that there was a statistically significant difference between males and females for the goal "Knowing better what to do for the environment" ($\chi^2 = 5.73$; $p = 0.012$; $\eta = 0.207$).

A *t*-test was conducted to examine gender differences in perceived self-efficacy and collective efficacy and PEB at T0. As can be seen in Table 2, females gave a higher value than males for both self-efficacy and collective efficacy.

Table 2. Self- and collective efficacy and PEB in participants in T0.

	Male (*n* = 253) (*M, SD*)	**Female (*n* = 158) (*M, SD*)**	***t***	***p***
SE	18.70 (3.47)	20.20 (2.47)	−5.09	0.001
CE	19.23 (6.36)	20.77 (2.70)	−3.38	0.001

Note. SE = self-efficacy; CE = collective efficacy; *t* = *t*-test.

In T1, we asked participants to indicate whether the stated goals were achieved or not. The results in Table 3 show that the goals were achieved overall and, in the most part of cases, exceeded expectations (4 and 5 score). It is interesting to note that there were no gender-specific differences in the responses.

Table 3. Goals achieved by participants in T1. Values expressed in percentages.

	Male (*n* = 253)					**Female (*n* = 158)**					χ^2	*p*	η
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**			
GAS_1	1	1	11.5	27.9	58.7	1.7	1.7	10.9	33.3	52.3	1.65	n.s.	0.077
GAS_2	0	1.8	11.8	40	46.4	0.6	3.8	21.8	39.7	34	7.75	n.s.	0.171
GAS_3	4.1	9.3	18.6	32	36.1	1.7	7.4	24	23.1	43.8	4.49	n.s.	0.143
GAS_4	0	1.9	15.4	33.7	49	1.8	2.9	16.5	39.4	39.4	4.11	n.s.	0.122
GAS_5	0.9	9.4	15.1	31.1	43.4	2	3.4	22.8	30.9	40.9	6.32	n.s.	0.157
GAS_6	3.4	2.2	18	36	40.4	1.6	2.4	20.2	46.8	29	4.25	n.s.	0.141
GAS_7	2	1	20.4	35.7	40.8	0.8	2.3	25.8	34.4	36.7	2.67	n.s.	0.098

Note: GAS_1 = Doing something new. GAS_2 = Knowing better what to do for the environment. GAS_3 = Finding out what we can all do together to reduce our impact on the environment. GAS_4 = Getting information about how to use environmental resources. GAS_5 = Finding out what I can do to reduce my impact on the environment. GAS_6 = Knowing about the impact humans have on the environment. GAS_7 = Knowing what an Escape Room is. Values: 1 = baseline; 2 = less than expected outcome; 3 = expected outcome; 4 = more than expected outcome; 5 = much more than expected outcome; χ^2 = chi-square test; η = eta value; n.s. = not statistically significant.

Regarding self- and collective efficacy, the data obtained in T1 are presented in Table 4. As the data show, females tend to indicate self- and collective efficacy more than males.

The further analysis carried out with the *t*-test shows that the perception of self-efficacy in particular increases for males from T0 to T1 ($t = -2.06$; $p = 0.040$), while there are no changes in females.

The correlation analysis between self- and collective efficacy and GAS shows that for females, both self- and collective efficacy correlate with each other (r = 0.43, $p = 0.001$). In males, the goal "Knowing about the impact humans have on the environment" is related to self-efficacy (Table 5).

Table 4. Self- and collective efficacy in participants in T1.

	Male (*n* = 253) (*M, SD*)	**Female (*n* = 158) (*M, SD*)**	***t***	***p***
SE	19.35 (3.57)	20.61 (2.56)	−4.09	0.001
CE	19.64 (3.79)	20.66 (3.23)	−2.82	0.005

Note. SE = self-efficacy; CE = collective efficacy; *t* = *t*-test.

Table 5. Correlation between self- and collective efficacy and GAS in T1.

		Male (*n* = 253)	**Female (*n* = 158)**	
	SE	CE	SE	CE
GAS_1	0.41	0.32	0.04	0.06
GAS_2	0.61	0.16	−0.06	−0.14
GAS_3	−0.18	0.68	−0.02	−0.13
GAS_4	0.51	0.32	−0.07	−0.06
GAS_5	0.13	0.63	−0.04	−0.12
GAS_6	0.91 *	0.39	−0.03	0.00
GAS_7	0.47	−0.00	0.42	0.41

Note: SE = self-efficacy; CE = collective efficacy. GAS_1 = Doing something new. GAS_2 = Knowing better what to do for the environment. GAS_3 = Finding out what we can all do together to reduce our impact on the environment. GAS_4 = Getting information about how to use environmental resources. GAS_5 = Finding out what I can do to reduce my impact on the environment. GAS_6 = Knowing about the impact humans have on the environment. GAS_7 = Knowing what an Escape Room is. * = 0.05.

A linear regression analysis was conducted to predict the self- and collective efficacy in participants. To run the analyses, mean values were calculated to create dummy variables of self- and collective efficacy. The findings showed that self- and collective efficacy were not correlated significantly with any of the motives (GAS).

4. Discussion

The aim of this work was to analyze the impact of an environmental education tool (DERs) on self- and collective efficacy regarding human impact on the environment and the consequent adoption of pro-environmental behaviors among young people. The sample selected for this study consisted of students aged 12–18 years. The activity involved DERs focused on environmental resources played in small groups.

The results show that the proposed activity (DERs) received a positive evaluation after administration (T1) in relation to the goals that the participants had set for themselves, with ratings much higher than expected in most cases. In terms of self- and collective efficacy, it is interesting to note that males report a lower correlation between self- and collective efficacy, while for females there is a correlation between perception of efficacy. These data should be analyzed in more detail to understand how males and females assess perceptions of self-efficacy in different contexts, not only in relation to the environment, and to make comparisons between different areas of life (e.g., performance in studies and caring for the environment). For both males and females, mean scores increased from T0 to T1 for collective efficacy, although there were significant differences. There was a significant increase in self-efficacy scores for males at T1, which is particularly significant because it indicates that the DERs did not affect the propensity to adopt PEB and collective efficacy, but rather what is perceived as a burden for the individual. Perceived self-efficacy may then be an important factor in setting in motion the positive cycle described by [25]: the adoption of PEBs is linked to perceptions of efficacy, and when these are high, the likelihood that the subject will adopt a PEB increases. However, this finding may also be attributed to males' greater familiarity with online games and videogaming technologies with respect to females. A systematic review on gender differences in online gaming by Veltri et al. [54] reports that male gamers start playing video games earlier in life, play more frequently, and spend

more time playing video games than female gamers. Even though the gaming landscape is changing and gaming is penetrating female groups as well, research (e.g., [55]; see also statistics from https://www.statista.com/statistics/326420/console-gamers-gender/, accessed on 16 July 2024) still confirms that males spend significantly more time than females in all age groups playing video games on consoles or computers.

Regarding females' propensity towards self- and collective efficacy concerning the environment, this can be interpreted through the lens of eco-feminism. Historically, ecofeminism is associated with the work of Rachel Carson and other theorists (such as Francoise D'Eaubonne, Carol Merchant, and Val Plumwood; see [56]) who highlighted issues of pollution, destruction, and neglect of the environment, including spaces and places. They argued that females were closer to nature and criticized the human relationship with other species. Theorists such as Plumwood [57] and Merchant [58] argued for the "feminine principle" as a theory that could help understand how to tackle environmental degradation. However, since environmental problems affect everyone, it is important that both males and females are included in adaptation and mitigation measures. Therefore, the adoption of tools that can help people reflect on the use of environmental resources, the consequences of their exploitation, and the impact on the environment and humanity is essential to bring young people closer to the strategies adopted individually and collectively. This approach must take into account possible solutions to the negative feelings that may arise when dealing with these issues. Indeed, the phenomenon of "eco-anxiety", an excessive concern about the impact of humans on the environment, can lead to paralysis in severe cases. In contrast, a mild level of concern for the environment may increase the propensity to PEB, as it is a tool to mitigate the impact on the environment. The DERs in this conceptual framework can be useful to reflect on the PEBs that can be adopted by mitigating anxiety and promoting positive feelings and self- and collective efficacy. The Social Cognitive Theory developed by Bandura explains why the DERs, designed according to this theory, could be effective for PEB.

5. Conclusions

This study is not without limitations. Firstly, it focuses on a specific population group, as it is limited to participants from northern Italy. On the one hand, this choice has made it possible to even out the differences between the various Italian regions, for example in terms of the environmental policies implemented. On the other hand, it does not allow us to generalize the results. Future studies could be carried out in different territorial contexts in order to highlight common aspects and to allow greater participation in the DERs. Another aspect worth considering is the duration of the study: The long-term effects of DERs on self- and collective efficacy were not investigated. Future studies could benefit from a longer time span. Another omission in our study is the lack of understanding of factors such as family and general social environment, as the literature emphasizes that cultural and social norms and rules influence the propensity to engage in a particular PEB [59]. Future studies could therefore include data on regional, family, and social environments to provide a more holistic view of the factors influencing PEB. We also did not take into account possible participation biases, such as social desirability, i.e., the tendency to present a better image of oneself by giving answers that model what the reference group expects (or is believed to expect) [60]. Indeed, young people receive a lot of information about what they should do for the environment: if they do not feel responsible for the future of the planet, there is a risk that subjects will be excluded from a narrative that includes them [61]. Future research could then incorporate a social desirability scale. In addition, we did not consider other individual variables, such as the actual implementation of the stated PEB and the possible limitations for students with special needs in interacting with the technology. Future research could follow up on the results to assess their consistency over time, and the translation into actual behavior should be evaluated. Finally, any positive or negative effects on students with special needs should be carefully considered to ensure inclusion.

Despite these limitations, our study contributes to the literature in several ways. First, it assesses the use of DER as an environmental education tool and its effectiveness on self- and collective efficacy: this is particularly interesting because self- and collective efficacy may be a precursor to PEB. In addition, our study targets young people, who are a crucial population in PEBs, and suggests an interpretation of the results in terms of gender differences.

Understanding self-efficacy has profound implications for the design of educational interventions, particularly in fields like environmental education. In this context, self-efficacy plays a critical role in promoting pro-environmental behaviors. Environmental self-efficacy is closely tied to both individual self-efficacy, the belief that one can personally make a difference through their actions, and collective self-efficacy, the belief that a group can achieve meaningful environmental outcomes through coordinated efforts. Programs that enhance environmental self-efficacy—particularly through mastery experiences, such as hands-on learning and participation in environmental projects—have been shown to increase engagement and commitment to environmental causes. Game-based learning and tools such as Educational Escape Rooms provide mastery experiences and foster collaborative problem-solving, offering an engaging way to build both individual and collective efficacy. By structuring these activities to provide clear feedback, encourage peer collaboration, and reduce anxiety, educators can enhance students' self-efficacy, motivating them to adopt pro-environmental behaviors. Thus, self-efficacy could be considered an essential attitude that can be affected by relevant educational initiatives like the one investigated in this study.

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