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Research Article

The Carbon Footprint Game: An Innovative Approach to Teaching Climate Change

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Abstract

As the global community grapples with the urgent challenges of climate change, there is an increasing need for innovative and effective educational tools to enhance understanding and engagement with this critical issue. This paper introduces a novel pedagogical approach (the Carbon Footprint Game) that harnesses the power of gamification to educate students (11-14 years old) about the complexities of climate change and the impact of individual choices on carbon emissions. Through a blend of interactive gameplay, real-world data analysis, and collaborative learning, this teaching method seeks to cultivate a deeper awareness of environmental issues and promote sustainable behavior among students. We conducted the pilot study involving students at a lower secondary school in the northern of Italy. Two lessons with a different slant were taught in two different classes: the first class received a traditional frontal lesson, while the second class participated in the Carbon Footprint Game. Before and at the end of both lessons, the students engaged in filling in the evaluation questionnaire (the same for both classes), in order to assess the effectiveness of the tested novel pedagogical approach.

Keywords: Climate change; Education; Carbon footprint; Environmental awareness; Sustainability; Teaching innovation

Introduction

The global scientific consensus on climate change underscores the urgency of fostering environmental literacy among students to catalyze sustainable practices [1]. Traditional teaching methods, while valuable, often struggle to capture the complexity and interconnectedness of climate change dynamics. Recognizing this challenge, our study introduces an innovative pedagogical tool (the Carbon Footprint Game) to bridge the gap between theoretical knowledge and practical understanding of climate change.

Climate change is a problem that has plagued humanity for decades, first manifesting itself through sporadic anomalies in nature's behavior and becoming a global emergency over the years [2]. Rising air temperatures and humidity cause changes in atmospheric circulation, leading to an increase in phenomena such as heat waves, heavy rainfall events [3] and diminishment of snow precipitation [4]. The worldwide shrinkage of glaciers is driving sea level rise [5], endangering coastal areas, which will lead to an increase in the number of climate refugees [2].

The topic of climate change has become recurring and widespread, and the media, in the dissemination of information on this topic, occupy a role of primary importance [6]. Then, it is crucial that this communication should be done in the right way. If communication plays a fundamental role, even more so is the communication made to young people, to primary and secondary school students. In fact, school plays the role of spokesperson and educator on environmental issues [6] and then correct and effective communication to schoolchildren can give results to the whole society. Some studies have focused on young people's concerns

about the future of the Planet. Concerns that, although not directly linked to a specific climatic event, nevertheless have psychological effects on young people, and are linked to it. These manifestations are referred to as 'climate distress', 'climate change anxiety', 'climate anxiety' or 'eco-anxiety' [7-9]. Some research highlights how children, who are at an essential point in their psycho-physical development, are more vulnerable than their parents, and adults in general, to issues related to climate change and how destabilized they feel by the uncertainty of the Planet's future [10].

In order to convey these sensitive issues to young students, some studies argue that a traditional type of teaching, with frontal and unidirectional lectures, is more effective in case of the scientific mechanisms of climate change in conjunction with the social impacts they imply [11]. On the other hand, other studies rely on innovative teaching, through games for example, which is closer to the children's time, transforming the lesson into a moment of encounter, a shared and not imparted lesson, where the children are called upon to be an active part of learning [11,12].

The climate emergency is a complex social issue that many believe needs to be addressed in schools in an effective and direct way, in a daily challenge for teachers (Plutzer & Hannah, 2018). In Italy, MIUR (Italian Ministry of Education University and Research), Indire (Italian National Institute for Documentation, Innovation and Educational Research) and ASviS (Italian Alliance for Sustainable Development) have launched a project named "Scuola 2030". This is a training course inspired by the guidelines of the Agenda 2023 for Sustainable Development. The project "Scuola 2030" recommends that teachers address the issue of climate change at various levels: i) for children ranging from 6 to 11 years old is proposed the narration of fairy tales from different cultures, focused on the theme of ecology; ii) for lower secondary school students (age: 11-14 years) are planned lessons on global warming and the climate emergency; iii) for upper secondary school students (age: 14-19 years) are recommended lessons and activities on the contents of the UN 2030 Agenda for Sustainable Development.

This paper discusses the rationale behind the development of an educational game, called "The Carbon Footprint Game". This game was originally designed for students ranging from 11 to 14 years old. In this paper we outline its structure, objectives, and the theoretical framework underpinning its design. We draw upon interdisciplinary research in education, psychology, and environmental science to demonstrate the potential impact of gamification on enhancing climate change education. Furthermore, in this paper we present the results of a pilot study conducted with a group of students attending a public school in the Northern of Italy, evaluating the effectiveness of The Carbon Footprint Game in fostering a deeper understanding of climate change issues and promoting sustainable behavior.

Methods

To evaluate the effectiveness of a didactic game for understanding climate change and its causes and effects we conducted a pilot study in a public lower secondary school located in the northern of Italy. A few words to introduce the Italian educational system. In Italy the school is compulsory from 6 to 16 years old. Primary school is 5 years long and focused on children ranging from 6 to 11 years old. Secondary school is divided into a) lower secondary school, a compulsory three-year educational program devoted to educating children from 11 to 14 years; b) upper secondary school, a five-year long program offered to guys ranging from 14 to 19 years old. At the age of 16, students complete their compulsory education. However, most learners go on to complete upper secondary education. All public secondary schools in Italy are free. Still, parents need to purchase their children's textbooks and educational supplies. For our experiment, we focus on two classes of a public lower secondary school located in the northern of Italy. We chose the second year of the three yearlong educational program to offer our game to students in the middle of their didactic experience.

The topics of the lessons held in the second-year classes were climate change and carbon footprint. The lessons were conducted according to two different teaching methods: traditional and innovative methodologies. The traditional method involves the teacher reading or explaining the content of the lesson; students are required to listen and pay attention; times are fixed, and the exchange takes place in the form of a question or learning check [13]. Innovative teaching is constantly evolving and can include a wide variety of methodologies among which the game [14]. We decided to use a didactic game. These lectures took place in September 2023 and were aimed at comparing the two teaching methods, as well as investigating the adolescents' perceptions on the topic of climate change, evaluating their skills, and observing how engaged they feel in this topic. This project was also part of the civic educational programme chosen by the teachers at the secondary school where the experiment was performed.

Before the experiment, all students involved were given an assessment questionnaire containing 20 questions on the topic of climate change and carbon footprint. This questionnaire was also reproposed after the experiment allowing to assess which of the two teaching methods had been the most effective one, and in this way being able to record learning differences resulting from traditional method rather than the innovative one.

The lower secondary school chosen for the pilot study

The school chosen to conduct this pilot study was the lower secondary school "Istituto Comprensivo Giovanni XIII", located in Premana, a municipality in the province of Lecco (Northern Italy). The area is located between the upper Valsassina and Val Varrone, a mountainous territory stretching from 600 to 1000 m a.s.l. The school's students are mainly local residents, and only in the last decade there has been the presence of some students from non-EU countries. It has 106 students divided into 6 classes, 2 for each year of study. On the roof of the building, there are photovoltaic panels to support solar energy production, and at the entrance of the school there is a digital display board informing students how much energy has been produced and how much CO2 emissions in kg have been avoided.

The Carbon Footprint Game

The Carbon Footprint game has been proposed as an innovative teaching lecture as it can help to understand the concept of carbon footprint and the factors driving it. The carbon footprint is an

indicator of CO2-eq emissions [15], deriving from the general definition of ecological footprint, which refers to the biologically productive land and sea area required to sustain a given human population [16]. The carbon footprint is measured in mass units as it represents the greenhouse gas (GHG) emission mass.

The Carbon Footprint game was structured in a cardboard divided into 7 items, connected by arrows that linked the various situations and gave the students the perception of a path to follow (Figure 1). The cardboard presented the habits of an imaginary person, named Sophia (the most common name in Italy in 2023), a subject whose actions were purposely exaggerated to create a representation of a person with habits highly impacting on climate. The different habits focused on i) mobility, ii) television, iii) videogames, iv) electricity consumption for lighting, v) gas consumption for personal care, vi) holiday, and vii) waste management. For quantifying the carbon footprint of each item, we applied the methodology reported by Senese et al. [17].

In addition, an envelope of different behaviors was given (Figure 2) from which the students had to choose to reduce the total GHG emissions of each item. As in every challenge-game, players collected a score. In this case, the score depends on the total carbon footprint calculated by considering all the items (i.e. from mobility to waste management). The higher the score obtained, the higher the climate impact. As a surprise effect, students discovered that, contrary to their expectations, the winning group was the one collecting the lowest score.

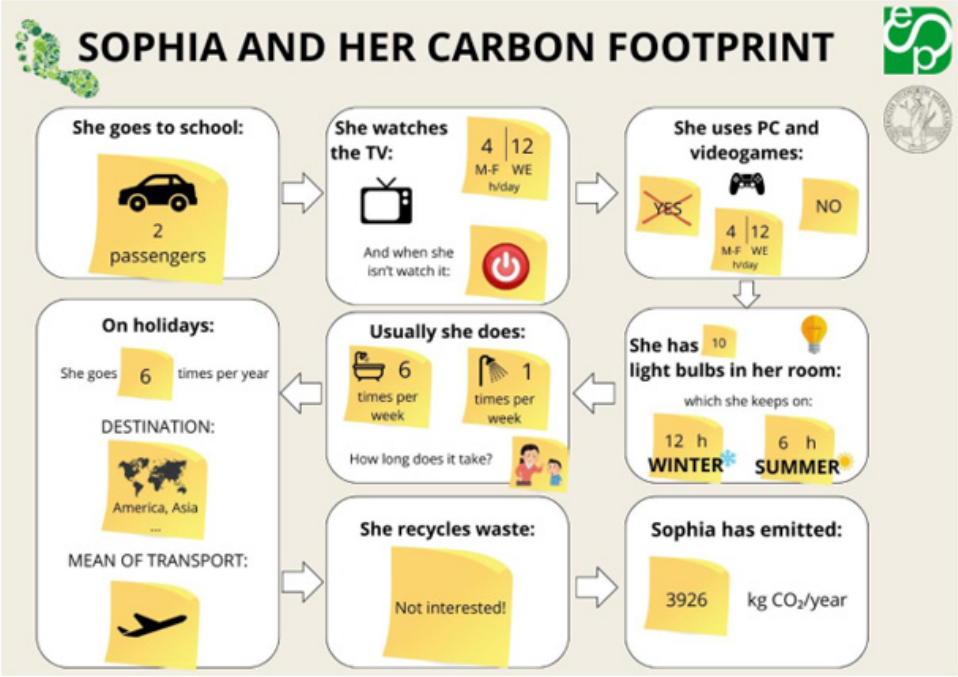


Figure 1: The display board of the Carbon Footprint Game divided into 7 items connected by arrows for giving the students the perception of a path to follow. It was designed in Italian, but here we report the English version.

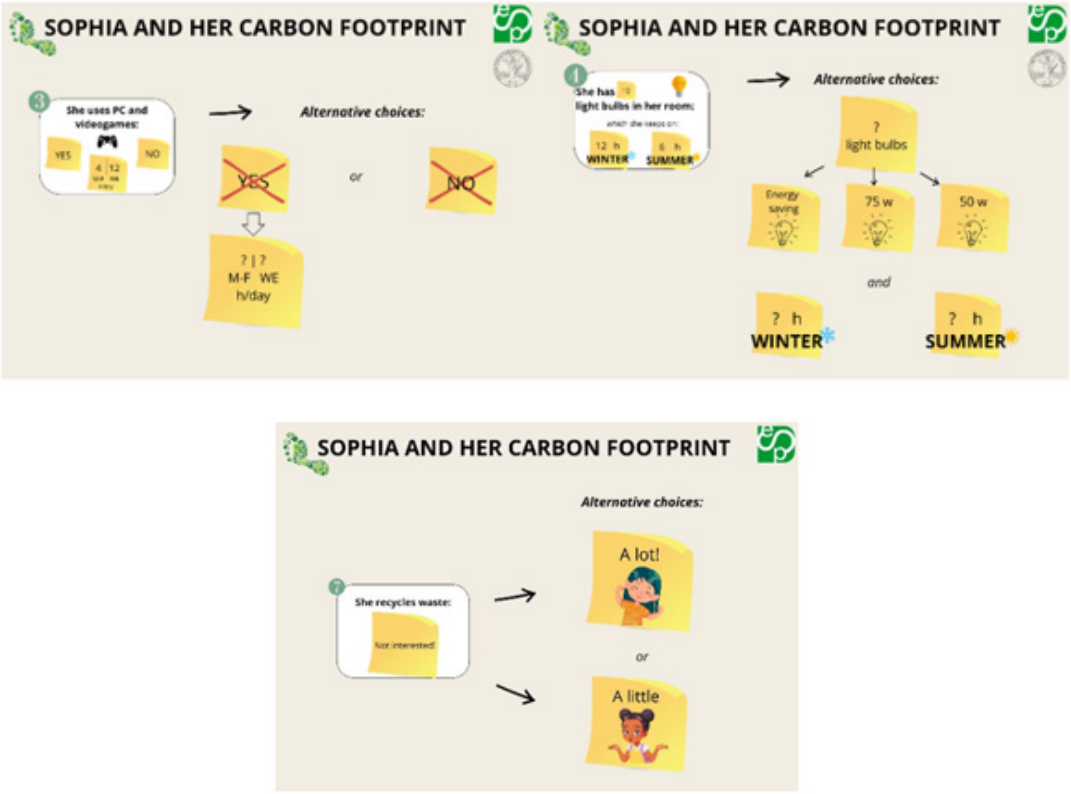


Figure 2: For each item, all the different possibilities among which the students can choose are shown. They were designed in Italian, but here we report the English version.

Traditional teaching

The traditional teaching method entails a frontal lecture about a subject which is addressed to the students by the teacher. Students are demanded to pay attention and express their doubts in the form of questions.

This form of lesson was held in a class of the second year. In particular, in this case, the explanation by the teachers was supported by a power point presentation consisting of sixteen slides, which were shown in class using the interactive whiteboard. The class consisted of 18 students, all Italians but one, who was born in Chad and later moved to Italy at an early age. In addition to the teachers, there was also a tutor in the class to support a student with LD (Learning Difficulties). There were also three cases of SLD (Specific Learning Disorders) and one case of SEN (Special Educational Needs) in the class.

A brief initial interview was conducted to reveal their prior knowledge of the lesson topics. This initial exchange of information was necessary to assess the gaps in the topics, and consequently to adapt the lesson, which had already been set up, deciding which topics needed more in-depth study and focusing on certain aspects that needed clarification.

During the lesson, the students were asked several times to reflect about climate change, its causes, and effects, in order to stimulate the thought process to find the answers they did not know and to prompt everyone to act.

The final part of the lesson was dedicated to the carbon footprint and the sustainable behaviors for which students could engage in to reduce their personal footprint.

Innovative teaching

With the term "innovative teaching" are recognized a wide variety of methodologies, in constant evolution [19]. The main feature of this teaching method is the active role of the students during the lecture through various activities [14]. This teaching method was applied in the other class, the B class of the second year. The class consisted of sixteen students, all coming from and originating from the local area, and in this class too, alongside the math's and science teacher, there was a tutor helping a student with LD. There were in the class two students with SLD as well.

The lecture was organized into two main parts: i) a cartoon video was shown to the students and later discussed, and ii) the class was involved in The Carbon Footprint Game. The video proposed was entitled "Paxi - The Greenhouse Effect" (https://youtu.be/RR30r52uQmQ, 2018), which is part of a series of materials created and promoted by the European Space Agency. The interactive whiteboard was used for its projection. The protagonist of the video is Paxi, the alien mascot of the European Space Agency, which is

used for the communication and dissemination of scientific and environmental content to middle and high school children.

For the Carbon Footprint game, the students were divided into four groups, to which an identical display board (Figure 1) was given. Each item was analyzed and discussed with the teachers, and each group was also given the envelope containing various behavioral options, all represented by a drawn image, markers and post-it notes (Figure 2). The aim of the game was to obtain the lowest possible score by replacing Sophia's actions/behaviors with the lowest impacting ones choosing among those available. In this way, this activity enhances the students' critical thinking and allows them to effectively understand how much a behavior (or another) could affect the total carbon footprint.

Carbon footprint questionnaire

At the end of the traditional and innovative lessons, a simple questionnaire with multiple answer was given to all students of class A and class B to allow them to quantify their personal carbon footprint through an analysis of their behaviors and habits (Figure 3). The proposed questions of our survey focused on the same items of the Carbon Footprint game. At the end of it each student was able to visualize their final score and thus their carbon footprint in terms of kg CO2-eq/year.

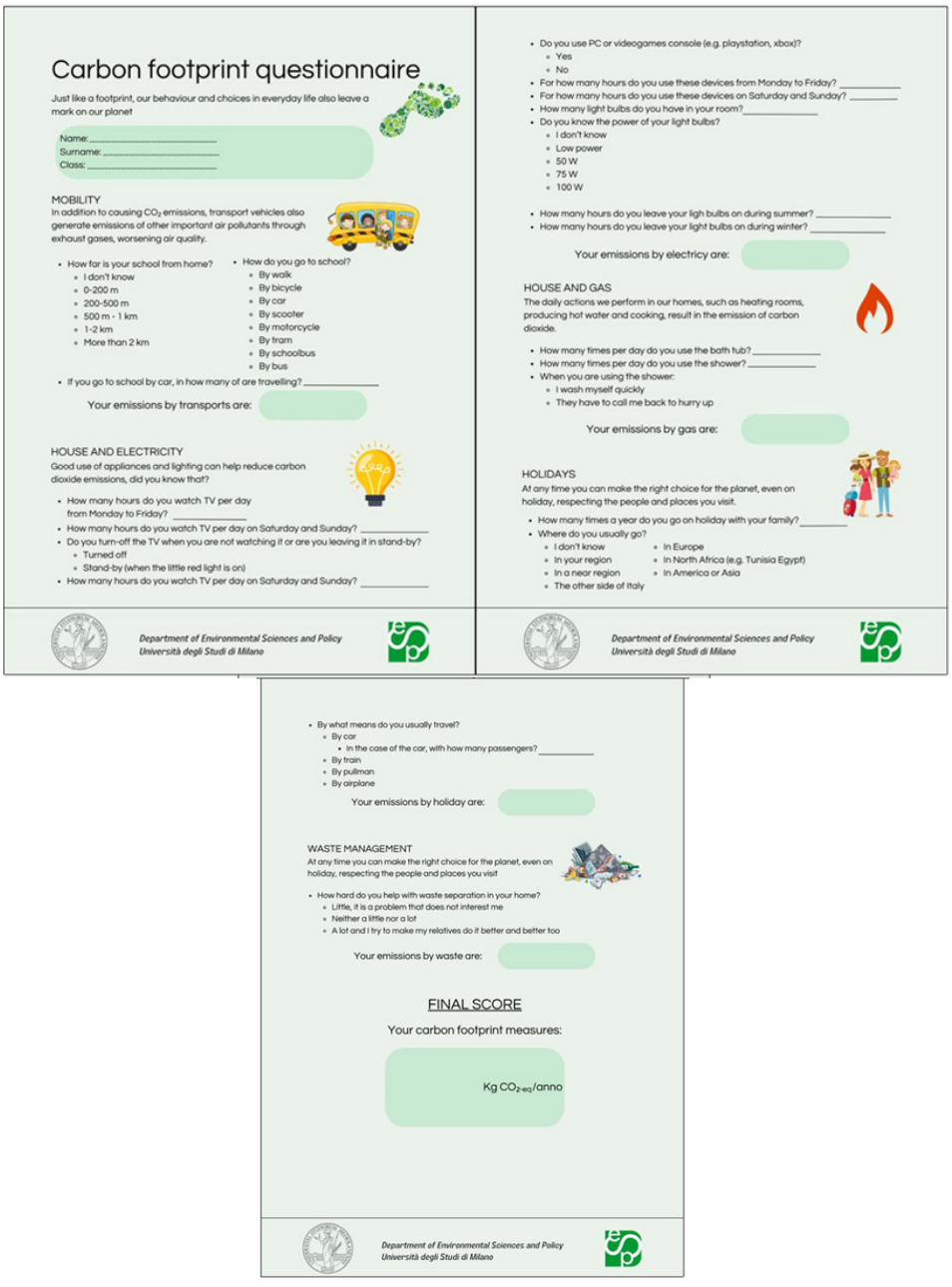
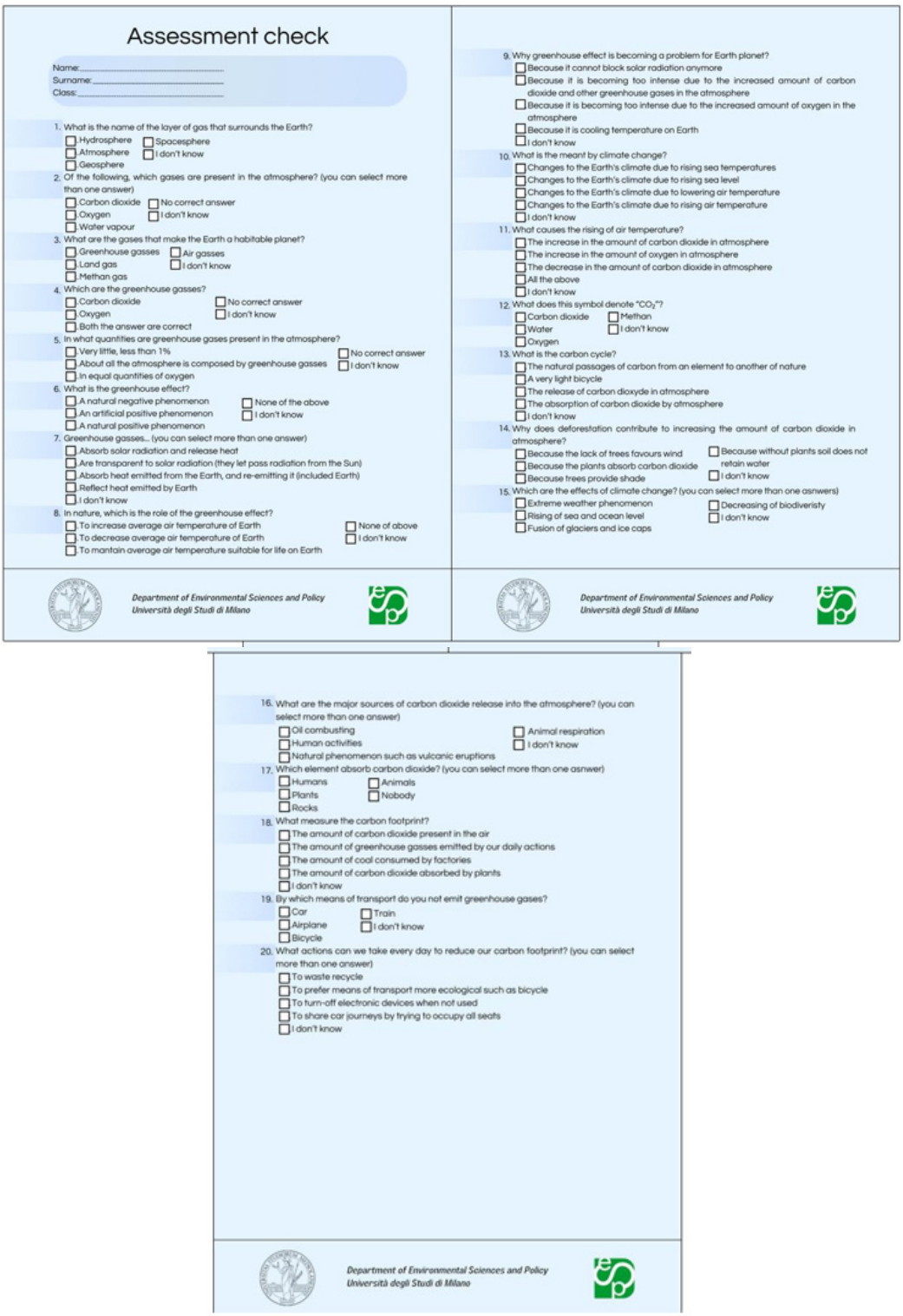


Figure 3: The carbon footprint questionnaire. It was designed in Italian, but here we report the English version.

This questionnaire could be a further useful tool to allow involved students to quantify their impact and to increase their awareness of the effects of their habits and behaviors [17]. Similarly to the Carbon Footprint Game, the proposed questionnaire was based on the tool developed by Senese et al. (2024), which had the main goal of helping people, and especially students, to understand more about GHG and how they contribute to their emissions.

Assessment questionnaire



Assessment check

Name:
Surname:
Class:

1. What is the name of the layer of gas that surrounds the Earth?
☐ Hydrosphere ☐ Spacesphere
☐ Atmosphere ☐ I don't know
☐ Geosphere

2. Of the following, which gases are present in the atmosphere? (you can select more than one answer)
☐ Carbon dioxide ☐ No correct answer
☐ Oxygen ☐ I don't know
☐ Water vapour

3. What are the gases that make the Earth a habitable planet?
☐ Greenhouse gasses ☐ Air gasses
☐ Land gas ☐ I don't know
☐ Methan gas

4. Which are the greenhouse gasses?
☐ Carbon dioxide ☐ No correct answer
☐ Oxygen ☐ I don't know
☐ Both the answer are correct

5. In what quantities are greenhouse gases present in the atmosphere?
☐ Very little, less than 1% ☐ No correct answer
☐ About all the atmosphere is composed by greenhouse gasses ☐ I don't know
☐ In equal quantities of oxygen

6. What is the greenhouse effect?
☐ A natural negative phenomenon ☐ None of the above
☐ An artificial positive phenomenon ☐ I don't know
☐ A natural positive phenomenon

7. Greenhouse gasses... (you can select more than one answer)
☐ Absorb solar radiation and release heat
☐ Are transparent to solar radiation (they let pass radiation from the Sun)
☐ Absorb heat emitted from the Earth, and re-emitting it (included Earth)
☐ Reflect heat emitted by Earth
☐ I don't know

8. In nature, which is the role of the greenhouse effect?
☐ To increase average air temperature of Earth ☐ None of above
☐ To decrease average air temperature of Earth ☐ I don't know
☐ To mantain average air temperature suitable for life on Earth

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9. Why greenhouse effect is becoming a problem for Earth planet?
☐ Because it cannot block solar radiation anymore
☐ Because it is becoming too intense due to the increased amount of carbon dioxide and other greenhouse gases in the atmosphere
☐ Because it is becoming too intense due to the increased amount of oxygen in the atmosphere
☐ Because it is cooling temperature on Earth
☐ I don't know

10. What is the meant by climate change?
☐ Changes to the Earth's climate due to rising sea temperatures
☐ Changes to the Earth's climate due to rising sea level
☐ Changes to the Earth's climate due to lowering air temperature
☐ Changes to the Earth's climate due to rising air temperature
☐ I don't know

11. What causes the rising of air temperature?
☐ The increase in the amount of carbon dioxide in atmosphere
☐ The increase in the amount of oxygen in atmosphere
☐ The decrease in the amount of carbon dioxide in atmosphere
☐ All the above
☐ I don't know

12. What does this symbol denote "CO_2"?
☐ Carbon dioxide ☐ Methan
☐ Water ☐ I don't know
☐ Oxygen

13. What is the carbon cycle?
☐ The natural passages of carbon from an element to another of nature
☐ A very light bicycle
☐ The release of carbon dioxyde in atmosphere
☐ The absorption of carbon dioxide by atmosphere
☐ I don't know

14. Why does deforestation contribute to increasing the amount of carbon dioxide in atmosphere?
☐ Because the lack of trees favours wind ☐ Because without plants soil does not retain water
☐ Because the plants absorb carbon dioxide ☐ I don't know
☐ Because trees provide shade

15. Which are the effects of climate change? (you can select more than one asnwers)
☐ Extreme weather phenomenon ☐ Decreasing of biodiveristy
☐ Rising of sea and ocean level ☐ I don't know
☐ Fusion of glaciers and ice caps

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16. What are the major sources of carbon dioxide release into the atmosphere? (you can select more than one answer)
☐ Oil combusting ☐ Animal respiration
☐ Human activities ☐ I don't know
☐ Natural phenomenon such as vulcanic eruptions

17. Which element absorb carbon dioxide? (you can select more than one asnwer)
☐ Humans ☐ Animals
☐ Plants ☐ Nobody
☐ Rocks

18. What measure the carbon footprint?
☐ The amount of carbon dioxide present in the air
☐ The amount of greenhouse gasses emitted by our daily actions
☐ The amount of coal consumed by factories
☐ The amount of carbon dioxide absorbed by plants
☐ I don't know

19. By which means of transport do you not emit greenhouse gases?
☐ Car ☐ Train
☐ Airplane ☐ I don't know
☐ Bicycle

20. What actions can we take every day to reduce our carbon footprint? (you can select more than one answer)
☐ To waste recycle
☐ To prefer means of transport more ecological such as bicycle
☐ To turn-off electronic devices when not used
☐ To share car journeys by trying to occupy all seats
☐ I don't know

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Figure 4: The assessment questionnaire. It was designed in Italian, but here we report the English version.

An assessment questionnaire about climate change and carbon footprint lesson was proposed to all the students of the two selected classes both before and after each lecture (Figure 4). The questions were multiple answer types and selected to be diversified about the two main topics. The questions for which more than one answer were correct was highlighted to be sure each student was aware of that.

Results

Traditional and innovative teaching

An assessment questionnaire was proposed to class A and class B both before and after the experiment, to evaluate the efficacy of each different teaching method. It is observable how, in general, the score has improved in both classes. The mean score before the traditional lecture was 6.44 (out of 10) while after the lecture it was 8.03, corresponding to an increase of +24.7%.

Regarding the innovative method, the results of the assessment check, before and after the lecture, show a slightly better improvement: the mean score before the innovative lecture was 6.57 while after the innovative lecture it was 8.23, corresponding to an increase of +25.3%. Before both lectures, 5 students of each class were achieved an insufficient score (i.e. lower than 6 out of 10), but after the lectures all have achieved the sufficiency. In particular, the lowest score in the class after the traditional lecture was 6.00 and after the innovative lecture it was 7.00, confirming the slightly better improvement with the innovative method.

Focusing on each question, for almost all the questions there was an increasing number of correct answers (Figures 5,6). Even if after the traditional lesson, the number of questions with an increasing number of correct answers was higher (17 out of 20 compared to 14 of the innovative lecture), the increase of the percentage of correct answers was higher after the innovative lesson (with a mean value of +30.1% compared to +24.6% of the traditional lesson). Nevertheless, some exceptions occur. For the traditional lecture, only one question (the 17th) reported that the totality of the class understood the topic and was able to answer correctly (Figure 5). The question regarded which elements of the Earth absorb carbon dioxide. Regarding the innovative lecture, it is possible to observe that for 3 questions (i.e. the 1st, the 3rd, and the 19th) the totality of the class was able to answer correctly (Figure 6). These questions regarded atmosphere, the positive impact of greenhouse gases on the live ability of our planet, and mobility and GHG emissions, respectively. On the other hand, there were one question (the 19th about mobility and GHG emissions) and three questions (the 7th, the 16th, and the 17th, which focused on definition of GHGs, carbon dioxide absorption and its emission) regarding the traditional and innovative lecture, respectively, in which the students didn't advanced in their knowledge.

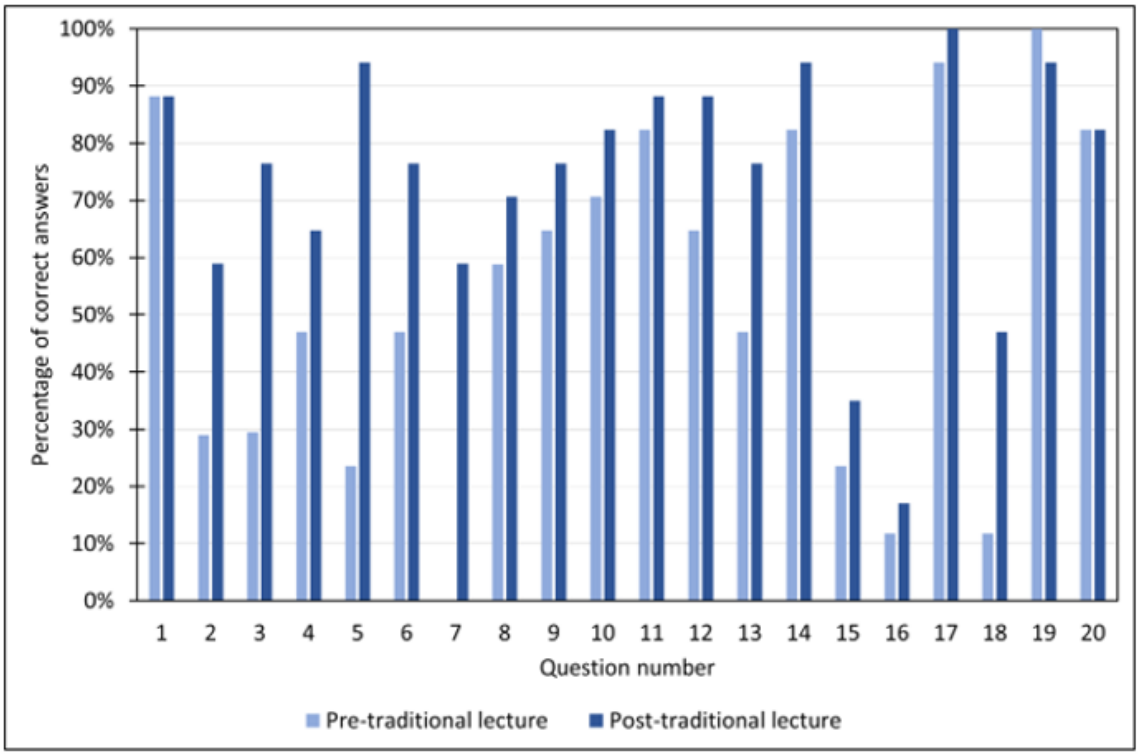

Figure 5: The percentage of correct answers of the assessment questionnaire proposed both before and after the traditional lecture.

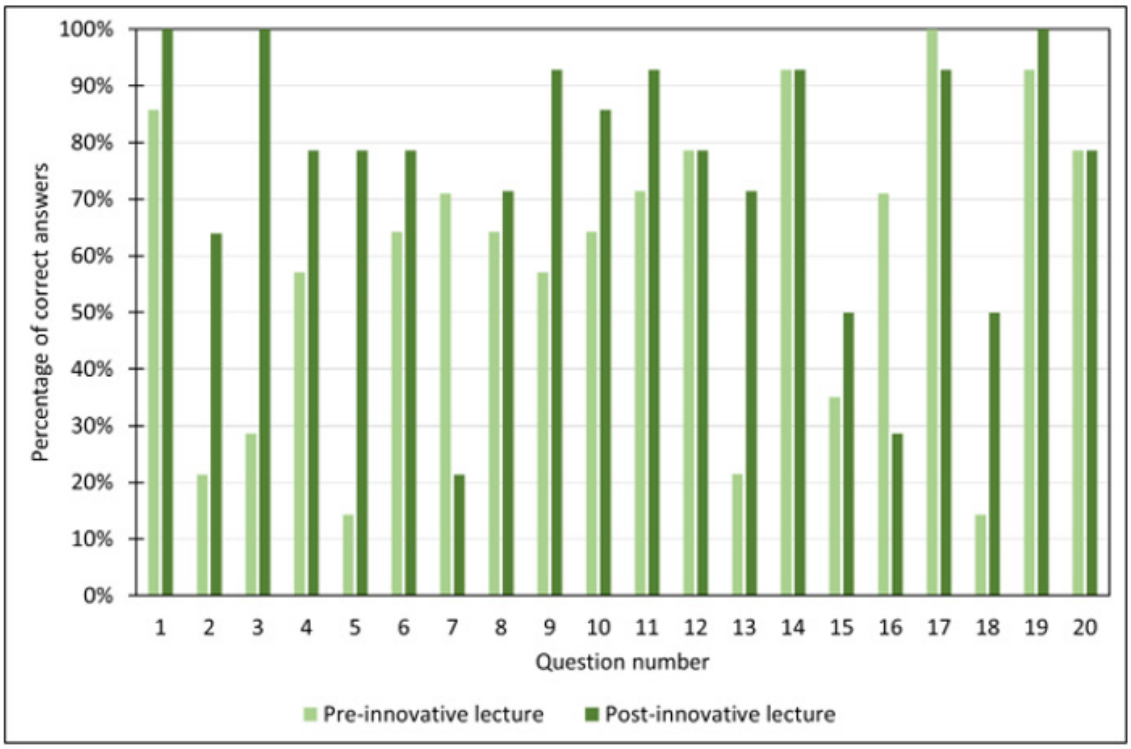

Figure 6: The percentage of correct answers of the assessment questionnaire proposed both before and after the innovative lecture.

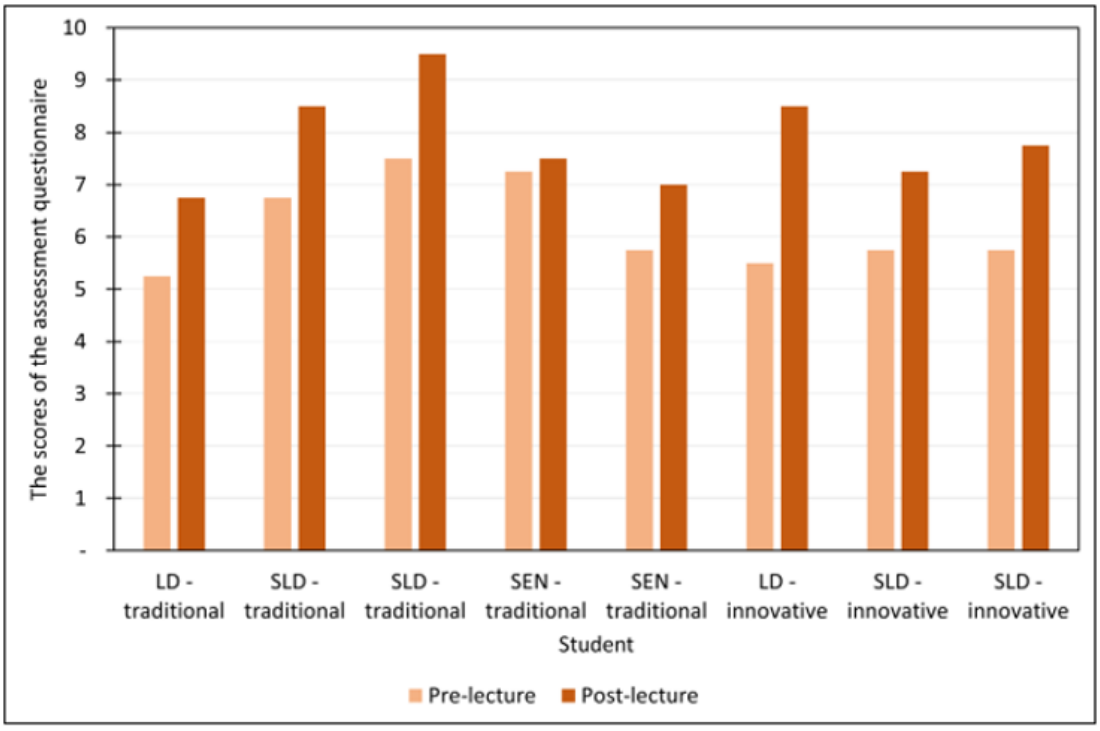

Figure 7: The scores of the assessment questionnaire achieved by LD, SLD, and SEN students both before and after the traditional and innovative lessons.

LD, SLD, and SEN students

LD, SLD, and SEN students were present in both class A and class B (5 and 3 students, respectively), but in higher number in the class where traditional teaching was applied. It is possible to observe that in both classes they improved their knowledge with a mean score from 6.50 to 7.85 before and after the traditional lesson, respectively, and from 5.67 to 7.83 before and after the innovative lesson, respectively. Nevertheless, since the very low number of students, the differences between the two approaches cannot be considered notable.

Carbon footprint questionnaire

The carbon footprint questionnaire was handed out to both classes at the end of the experiment before the assessment check. The answers to these questionnaires made it possible to conduct an analysis of the students' behavior, highlighting some common habits.

The questions were divided into 5 main topics ranging from mobility to habits at home and to waste management. Regarding mobility, it is observable that most students (45%) walk to school, while those further away use the school bus (26%). The minor percentage is encountered for the use of bicycle (6%) and public transports (10%). The habits regarding the electricity consumption show that the majority of the students leave the television in stand-by when not used (68%) and do not know the power of the bulb lights (58%). The answers about the personal care indicate that 87% of students wash quickly without any prevalence between shower or bath. On the regards of holiday break, it resulted that they go on vacation on average twice a year and go to a neighboring region (35%) or in Italy (29%). Only 16% go to Europe and even fewer to North Africa (6%). The last question concerned waste management and their recycling practices. Most of the students revealed that they do it with a medium level of attention to it (52%), instead, a very little percentage (3%) has little interest in it and do it habitually with very little care. Comparing the average amount of carbon emissions between the two classes it was found that the class with the traditional lecture had a total amount of GHG emissions of about 543.47 kg CO2-eq/year and the class with the innovative one 473 kg CO2-eq/year.

Discussion

Teaching methods can be divided into two broad groups: traditional and emerging or innovative methodologies. The transition from an academic approach to a more active one is marked by various activities such as, for example, role-play simulation. This latter consists of tackling a certain subject by asking students to make choices, on which the results will be checked by defining different objectives each time, a role-play in which it is possible to 'put oneself in the shoes of' by experimenting with the various learning contents [19].

A very successful example of innovative teaching is the educational programme of the European Space Agency, whose aim, according to the agency itself, is to help raise informed future citizens, who are able to make decisions and act responsibly towards the planet they inhabit and who have adequate knowledge to deal with everyday life. In December 2022, ESA member states approved the Space for Education 2030 plan, within which the STEM Learning and Inspiration programme is dedicated to the education of children aged 3 to 18, both directly and indirectly through their educators (https://www.esa.int/kids/en/home). The new STEM Learning and Inspiration programme consists of two sets of activities, the first one, called "Learn with Space", is strictly didactic and includes activities designed with specific learning objectives, for both children and their educators, a broad portfolio of initiatives aimed at age groups ranging from early childhood to upper secondary school. These activities consist of training professional educators, providing teaching resources, supporting interdisciplinary school projects and thematic workshops. The second activity, "Let Space Inspire You" instead, is strictly inspirational and it aims to stimulate the curiosity and imagination of children and adolescents. It includes a wide range of inspirational and engaging events, role-playing games, space career initiatives and access to industry experts, including astronauts, so that young people and their families can share the fascination and importance of space. Among these projects, it should be notable "Climate Detectives" (https://climatedetectives.esa.int), addressed to students between the ages of 8 and 19, in which they must identify a climate problem by observing their local environment. For this purpose, they can use available Earth observation data, or they can carry out measurements on the ground. Based on their investigation, the climate detective teams must propose a way to help reduce the problem. In this way, students learn how the Earth's climate is a complex and evolving system, thus understanding the importance of respecting the environment. The European Union has about 140 didactic materials for teachers ranging from videos to board games, from quizzes to role-playing games, aimed at a proposal that goes beyond the traditional frontal lesson but relies on a more innovative and varied path. One of the climate change-themed materials on the EU website is "2050 – It's up to you", an online role-playing game in which students are asked to make choices during a hypothetical day. Through the game, it is conveyed the necessary information to educate children who are aware of their choices.

There is ample evidence of the effectiveness of learning when a playful pedagogical approach is used, using video games, especially those that simulate the real world in interactive virtual environments. Students become, with this type of approach to teaching, protagonists of the learning process, being able to freely express their creativity [20]. For example, the digital game platform Minecraft could be used as part of a Geography project on climate change and sustainability, for creating, with the help of the Minecraft Education Edition tool, an ecosystem-friendly, sustainable, and environmentally aware city. Its learning efficacy in primary school is proven and supported by a massive bibliography [21] for subjects such as mathematics [22] and natural sciences [23], but outstanding results have also been recorded in colleges and universities [24]. It was also used for children with autism spectrum disorder with successful results [25], thus demonstrating that Minecraft Education Edition is a very inclusive innovative teaching tool that can be

adapted to a wide range of users. Our pilot study highlights the importance of different perspectives regarding teaching methods to better engage with students. While the traditional approach is definitely valid, a more hands-on one could be more effective on certain typology of students. The positive results obtained, as well as the interest demonstrated by students, confirm the effectiveness of an active learning approach [26] based on constructivism [27] as a strategic approach to address sustainability [28], also thanks to the relationships of the topics with reality. According to Maraffi et al. [29], the game-challenge and cooperative learning have been catalyst of student's learning and motivation, thanks also to the eye-catching challenge: to help Sophia to reduce her carbon footprint. This approach was implemented also in the study "How much Earth is on my plate?" by Beccaceci & Paris [19], in which they proposed a game to students of 12 years of age. In this game they had to construct a sustainable menu. With this method the students were able to discover the strong environmental impact of everyday life behaviors, including eating and started to change their way of thinking looking at the food pyramid and healthy diet not only as a tool for achieving human well-being, but also as an individual challenge to save the planet [19].

A game, like the one proposed in our study, could be taken into consideration when dealing with children of about 11-14 years old. It can be modified to be more appealing with students of different ages (10-16 years old) and context (e.g., school or museum or public event). An important aspect that should be taken into consideration is the competition that may be created among the students. Depending on the context of the class, the behavior of the students, and their heterogeneity in terms of personality, the teacher should try to make this competition a useful opportunity to increase the attitude of "putting oneself out there" and the willingness to help others.

The results of this study underlined nevertheless the efficacy of traditional didactic when dealing with more complex topics to be internalized by students. While it could lead to not easily engage with the attention and curiosity of the students, it showed the importance of a teacher figure that can help students to understand difficult topics. In the context of environmental topics, games are indeed an excellent medium for achieving attitude and behavioral change regarding sustainability in young learners. This is because games provide learners with an opportunity to exhibit their environmental-related behaviors in safe, simulated conditions where they can test themselves without the fear of being wrong, try alternate solutions and learn new behaviors in the process [30]. Several studies have shown that games are effective in producing attitude and behavior changes towards the environment [31-34]. Although several studies have shown games' effectiveness in producing lasting attitudes and behaviors in environmental sustainability-related topics, the adoption of games specifically for sustainability education is not widespread mainly due to lack of time (teachers must adhere to strict guidelines in formulating the annual teaching program) or resources (both financial and space). In this context, this paper wants to show teachers an easy and cheap to apply approach (it requires only a monitor where to project the videos already developed by the European Space Agency and the cardboard for the Carbon Footprint Game) that, if interposed to the traditional one, can assist to build a successful didactic. Indeed, didactic games, if properly integrated with more traditional teaching methods, have many advantages: they motivate students, facilitate the learning process, and provide an informal situation, creating favorable conditions for focusing on concepts, asking questions and consolidating skills ([35].

Regarding the Carbon footprint questionnaire proposed to both classes at the end of the lesson, it allowed each student to quantify their carbon footprint. Analyzing the answers, it is possible to observe that most of the students walk to school, even though Premana is a mountain town whose roads have a considerable gradient, and the climate is quite harsh for most of the school year. The question about the behavior related to the use of television allowed to introduce to the students the negative impacts of leaving the television in stand-by. This stimulated their curiosity and engaged with the part of them that wanted to take an active role in the fight against climate change. The total amount of carbon emissions resulting from each questionnaire was shown to all students. It was observed that the class that received the innovative lesson had a lower carbon footprint than the class with the traditional lesson. The correspondence between the teaching approach and the results of the questionnaires could be explained in different terms. First, it could be certainly due by casualty, but it is important to also consider the possible presence of a sense of eco-anxiety in the class that has most felt the pressure of climate change. The term eco-anxiety is used to describe the emotional and mental states associated with heightened awareness of climate change and concurrent distress in the face of its threatening implication for the future [36]. Therefore, the students in the innovative lesson, being more affected by the topic thanks to the game, could have felt this sense of eco-anxiety and decided to lie in their questionnaire to decrease the pressure of their actions on their carbon footprint. Another explanation could be also that they wanted to show their willingness to change their habits and behaviors in more responsible and virtuous ones, thus answering to the questions with the actions that they want to implement.

Conclusion

Our pilot study allowed to investigate the children's perception of the problem of climate change and their level of knowledge about it, and to understand and compare which teaching approach was the best one in terms of learning by evaluating and comparing two different methods. Thus, this paper presented a comparison between two approaches: a more traditional frontal lecture, and an innovative approach where the students were engaged in a didactic game. The efficacy of both teaching methods was reviewed through an assessment check proposed before and after the experiment. The preliminary results of this pilot study show that, while both teaching approaches improve the knowledge of the students, the innovative one was more effective.

The study included also an evaluation of the two methods for students that needs special attention, such as LD, SLD, and

SEN ones. Due to the very low number of this kind of student, the results cannot explain the presence of a higher efficacy of one approach compared to the other one. To both classes it was also a questionnaire to evaluate the habits and behaviors of the students allowing them to quantify their carbon footprint. With our pilot study we are able to show the importance of including innovative methods in the school didactic plan, for which a mixed approach is not only encouraged by national and international bodies, but also a powerful tool when dealing with special topics.

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Conflict of Interest

No conflict of interest.

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