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Make it Green: An Educational Board Game on Solutions for Climate Change for Grade 7 Students

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Research Article

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ABSTRACT

Climate change is a global issue with wide-ranging effects on ecological, social, and economic systems, emphasizing the need for climate change literacy and awareness to implement effective adaptation and mitigation strategies. Employing gamification, mainly through board games, offers a communication and educational method to enhance both literacy and awareness surrounding climate change. This study aimed to develop an educational board game illustrating the concept of climate change and its consequence in the community. The Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model served as the instructional design for game development, and the game underwent evaluation by game designers, science educators, earth science specialists, and environmental sustainability associate. To test its effectiveness, the researchers conducted a pretest-posttest evaluation involving 70 Grade 7 students from a legislated Science high school who voluntarily participated in the study. The results showed that the average scores of the posttest were higher than compared to the pretest. This implies that the students have improved their knowledge and awareness after playing the game. The findings of this study show that the board game Make it Green could be used as a teaching aid for climate change.

Keywords: Tabletop game, Renewable and non-renewable resources, Environmental awareness, Gamification, Sustainability

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INTRODUCTION

The United Nations (UN, n.d.) define climate change as long-term changes in temperature and weather patterns. However, human activities have been the primary cause of climate change since the 1800s, owing mostly to the use of fossil fuels such as coal, oil, and gas. The Philippines is one of the most vulnerable nations where one can observe and project the impacts of climate change (Cruz et al., 2017). Due to a combination of political, geographic, and social factors, the Philippines is recognized as vulnerable to climate change impacts, ranked 113th out of 181 countries in the 2020 ND-GAIN Index. Consequently, the country ranks third in the 2017 World Risk Index (WRI) of the United Nations University and fifth in the Long-Term Germanwatch Climate Risk Index (CRI) (1996-2015) (United Nations University, 2017 as cited in PAGASA, 2019).

Furthermore, climate change's impact on the Philippines is most often associated with extreme weather disturbances such as super typhoons, floods, more intense heat and heat waves, and prolonged severe droughts which, in turn, affect many other sectors of economic life. With 50.3 percent of its total area and 81.3 percent of the population vulnerable to natural disasters, the Philippines is considered a disaster hot spot. (Intergovernmental Panel on Climate Change [IPCC], 2018 as cited in Climate Change Commission, 2018). In order to reduce the Philippines' vulnerability to the effects of climate change whilst improving the populace's capacity to adapt, solutions such as mitigation and adaptation are recommended by National Aeronautic Space Administration (NASA 2022).

Mitigation can be achieved by carefully utilizing renewable energy and avoiding over-exploitation of the limited quantity of renewable resources, allowing its stock to be replenished naturally. (National Geographic, 2022; OAS, n.d.). On the other hand, adaptation can be taught to people by raising public awareness on climate change. Raising society's awareness of climate change is crucial, as awareness shapes and influences people's engagement, especially the youth. In addition, youth should be given special attention, as they are the generation whose lives will be more affected by climate change than any generation before (Ojala, 2012). They are among the marginalized sector of society that bears much of the impacts of disasters. As future decision-makers, they will be responsible for dealing with the environmental and societal consequences of climate change (Corner et al., 2015; Ojala & Lakew, 2017).

Following the design paradigm (Figure 1), this study aims to develop an educational board game that illustrates the concept of climate change and its consequences in the community. It also determined the change in Grade 7 students' environmental knowledge and awareness, particularly on climate change increased playing the board game. Furthermore, the technical aspects of Make it Green such as accuracy of learning content, alignment with learning objectives, and players' satisfaction with the overall gameplay experience was also determined.

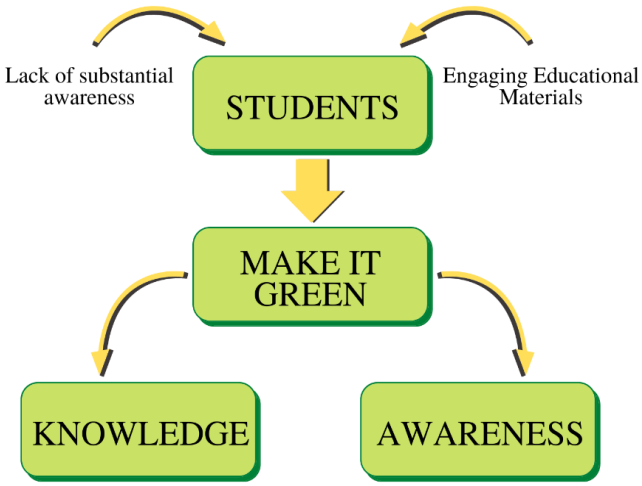

Figure 1. Paradigm

According to Marshall et al., (2013), countries with a higher climate change awareness tend to have a better capacity to cope and adapt in the case of disasters due to having significantly better management and planning. In contrast, the absence of awareness hinders progress especially in developing countries, as it is critical to cultivating the population's knowledge to mitigate disasters caused by climate change.

Humans naturally tend to ignore issues that are not directly relevant to their life. Some individuals are largely uninformed of the present level of climate change. These are commonly associated with a lack of education. Being environmentally literate is essential to building a sustainable relationship with the environment and understanding the threat posed by pressing issues such as climate change. However, environmental literacy is challenging because it encompasses many complex dimensions (Fauville et al., 2020). Moreover, there is often a gap in understanding the connections between individual actions and their consequences on the environment. Thus, educational games could be a promising tool to address these challenges.

Learners may utilize these educational games for experimental learning to improve their decision-making and problem-solving abilities in a dynamic learning environment (Adachi & Willoughby, 2013). Additionally, instead of obtaining delayed responses via traditional evaluation techniques such as written tests and examinations, students can receive feedback/results quickly to acquire answers through the game. These simple techniques can help students grasp and remember complex material (Hanus and Fox, 2015). One such application of gamification is the creation of board games.

Board games are interactive experiences that are generally engaging, especially for the younger demographic, professionals, and the general public alike (Gerber et al., 2021). This has the potential to raise the public's attention to the issues surrounding climate change. In the STEM field, it has proved effective educational materials to learners as it provides motivation, curiosity, and immersion that all contribute into creating an enabling learning environment

(Chiarello & Castellano, 2017). Consequently, students who play educational board games develop increased factual understanding and interpersonal interactions (Shirotsuki & Nakao, 2019). Overall, board games are developing as effective educational materials that help students learn complex concepts.

Currently, there is a lack of climate change educational materials focusing on the perspective of students as board-type games usually have large scales, such as managing a city, country, or even the entirety of Earth. The immense scope of these simulations may be good in demonstrating the effects of climate change on a wider scale; however, it rarely presents significant actions an individual can take in mitigating climate change.

Due to the scarcity of small-scale board games and educational materials, a disconnect exists between individual actions and their effects on the environment. Prominently taught strategies for reducing one's carbon footprint, such as recycling, fail to educate people about more impactful solutions in climate change mitigation (Wynes & Nicholas, 2017).

One such solution is the conversion of one's community to a more sustainable environment with the use of renewable resources, yet the lack of public awareness of renewable energy hinders progress on sustainability. Since renewable sources are often found within local communities, raising awareness on the matter is essential for further development, expansion, and support of renewable energy sources (Lloyd & Nakamura, 2022).

The board game, Make it Green, was then develop to promote climate change awareness among grade 7 students and help them encounter situations needing to make in-the-moment decisions that allow them to assess the consequences of their choices quickly. It was also developed for educators to use to teach students about climate change solutions in an interactive manner. The study is particularly relevant to students as it will help them evaluate their decisions and understand how it affects their physical, cultural, social, and political environments.

METHOD

Research Design

A descriptive developmental research design was employed in the study. ADDIE is a strategy and approach that instructional designers and training creators utilized. It features a flexible framework that assists researchers in developing effective support tools. The model's phases include analysis, design, development, implementation, and evaluation. Each phase represents a dynamic and adaptable standard for designing efficient training and performance support instruments (McIver, Fitzsimmons, & Flanagan, 2015). To achieve the aim, the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model, as seen in Figure 2, was adopted to design and develop the educational tool, "Make it Green," which comes as a board game.

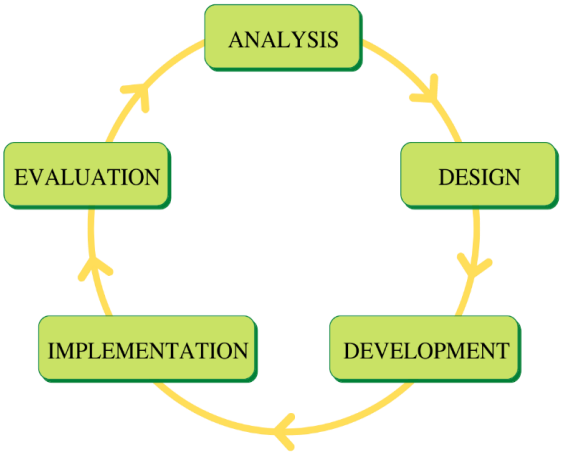

Figure 2. ADDIE Model

Through this model, the researchers could make further improvements during the game's development. The revision made was then subjected to the research advisers' evaluation. Their ideas, comments, and suggestions were also integrated into the board game.

Analysis

As the board game was intended to be an educational tool; the concept of climate change was assessed through the review of related literature. The content of the board game focused on and was based on "Act Now: The UN Campaign for Individual Action" by the United Nations, (n.d.) It was designed as an instructional collaborative board game and was developed to promote climate change awareness and evaluate the make-in-the-moment decisions that allow them to understand how it will affect them.

Furthermore, the content of the game was suitably adjusted to improve the game's level of engagement and to ensure that the concepts of the game were acquainted with the target participants of the researchers who are Grade 7 Students.

Design and Development

In the design phase of the study, the findings from the analysis phase served as the basis for the conceptualization of the game's content. A set of gameplay mechanics was created to outline the board game's flow. Make it Green is conceptualized as an educational collaborative board game, and the gameplay follows this core concept. It is designed to encourage player-to-player interaction and teamwork as the game is intended to be played easier with collaboration than competition. The board game's mechanics are made to be recognizable, to ensure that some of the gameplay concepts are familiar to the players.

In order to playtest the board game during its initial stages, several iterations of the game's prototype were created. The prototype was played by the researchers along with their colleagues who volunteered as well as board game experts to gather feedback on the game's mechanics. Playtesting is composed of explaining the existing and revised mechanics to the group before

playing, observing the behavior and interaction of players with other players and the game during play, and asking for feedback about the content and satisfaction of the playtesters. The playtesting process was repeated multiple times over the course of four months to ensure that the product was fair, enjoyable, and simple for the players.

Gameplay

The game is played with a set of two six-sided dice, three decks of custom cards with each deck having 15 cards, 15 risk tokens with 5 tokens for each risk level (green, orange, and red), 6 player tokens, a deck mat, and a game board. It is played by two to six players taking turns to roll the dice and moving that many tiles on the game board. Depending on what kind of tile one lands on, one may draw cards representing facilities, risks, or actions relevant to climate change and sustainability. The objective is to turn the game's risk tokens, which represent the severity of the climate, to green before they can turn red.

Game Board

Figure 3. Make it Green's Game Board

The game board is designed to be simple, vibrant, and comprehensible. Its composition resembles the characteristics of classic board games such as "Monopoly" to create a sense of familiarity for the players. The tiles on the board are color-coded to match their card counterparts and suggest their functions. Facility tiles are colored blue to symbolize developing technologies, risk tiles are red to signify danger, and action tiles are green to contrast the risk tiles and to indicate hope and nature.

Cards

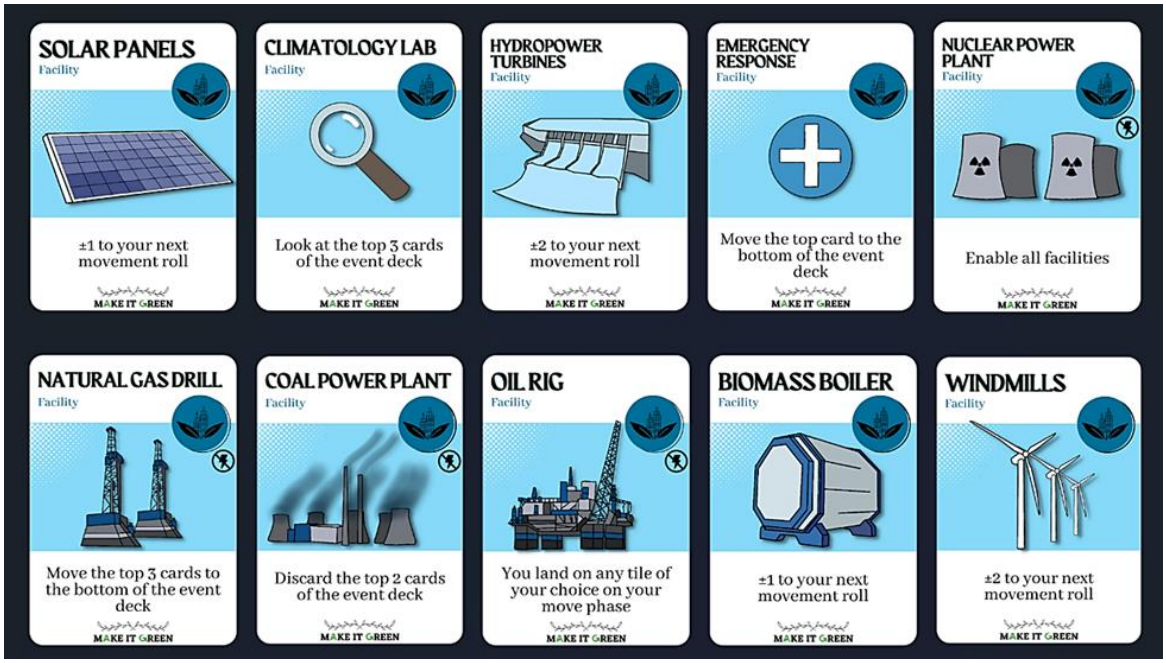

Figure 4. Facility Cards

Figure 5. Risk Cards

Figure 6. Action Cards

The majority of Make it Green's content is put into the variety of cards in the game. The cards act as the core gameplay feature and educational material of the game. These cards are divided into three categories: facility, risk, and action. Facility cards contain renewable and non-renewable sources of energy and other miscellaneous establishments; their cards focus on the effects they have on climate change. Risk cards are a collection of different disasters; these directly affect the facilities and the risk level of the board. Action cards are actions one can take to mitigate climate change; these cards teach the players different ways of climate change mitigation and adaptation while also inspiring them to take appropriate actions against climate change.

Risk Tokens

The constant change of risk levels is a core mechanic of Make it Green, so risk tokens were created in order to clearly represent the severity of the risk on a given tile. The use of risk tokens can reflect one of three states on a tile: green, orange, and red, with green being safe zones and red being, especially risky areas. These are placed on the risk tiles to display the current risk level of that tile.

Player Tokens

Figure 7. Make it Green's Player Tokens

Engaging individuals of all ages is essential to address the pressing issue of climate change. Recognizing this need, the researchers' game design takes a unique approach by incorporating player tokens representing teens, adults, and older individuals. By including a diverse range of age groups, the game aims to create an inclusive and collaborative experience where players from all generations can actively contribute their valuable insights, knowledge, and unique perspectives to address and mitigate the challenges of climate change effectively.

In the game's development phase, graphic designing applications such as Canva and Ibis Paint X were utilized in creating the visual design of the game board and cards. Afterward, the cards were printed at Stkr Labs, a printing studio, while additional materials such as dice and player tokens were purchased online. The rest of the game materials were handmade by the researchers including the printing of the deck mats and painting risk tokens that were bought online.

Implementation and Evaluation

Make it Green was first introduced to five educators knowledgeable in science, three earth science specialists, one knowledgeable in environmental sustainability, and two game designers. The evaluators were gathered through a call for experts, who were chosen using purposive sampling. Communication letters were sent through email which informs the purpose of the research and how their feedback will be utilized for the study.

The game was evaluated by completing a survey form using a four-point Likert Scale. Likert Scale was used as the instrument in this study's questionnaire because it is the simplest and most practical approach to gauge opinion strength. This had the following options: Very Satisfactory (4), Satisfactory (3), Poor (2), and Not Satisfactory (1). The survey form has 12 game descriptions, wherein the evaluators utilized the scale to agree or disagree with them.

The game was evaluated and validated for the specific attributes, which were modified based on DepEd Guidelines and Processes for LRMDS Assessment & Evaluation. Moreover, a subjective feedback option was provided for possible comments, suggestions, and clarifications. The Likert Scale scores obtained from the evaluators were tallied. The mean and standard deviation of all scores were used to assess the game's reliability and accuracy.

Table 1. Interpretation of the Mean of Evaluation Scores

(1) Mean	(2) Verbal Interpretation
(3) 3.26-4.00	(4) Very Appropriate
2.51-3.25	(5) Appropriate
1.76-2.50	(6) Requires Revision
1.00-1.75	(7) Not Appropriate

Table 1 presents the evaluator's interpretations of the mean of their scores. This was based on the 4-point Likert scale interpretation table by Lawsin and Garcia (2017).

Pilot Testing

In this study, researchers use pilot testing with Grade 7 students as the participants. The participants undergo a pretest-posttest evaluation to measure the difference in knowledge and awareness that existed before and after playing the board game "Make it Green."

"Make it Green" was initially introduced to a group of educators specializing in earth science, experts in board games, and researchers' colleagues who volunteered to participate in playtesting the game. Before their participation, they were given an informed consent form containing information on the research's pilot testing. Researchers asked them to confirm their participation and provide sufficient information and assurances about their involvement in the research, which served as their consent. Underage participants, on the other hand, were first asked permission to participate in the study. They were given an informed assent and parental consent form. Forms completed by their parents act as consent and confirmation of participation. Furthermore, all data obtained from participants was securely maintained and strictly conformed to relevant policies and regulations.

Before conducting the study, researchers asked permission from the school head to conduct their research on Grade 7 students. Then, an orientation was held to present the objectives of the research, terms, and conditions of participating in the study, guidelines, and gameplay instructions. Afterward, students were subjected to answer the given pre-environmental awareness assessment and pre-test. Following the completion of that, the board game's mechanics were handed to the players to assist them and ensure that some of the gameplay principles were recognizable to them. The board game takes between 10 and 20 minutes to complete. After playing the game, the participants took the gameplay satisfaction survey, post-environmental awareness, and post-test, which measured the same levels as the pre-test. This part was carried out to evaluate the efficiency of the game-based education tool in the students' learning as well as their decision-making and problem-solving abilities in a dynamic learning environment.

Research Instrument

The study utilized pre-test and post-test evaluation for the pilot testing to assess the students' environmental knowledge and awareness, particularly on climate change. According to (Malik & Alam, 2019), "Pre-and post-test designs are significant assessment tools that help in the direct and effective evaluation of a course or lecture to improve student learning." The purpose of conducting a pre-test before the game was to assess the students' baseline knowledge regarding environmental awareness. Hence, administering a post-test afterward evaluated the student's learning on the topic and views toward climate change after playing the board game. In addition, comparing participants' post-test scores to their pre-test scores enables the researcher to know whether the board game was effective in increasing and improving students' knowledge of the taught content.

The pre-test questionnaires were composed of three sections: (i) environmental awareness, (ii) knowledge of climate change, and (iii) knowledge of environmental sustainability. At the same time, the post-test questionnaires issued the same set of questions with the addition of a Likert scale survey of the user satisfaction rate. Seven (7) questions were presented as a 5-point rating scale in the environmental awareness section, and fifteen (15) questions were presented as a 4-point rating scale for the gameplay satisfaction survey. The rest of the questions were multiple choice with ten (10) questions for the knowledge of climate change section and five (5) questions for the knowledge of environmental sustainability section.

Content validity was used to verify the relevance of the questions as it measures the extent to which the items on a test are representative of the entire domain the test seeks to measure (Markus & Smith, 2012). The instrument was verified by comparing the questions asked from reliable and existing sources. Furthermore, the pretest/post-test questionnaires contents were verified by an Environmental Science expert specializing in Sustainability.

Test-Retest Reliability

Table 2. Reliability Tests of the Sections of the Instrument

	Pearson's r	**Spearman's rho**	**Cronbach's α**
Environmental Awareness	-	-	α=0.810
Climate Change	0.753 (p=0.001)	0.829 (p<0.001)	-
Environmental Sustainability	0.505 (p=0.386)	0.821 (p=0.089)	-
Gameplay Satisfaction	-	-	α=0.705

Pearson's Correlation and Spearman's Rho were used for the test-retest reliability of the pre-test and post-test of the participants' knowledge of climate change and environmental sustainability. Additionally, Cronbach's Alpha was used for the test-retest reliability of the

gameplay satisfaction survey and the pre-test and post-test of the participants' environmental awareness as it is more appropriate for Likert-scale questions (Glen, n.d.).

Table 2 presents the values acquired for the Pearson's Correlation Coefficient, Spearman's Rho Correlation, and Cronbach's Alpha tests. The climate change and environmental sustainability of the contents measure the factual knowledge the participants have on the topics. The p-value yielded by the climate change section is less than the level of significance ($\alpha = 0.05$). Thus, it is proven that the section satisfies the test-retest reliability. The Pearson's r and Spearman's rho acquired supports this due to having a strongly positive and very strong correlation respectively. The participants' level of knowledge on environmental sustainability yielded Pearson's r and Spearman's rho of strongly positive and very strong correlation as well. However, as their p-values yielded are greater than the level of significance ($\alpha = 0.05$), the data do not satisfy the condition for test-retest reliability.

The environmental awareness and gameplay satisfaction sections measure the experience of the participants on the given topics using a Likert-scale. The Cronbach Alpha for the environmental awareness section yielded a value that is interpreted has a good internal consistency while the gameplay satisfaction yielded an acceptable internal consistency. Moreover, both sections are closer to 1.00 than 0, thus can be concluded that the environmental awareness and gameplay satisfaction sections satisfy the test-retest internal reliability.

The environmental sustainability section is the only one that yielded no significant results for the test-retest reliability. This could be due to sustainability being one of the competencies covered in the grade 7 science curriculum resulting in mostly different scores on the second taking of the test due to their new knowledge of the topic. More studies can be done in lower grade levels to validate this claim.

Table 3. Five-Point Likert Rating Scale Interpretation of Weighted Mean

Mean	Verbal Interpretation
4.50-5.00	Highly Acceptable
3.50-4.49	Acceptable
2.50-3.49	Moderately Acceptable
1.50-2.49	Fairly Acceptable
1.00-1.49	Not Acceptable

Table 3 shows the interpretation of five-point Likert scales for instructional materials based on the study of Terano, H.J. (2015).

To analyze the data from the Likert scale, the options provided were quantified into point values: Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), and Strongly Disagree (1). The data was averaged for each participant to assess the acceptability of their results. Moreover, it

was also totaled to represent their weighted score for their general environmental awareness in order to assess the significant difference during the pre-test and post-test.

Participants

The study involved seventy (70) Grade 7 students from all the sections of a legislated Science high school for the pilot testing. The decision to choose grade 7 students as participants in this study is based on the alignment of the topic, which pertains to climate change, with their learning competencies set in the curriculum for their Grade level. This selection is made with the intention of ensuring that the content presented is both relevant and age-appropriate for this demographic. Permission to administer the research material to grade 7 students was requested, and it was approved by the school head and the research advisers. Furthermore, the convenience sampling method was used where only those who were willing to participate and had their parental permission and assent forms signed were sampled for the study.

Data Collection

A one-group pre-test post-test design was utilized among the participants in gauging the efficacy of the material. The knowledge assessments and environmental awareness evaluations were administered to the grade 7 learners using Zipgrade bubble sheets. Between the two assessments, the students were presented with the board game and taught how to play by the researchers while also teaching them climate change and environmental sustainability concepts during gameplay. During the post-test evaluation, a Likert scale survey was also given to the participants in order to evaluate their experience and satisfaction while playing the board game.

Data Analysis

The data gathered from the assessments and surveys distributed during the pilot testing returned results of ordinal and interval data which was analyzed using the appropriate statistical techniques. The Likert scale questionnaires of the environmental awareness and game evaluations were given point values in order to obtain interval data. Strongly disagree was given a value of 1, and strongly agree was given a value of 4 or 5 for four-point and five-point Likert scales, respectively.

The Shapiro-Wilk test was utilized to test for normality, and Levene’s test was used to test for equal variances. Wilcoxon Signed Rank test was used for the participants' scores to test the difference between the pre-test and post-test scores. This acts as the criteria for evaluating the student’s knowledge and awareness on the topic. Moreover, a descriptive statistical analysis was applied to find the mean and standard deviation of the Likert scale survey of the gameplay’s satisfaction rate. Microsoft Excel and the Jamovi software were used to perform the statistical tests.

Results and Discussion

Game Evaluation

The collected data given by educators and experts during the evaluation phase were tabulated for their intended computations. The corresponding interpretations are indicated in detail below for each category.

Table 4. Mean and Standard Deviation Interpretation for Content

Sub-Characteristics	Mean	Standard Deviation	Interpretation
Alignment with Objectives	3.73	0.4671	Very Appropriate
Level of Development	3.64	0.5045	Very Appropriate
Fact Accuracy	3.82	0.4045	Very Appropriate
Engaging Content	4.00	0.0000	Very Appropriate
Age and Interest Relevance	3.64	0.5045	Very Appropriate
Clear and Effective Visual Communication	3.73	0.4671	Very Appropriate
Appropriate Size of Material	4.00	0.0000	Very Appropriate
Durability	3.82	0.4045	Very Appropriate
Content	**3.80**	**0.4057**	Very Appropriate

Table 4 shows the mean and standard deviation of each attribute within the Content category. It received the highest average score of 4 in terms of Engaging Content and Appropriate Size, indicating that the game successfully captivated and stimulated the players while also being suitable for educational settings.

Furthermore, the interpreted mean scores for each of the sub-characteristics corresponded to the following implications: the material aligned with the subject area and grade-level objectives (Alignment with Objectives), the content of the game was applicable to students' developmental level (Level of Development), the facts were precise and reliable (Fact Accuracy), the visuals matched the target user's age and interests (Age and Interest Relevance), the visuals effectively conveyed the subject or topic message (Clear and Effective Visual Communication), and the material was user-friendly and durable (Durability). Overall, the game obtained a mean score of 3.80 in this category with a standard deviation of 0.4057, indicating a very appropriate interpretation. Thus, Make it Green is an accurate and suitable teaching aid, as it demonstrates excellent content and aligns with the needs and preferences of the users.

Table 5. Mean and Standard Deviation Interpretation for Instructional Quality

Sub-Characteristics	Mean	Standard Deviation	Interpretation
Defined Purpose	3.91	0.3015	Very Appropriate
Achievement of Purposes	3.64	0.5045	Very Appropriate
Appropriate Level of Difficulty	3.45	0.5222	Very Appropriate
Engagement	3.91	0.3015	Very Appropriate
Instructional Quality	**3.73**	**0.4505**	Very Appropriate

Table 5 shows the mean and standard deviation of each characteristic under Instructional Quality. Evaluators highly rated Make it Green across all the sub-characteristics in this category. It achieved the highest score in Defined Purpose and Engagement, indicating that the game had a clear and articulated purpose and provided an enjoyable, stimulating, challenging, and engaging user experience.

Moreover, the very appropriate interpretation of the mean score for Achievement of Purposes and Appropriate Level of Difficulty implies that the game effectively fulfilled its intended purpose and desired outcomes while maintaining an appropriate level of challenge for the target users. The overall mean score for Instructional Quality was 3.73, with a standard deviation of 0.4505, indicating a very appropriate rating. Therefore, Make it Green is an appropriate instructional material for supporting educational goals and engaging students.

According to Chiarello and Castellano (2017), the duration, engagement, difficulty, fairness, and the quality and quantity of the content of board games must be accounted for when designing to use it in an educational setting. Thus, these were the factors considered for evaluation by the experts, with the factor of fairness being combined with difficulty and the factual accuracy of the content while the factor of quantity was part of the achievement of the purpose of the material. For the factor of duration, the researchers had tested that the material would fit within the duration of one hour for one class.

Table 6. Overall Mean, Standard Deviation, and Mean Score Interpretation

Category	Mean	Standard Deviation	Interpretation
Content	3.80	0.4057	Very Appropriate
Instructional Quality	3.73	0.4505	Very Appropriate
OVERALL	**3.77**	**0.4207**	Very Appropriate

Table 6 presents a summary of the mean scores and standard deviations for each category. Among these categories, Make it Green received the highest rating in Content, indicating that the game successfully fulfilled the needs of its intended target level. Instructional materials are vital for effective teaching and learning, as their proper utilization in the classroom enhances the quality and adequacy of instruction (Tety, 2016). Thus, the evaluators recognized the board game as a great educational tool that effectively met its objectives.

Test for Normality and Equal Variance

In order to test if the data sets satisfy the conditions of a paired t-test, Shapiro-Wilk test and Levene's test was conducted.

Table 7. Shapiro-Wilk Test for Pre-Test and Post-Test of Instrument

	Pre-Test			**Post-Test**		
	Environmental Awareness	Climate Change	Environmental Sustainability	Environmental Awareness	Climate Change	Environmental Sustainability
Shapiro-Wilk W	0.948	0.950	0.902	0.925	0.868	0.765
Shapiro-Wilk p	0.006	0.007	<0.001	<0.001	<0.001	<0.001

Table 7 shows the results for the Shapiro-Wilk test of the contents of the pre-test post-test evaluations. The p-values returned are less than the level of significance ($\alpha = 0.05$). Hence, the Shapiro-Wilk test's null hypothesis must be rejected, meaning the data is not normally distributed. The evaluation scores are not from a normal distribution.

Table 8. Levene's Test for Pre-Test and Post-Test of Instrument

	Pre-Test			**Post-Test**		
	Environmental Awareness	Climate Change	Environmental Sustainability	Environmental Awareness	Climate Change	Environmental Sustainability
F	0.4859	0.0709	0.5297	1.0609	3.1476	0.9388
df1	3	3	3	3	3	3
df2	66	66	66	66	66	66
p	0.693	0.975	0.680	0.372	0.031	0.427

Table 8 presents the results of Levene's test for the contents of the pre-test post-test evaluations. Except for the post-test of the climate change knowledge, the p-value returned by each section is greater than the level of significance ($\alpha = 0.05$). Thus, Levene's test's null hypothesis must not be rejected, meaning that the data has equal variances.

According to Kim (2015), a paired t-test assumes that the data should have normal distributions, equal variances, and dependent samples. Since the scores acquired do not satisfy the conditions for normality and homogeneity of variance, the Wilcoxon Signed Rank test must be used.

The sample is not normally distributed could be because of the more intensive and advanced programs in Science that were set for science high school students being taught in a Science high school. This can be seen in the resulting graph of the scores being negatively skewed in *Figures 8-10*. Further studies that are conducted in non-science schools can be done to validate the results of the scores.

Environmental Awareness

Before the participants answered the knowledge assessments for the pre-test and post-test, they were asked to rank their current level of environmental awareness by answering the five-point Likert scale questionnaire provided. The questionnaire consisted of seven statements consisting of behavioral characteristics on how the participants perceive climate change.

Table 9. Descriptive Statistics of Environmental Awareness for Acceptability

	No. of Items	Mean	SD
Pre-Test	7	4.25	0.85
Post-Test		4.43	0.81

Table 9 describes the averaged data of the participants' environmental awareness Likert scale answers. During the pre-test, the grade 7 students had acceptable results ($\bar{x} = 4.25$) thus far, indicating that the participants were currently aware about the issues surrounding climate change. After the intervention, the mean had increased by 0.18. However, it was not enough to satisfy the conditions for highly acceptable results. The students learned more about the relationship of their awareness to climate change issues, however the awareness are still lacking in some areas of the topic.

Table 10 describes the mean and standard deviation of the scores for the individual statements of the Likert scale survey. The highest mean scores are Statement 4 ($\bar{x} = 4.72$) for the pre-test and Statement 7 ($\bar{x} = 4.79$) for the post-test, while Statement 2 had the lowest mean score for both the pre-test ($\bar{x} = 3.67$) and post-test ($\bar{x} = 3.92$). This indicates that while the grade 7 students are aware about the causes and effects of climate change that they encounter in their daily life, there is a lack of awareness in which actions to take to mitigate climate change. While the mean

had increased during the post-test, there is still room for improvement to educate students about environmental awareness.

Table 10. Descriptive Statistics of Environmental Awareness for Each Statement

Statement	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD
I follow the news about environmental issues.	3.99	0.72	4.13	0.72
I discuss environmental problems with my friends and family.	3.67	0.93	3.92	0.93
I am aware of the environmental concerns within my community.	4.49	0.74	4.75	0.74
I am aware of the pollution I may cause in my daily life.	4.72	0.54	4.75	0.54
I am aware of the greenhouse gases emitted by vehicles.	4.51	0.81	4.64	0.81
I actively participate in environmental activities in school.	3.79	0.84	4.00	0.84
I am aware of my responsibilities to the environment.	4.58	0.65	4.79	0.65

Table 11 shows the mean and standard deviation of the total weighted scores acquired for the students' environmental awareness during the pre-test and post-test. The mean scores increased by 1.2 after playing the board game, indicating an increase of environmental awareness among the participants. The standard deviation had also increased by 0.36, suggesting that while there is a general improvement of environmental awareness among the group, the answers varied more in the post-test evaluation. This could indicate that the students are more carefully considering the questions and answering them more thoughtfully as they have learned more climate change concepts since the pre-test, resulting in values that are scattered in both the high and low end of the data set.

Table 11. Descriptive Statistics of Environmental Awareness for Paired Comparison

	No. of Items	Maximum Weighted Score	Mean	SD
Pre-Test	7	35	29.8	2.79
Post-Test			31.0	3.15

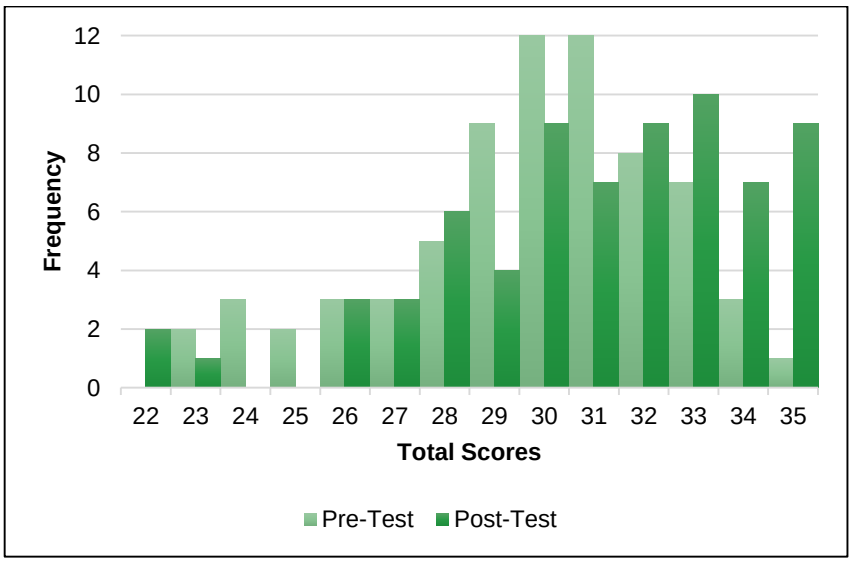

Figure 8. Pre-Test Post-Test Scores of Participants' Environmental Awareness

Figure 8 presents the distribution of the pre-test and post-test scores among grade 7 students. While the most frequently obtained scores in the pre-test are in the 29-32 range, the most frequent scores in the post-test are in the 30-35 range, showing an increase of where the students identified their environmental awareness to currently be at. There are also fewer scores in the 23-25 range; however, two (2) participants had gotten lower scores in the post-test than the rest of the group, being 22. These participants are among the 13 of the 70 participants (18.57%) that yielded lower results in this section of the post-test. While these students had lower scores for the self-evaluation questions (environmental awareness), their scores for the knowledge assessment questions (climate change & environmental sustainability knowledge) increased.

The decrease in the scores may be the result of the Dunning-Kruger effect (Dunning, 2011), where the self-evaluated perceived knowledge of the participants is rated higher for beginners while more knowledgeable individuals rated their perceived knowledge more fairly. This aligns with the study of Fuchs (2023) where students in higher years reported that their perceived knowledge of environmental sustainability as more modest than those of first years. This suggests that the participants acknowledged that there is still more to learn in the environmental

issues surrounding climate change, hence they answered less confidently in the environmental awareness section.

Table 12. Wilcoxon Signed Rank Test of Environmental Awareness

	Statistic	*p*	Mean Difference	SE Difference
Pre-Test-Post-Test	287	<0.001	1.50	3.15

Table 12 displays the non-parametric test used to test the significant difference between the pre-test and post-test results of the environmental awareness survey. After running the test through Jamovi, the test returned a p-value of $p < 0.001$. Since the p-value is less than the level of significance ($\alpha = 0.05$), H_0 must be rejected. Therefore, there must be a significant difference between the pre-test and post-test scores. Since the mean weighted score of the post-test is greater than that of the pre-test, it can be said that there is a significant increase in environmental awareness after playing the Make it Green board game. This indicates that the material effectively increased the environmental awareness in an educational setting.

Make it Green does induce an increase in the environmental awareness of the participants due to the fact that the learners can see the first-hand effect of their actions through the board game. According to Kwok (2019), as climate change games tend to focus on resource management, climate-induced disasters, and consequences of inaction, these kinds of games affect how the general public's knowledge, perception, and attitude will change about climate change. Since Make it Green also encompasses the same focus, the resulting effect is also observed to be similar.

Climate Change Knowledge

After taking the environmental awareness survey, the participants were subjected to answering the climate change knowledge questionnaire which gauges the current knowledge of the students about the causes and effects of climate change. This section of the questionnaire is composed of 10 multiple-choice items asking different factual concepts surrounding the topic.

Table 13. Descriptive Statistics of Climate Change Knowledge

	No. of Items	Mean	SD
Pre-Test	10	7.21	1.43
Post-Test		8.70	1.03

Table 13 describes the mean and standard difference yielded by the scores of the participants. Despite the questionnaire tackling advanced concepts about climate change, the students had a mean score of 7.21 for the pre-test. This could be because of the special science subjects taught in the legislated Science school covering advanced topics. The increase in the mean and the decrease in the standard deviation can be interpreted such that the intervention had a positive effect on the scores of the climate change knowledge of grade 7 students.

Figure 9. Pre-Test Post-Test Scores of Participants' Climate Change Knowledge

Figure 9 shows the distribution of scores for climate change knowledge among the participants. While the pre-test scores ranged from 4-10, the post-test's minimum score obtained is 7. Most of the participants' scores are on the 8-10 range as well, indicating an increase of knowledge among the students in regards to the different concepts of climate change.

Table 14. Wilcoxon Signed Rank Test of Climate Change Knowledge

	Statistic	***p***	**Mean Difference**	**SE Difference**
Pre-Test -Post-Test	54.0	<0.001	2.00	0.164

Table 14 describes the non-parametric test used for testing the significant difference of climate change knowledge in the pre-test and post-test of grade 7 students. The test yielded a p-value of $p < 0.001$. Since the p-value is less than the level of significance ($\alpha = 0.05$), the null hypothesis must be rejected. Thus, it can be concluded that there is a significant difference between the scores of the students before and after playing the board game. The mean score of the post-test is greater than the pre-test, indicating that it had a significant increase between the scores. Therefore, it can be said that the Make it Green board game significantly increases the players' knowledge of the concepts surrounding climate change.

Make it Green as a board game has shown significant increase in the development of knowledge on climate change topics. This aligns with the other video games and tabletop games that are developed to tackle climate change (Reckien and Eisenack, 2013). This adds that climate change-centric games can be used in education, and in turn discussion surrounding the trends of climate change. Due to the observed efficacy of gamification as a tool for climate change education, further games and studies can be developed to push the complexity of the climate change topics into a wider audience, and in turn, encourage action. Furthermore, Wu and Lee (2015) state that educational games can help enforce civic duties to societies, further developments can help push the problems and solutions for climate change to the general public.

Environmental Sustainability Knowledge

Like the climate change knowledge section of the questionnaire, the environmental sustainability knowledge section tackles the participants' factual mastery in the given topic. It is also comprised of multiple-choice questions, and it was administered before and after playing the board game.

Table 15. Descriptive Statistics of Environmental Sustainability Knowledge

	No. of Items	Mean	SD
Pre-Test	5	3.51	1.201
Post-Test		4.07	0.968

Table 15 describes the mean scores and standard deviation acquired from the pre-test and post-test of knowledge of environmental sustainability. The mean scores had increased, and the standard deviation decreased from 1.201 to 0.968 after the participants played the board game, indicating that the participants are getting higher scores closer to the mean of the group. This shows an increase in the knowledge of sustainability among the participants.

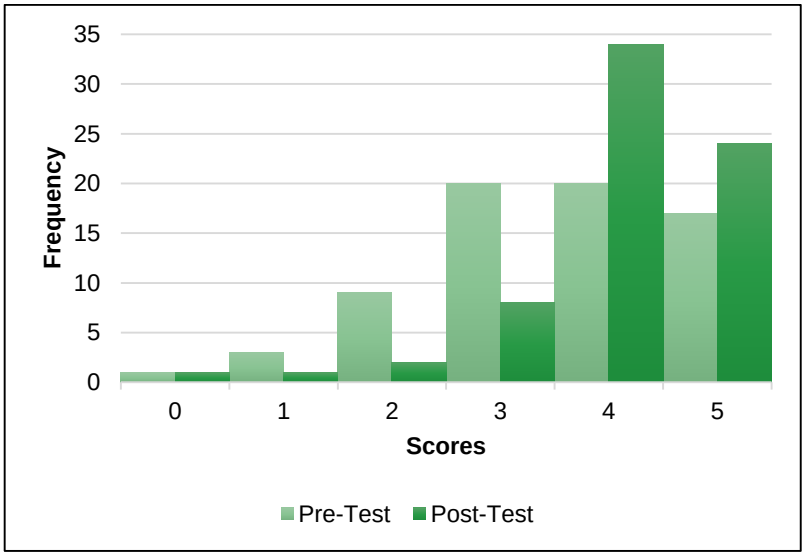

Figure 10. Pre-Test Post-Test Scores of Participants' Environmental Sustainability Knowledge

Figure 10 shows the histogram of the scores of the pre-test and post-test of grade 7 students on their knowledge on sustainability. While there are still those who got low answers where one participant got a zero in the pre-test and a different participant got a zero in the post-test, most of the students yielded increased results in their scores. Most of the scores in the pre-test were in the 3-5 range, but the post-test had the range increased to 4-5. This shows that most of the participants scored better after learning the sustainability concepts through Make it Green.

Table 16. Wilcoxon Signed Rank Test of Environmental Sustainability Knowledge

	Statistic	*p*	Mean Difference	SE Difference
Pre-Test -Post-Test	146	<0.001	1.00	0.131

Table 16 describes the non-parametric test used to test for the significant difference of the environmental sustainability knowledge of the participants in the pre-test and post-test. The test yielded a p-value of $p < 0.001$, indicating that the null hypothesis must be rejected at level of significance ($\alpha = 0.05$). Hence, there is a significant difference between the pre-test and post-test scores of the students. Since the post-test scores yielded a higher mean, it means that there is a significant increase of scores due to the intervention. Thus, it can be concluded that Make it Green can increase the knowledge of the players in environmental sustainability.

According to Scurati, Ferrise, and Bertoni (2020), the gamification of the topics surrounding sustainability helped visualize the issue at hand, and the same is evident for Make it Green. The use of the board as a visual tool for the learners to see the facilities and risks in the environment helped them make informed choices while playing the game which they can also translate in their life. Still, Make it Green mostly focused on climate change with environmental sustainability as a supporting topic, so further studies on purely sustainability-focused gamifications can still be conducted.

Gameplay Satisfaction

After the participants played the game, they were surveyed about their satisfaction with the different aspects of the game. The students were given a set of 15 statements to be evaluated with a four-point Likert scale. Each of the statements fit in one of four criteria for evaluating the participants' satisfaction with the game in terms of: (i) Enjoyment, (ii) Mechanics, (iii) Set-Up, and (iv) Visuals. The options presented in the questionnaire were given point values in order to quantify its scores: Strongly Agree (4), Agree (3), Disagree (2), Strongly Disagree (1). Negatively worded statements were given inverted point values with strongly disagree being 4 and strongly agree being 1. The data was averaged to assess the appropriateness of the results as outlined by the four-point Likert scale interpretation of Lawsin and Garcia (2017).

Table 17. Descriptive Statistics of Participants' Gameplay Satisfaction

Criteria	Items	No. of Items	Mean	SD
Enjoyment	Q1, Q2, Q9, Q12, Q15	5	3.74	0.46
Mechanics	Q3, Q4, Q7, Q13	4	3.23	0.75
Set-Up	Q5, Q6, Q10	3	3.48	0.59
Visuals	Q8, Q11, Q14	3	3.59	0.58

Table 17 describes the mean and significant difference of the scores of the gameplay satisfaction survey. The game enjoyment criteria ranked highest ($\bar{x}$ = 3.74) out of the four criteria while mechanics ranked lowest ($\bar{x}$ = 3.23). The enjoyment, set-up, and visuals criteria are interpreted as very appropriate results ($4.00 \geq \bar{x} > 3.25$). However, the resulting mean of the mechanic criteria is only considered as appropriate ($3.25 > \bar{x} > 2.50$). This could be due to the fact that board games are usually rules-heavy especially while the players are learning the game at the beginning, resulting to most players feeling overwhelmed with information overload.

For the individual statements, Statement 3 which reads *"I found the game overwhelming,"* scored lowest ($\bar{x}$ = 2.82, σ = 0.86; inverted value) across all the statements which supports this claim. For the highest result, it was Statement 15 which reads *"Given the chance, I want to play the game again,"* at a mean of 3.91 and a standard deviation of 0.30. This is because Make it Green is designed with replayability in mind. There is a variety of cards in the game, however there are only so much that will be used in a single game. This adds to the satisfaction of the participants as they end up wanting more of the game, and in turn they also learn more concepts about climate change.

The different criteria set to evaluate the board game is proven to be at least satisfactory for the grade 7 learners. Board games can be used to immerse and engage students in the topics to be discussed as it does enable a motivating game-based discussion as observed in our pilot testing and as stated by Chiarello and Castellano (2017). Additionally, Noda and Kakao (2019) discuss an anticipated increase in factual understanding, interpersonal interactions, and motivation among the participants which the grade 7 students agree they have achieved in our study. Statement 9 which reads *"I learned interesting new concepts from the game,"* earned a mean of 3.67 and a standard deviation of 0.50, Statement 12 which reads *"I enjoyed the social aspect of collaboration within the game,"* had a mean of 3.73 and a standard deviation of 0.46, and Statement 1 which read "I enjoyed playing the game" acquired a mean of 3.83 with a standard deviation of 0.38; all of which obtained very appropriate results.

Limitations

Due to the stringent guidelines required from the researchers, the data gathering was delimited to the legislated Science high school Grade 7 students in the current school year, 2022-2023. The study was conducted within the first and second semesters of the school year.

Conversely, the limitations of this study include technical suggestions provided by evaluators, which surpassed the researchers' expertise in game development. While the feedback received was valuable, implementing certain recommendations proved challenging due to the researchers' limited capabilities in that specific domain. Another constraint was time, which imposed limitations on the exploration of additional ideas to incorporate into the game and the overall study. Given the time constraints, an observational study on the students' awareness and in turn action regarding climate change was supplanted with a self-evaluated survey, restricting the ability of researchers to incorporate a control group which limits the ability to establish a cause-and-effect relationship between the intervention and the observed effects. Consequently, the researchers had to carefully evaluate and prioritize the relevance of the paper's contents, ensuring that the most crucial aspects were addressed within the given timeframe.

CONCLUSIONS

Make it Green's effectiveness was successfully determined since there was an increase in the Grade 7 student's level of climate change and environmental sustainability knowledge and awareness after the playthrough. They also found the visuals appealing and were very satisfied as they wanted more of the game. Moreover, they are very engaged in playing the game as a tool for enhancing their climate and environmental knowledge and awareness.

Similarly, the board game received favorable responses from evaluators that implied their attitudes toward its appropriateness as an educational tool for the domains targeted in this study. The game's strongest characteristics were Engaging Content and Appropriate Size, indicating that the game successfully captivated and stimulated the players while also ensuring that it fulfilled the needs of its intended target level. Furthermore, the rest of the characteristics (Defined Purpose and Engagement) achieved scores near the highest. This indicated high accuracy in showing clear and elucidated purpose and was deemed highly operational and engaging for the players.

As it demonstrates excellent content and aligns with the users' needs and preferences, and with an overall rating of 3.77 during the evaluation, Make it Green was perceived to have a very positive performance as a great educational tool on climate change.

Recommendations

Based on the summary findings and conclusions, the researchers recommend testing the game in non-science schools to address potential biases that may arise from a science-focused educational setting, allowing for a more diverse sample and improved generalizability of the findings. To establish a balanced and captivating gameplay experience, an appropriate correspondence between the number of cards and their effects should be ensured. Further studies can also explore the following directions: (a) incorporating a greater variety of facility

cards focusing on renewable sources, and (b) integrating anthropogenic activities into the risk cards will gain a deeper understanding of the importance of individual and collective responsibility in addressing climate change. Additionally, in order to assess the game's influence, it is crucial to measure players' behavior towards climate to measure and track changes in players' attitudes and actions related to climate change. Due to the researchers' limited expertise in coding, transforming the board game into a mobile app is recommended, as it will enhance accessibility and enable a broader audience to engage with the game's educational content.

DECLARATIONS

Data Availability: Data is available upon request to the author.

Ethical Rules: This research's ethical report received from Republic of Philippines Department of education dated May 11, 2023. The report signed by Dr. Jovelyn Ö. Alinab (Chief Education Superviser – CID)

Conflict of Interest: There is no conflict interest.

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