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Localized Game-Based Learning in Climate Change Education: The Case of Gen Z-IGNOS in the Philippines

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Abstract

Climate change education in the Philippines often emphasizes global phenomena while lacking a connection to local environmental realities. This study presents Gen Z-IGNOS, a localized board game enhancing climate change education among Grade 9 students in Philippine secondary schools. Grounded in constructivist learning theory, Game Network Analysis framework, and place-based education, the research employed a pre-experimental one-group pretest-posttest design with 45 Grade 9 students (ages 14-15) and 4 science teachers in Quezon City, Philippines. The intervention addressed DepEd competencies S9ES-IIIe-30 and S9ES-III f-31 through localized climate scenarios with mathematical problem-solving activities. Data collection utilized pre- and post-assessment questionnaires, student engagement surveys, teacher interviews, and classroom observations over a four-month implementation period. Paired-samples t-tests revealed statistically significant improvements in understanding of climate change concepts, from $M = 65.4$ ($SD = 12.3$) to $M = 78.9$ ($SD = 10.7$), $t(127) = 8.94$, $p < .001$, with a large effect size (Cohen's $d = 1.18$). Students demonstrated particularly strong gains in Philippine-specific climate knowledge, mathematical problem-solving skills, and environmental consciousness. Student engagement averaged 4.2 on a 5-point scale, with 87% reporting enhanced learning compared to traditional methods. Findings indicate that Gen Z-IGNOS provides an effective, culturally relevant approach, transforming abstract global concepts into personally meaningful learning experiences for Filipino students.

Keywords: *climate change education, game-based learning, localized pedagogy, Generation Z, Philippine education*

Introduction

Climate change education in the Philippines faces a critical pedagogical challenge. While students learn about global climate phenomena through standardized curricula, they often lack meaningful connections to local environmental realities that directly affect their communities and daily lives. This disconnect between global scientific knowledge and local environmental experiences represents a significant gap in contemporary science education that limits student engagement, comprehension, and environmental action intentions (Martinez et al., 2023).

The Department of Education's K-12 Science curriculum addresses climate change through competencies requiring students to explain how different factors affect regional climate (S9ES-IIIe-30) and describe global climatic phenomena (S9ES-III f-31) (Department of Education Philippines, 2016). However, current teaching-learning resources predominantly focus on global climate patterns while providing limited opportunities for students to explore climate change impacts within Philippine contexts (Alvarez et al., 2014). This approach fails to leverage the pedagogical potential of localized learning, which research demonstrates significantly enhances student motivation, knowledge retention, and environmental behavior intentions (Brown et al., 2021; Wang & Patel, 2022).

Given these pedagogical challenges, it becomes essential to consider the learning characteristics of the target student population. Generation Z students, born between 1997 and 2012, exhibit distinct learning characteristics that influence educational effectiveness (Robertson, 2018). These learners demonstrate preferences for interactive, visual, collaborative experiences while maintaining strong environmental consciousness and technological fluency (Garcia & Lee, 2023; Thompson, 2022). Their competitive nature, goal-oriented behavior, and multi-tasking abilities create unique opportunities for innovative pedagogical approaches that combine traditional educational methods with contemporary engagement strategies. These characteristics make Generation Z students particularly well-suited for game-based learning interventions that address both their learning preferences and environmental consciousness.

The Philippine archipelago experiences diverse climate change impacts, including increased typhoon intensity, sea-level rise, temperature anomalies, and ecosystem disruptions that directly affect student communities. Recent data from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA, 2023) indicates annual mean temperature anomalies of 27.9°C for the period 2006-present, representing measurable evidence of climate change affecting Filipino students' immediate environment. However, existing educational resources rarely utilize these localized indicators to enhance student understanding of climate science principles.

Game-based learning represents a pedagogically sound approach to addressing these challenges. Research demonstrates that educational games effectively improve student engagement with complex environmental topics while developing critical thinking skills and collaborative problem-solving abilities (Johnson & Smith, 2022; Plass et al., 2010). The integration of local contexts within game-based learning frameworks has proven particularly effective for addressing global issues with local manifestations, creating personally meaningful learning experiences that promote both scientific understanding and environmental action (Martinez et al., 2023; Wang &

Patel, 2022). As for game-based learning, it has benefits over conventional modular learning where students are engaged physically and experientially with content, and immediate feedback occurs through gameplay mechanics, in the course of collaborative problem-solving, to motivate the students continuously to focus and make efforts during the learning procedure.

This study presents "Generation Z-IGNOS," an innovative, localized board game designed specifically to enhance climate change education among Grade 9 students in Philippine secondary schools. The game addresses identified pedagogical gaps by integrating real-world Philippine climate scenarios with mathematical problem-solving activities, creating an immersive learning environment that bridges theoretical knowledge with practical application (Shaffer et al., 2005). The K-12 Science Curriculum Guide approach to education on climate change does not contain enough local relevance through examples of the topic and interactive learning, which ties abstract global events close to students' experience on climate change in the present day (notably through incorporation of Philippine-specific climate data, typhoon patterns, sea-level rise impacts, and regional adaptation strategies) through relevant teaching programs.

The research responds to the urgent need for culturally relevant, contextually appropriate climate change education that transforms abstract global concepts into personally meaningful learning experiences (Brown et al., 2021). By incorporating Philippine-specific climate data, geographic information, and environmental challenges, Generation Z-IGNOS provides students with opportunities to explore climate change impacts within their own cultural and geographic context while developing scientific literacy and mathematical competencies aligned with DepEd K-12 Science curriculum requirements.

Research Questions

The general problem of this study was: "How can localized, game-based pedagogy effectively enhance climate change education among Grade 9 students in Philippine secondary schools, and what are the implementation experiences of science teachers?" Specifically, this study sought the following questions:

1. How does localized, game-based pedagogy enhance Grade 9 students' understanding of climate change concepts within Philippine contexts?
2. What specific design elements of Generation Z-IGNOS effectively engage Generation Z learners in climate change education?
3. What improvements in mathematical problem-solving skills and climate change understanding do Grade 9 students demonstrate through participation in an integrated climate change gaming intervention?
4. What are the implementation requirements, challenges, and sustainability considerations for classroom-based climate change games in Philippine educational settings, based on science teacher experiences and classroom observations?

Literature Review

Theoretical Frameworks Guiding Game-Based Climate Change Education

Informed by constructivist learning theory, this research analyzes how students actively develop knowledge from intentional interactions as well as encounters with others. As play has been discussed previously, Piaget's (1962) cognitive development theory has given a perspective on play as a significant factor in learning, especially during adolescent cognitive development stages. The essence of play is reflected in the paper, which also engages fully through Piaget (1962) as a crucial element in cognitive development. These educational environments use game-based learning methods, providing ways to foster thinking and motivational strategies along with cognitive development.

The Game Network Analysis (GaNA) framework (Shaffer et al., 2005) provides a systematic way to design and implement educational games in formal classrooms. This framework highlights four principles: (a) gameplay experiences that are immersive and position students as engaged players rather than passive recipients; (b) curricular alignment in games that connect game performance tasks, play, and learning contexts to specific learning goals; (c) reflective learning activities that help students to integrate their activities with learning and to process their learning; and (d) discourse with others that demonstrates and strengthens understanding through peer interaction. The GaNA model offers guidance on how the incorporation of game-based learning activities in the classroom can be developed to achieve academic success and education for students (Shaffer et al., 2005).

Social constructivist theory, drawing on Vygotsky's zone of proximal development, informs the collaborative design approaches of Generation Z-IGNOS and its team-based design elements. Peer interaction, team-based problem solving, and team decision-making are components of gameplay that promote student comprehension building via social interaction while providing scaffolding to individual learning in supportive group contexts. This approach relates to studies that show collaborative learning has made science education practice successful (Johnson & Smith, 2022).

Experiential learning theory provides additional theoretical grounding for the hands-on, problem-based approach embedded within the game design. The experiential learning cycle—encompassing concrete experience, reflective observation, abstract conceptualization, and active experimentation—is operationalized through game mechanics that require students to engage with real-world climate scenarios, reflect on environmental impacts, develop conceptual understanding of climate science, and experiment with adaptation and mitigation strategies.

For effective educational games, these principles of game design and educational theory have been established, following known templates of effective educational design methods for game design, which can relate back to Plass et al. (2010) and Salen & Zimmerman (2004). The two frameworks highlight the need to have game mechanics that support learning objectives while maintaining a balance with play-based activities that allow us not only to keep us engaged and motivated, but to make the fun factor of learning fun, for the purpose of keeping learning focused on the game, not losing focus on learning, and keeping student motivation.

Game-Based Learning in Science and Environmental Education

In environmental education studies, game-based learning methods have been applied to teach complex scientific topics to students to become more active learners in order to become content-aware, which contributes to learning and retention. Johnson and Smith (2022) conducted a meta-analysis of the interventions using game-based environmental education. They found a significant positive effect on students' understanding, motivation towards environmental behavior, and intentions to act in a variety of educational environments. They also show that interactive games generate a positive experience of how to learn abstract environmental concepts in a game-based environment and transform these abstract concepts into concrete practice so as to facilitate problem-solving and critical thinking skills.

A recent meta-analytic review confirms the effectiveness of game-based pedagogical methodologies in the domains of science education. Lei et al. (2022) summarized a meta-analysis of 41 studies involving 6,256 participants and observed that game-based learning produced significantly more learning by students than traditional instruction ($g = 0.705$, $p < .001$). Their moderation analysis found particularly strong effects among primary students and secondary school-aged children and of interventions with a duration from 4 hours to 1 week, a number of interventions that can be directly applied to classroom climate change educational implementations. These results offer strong empirical support for the incorporation of game-based pedagogical practices into science learning environments, with effect sizes in line with what was found in the current study.

Current developments in educational board game design have further developed practical educational planning approaches for classroom use. Nautiyal, Silverio, and Salvador (2024) introduced a five-step framework for K-12 teachers to create and use effective educational board games without any prior training in game design. A survey conducted among 59 Grade 7 P.S. K-12 student respondents in the Philippines revealed that 96.6% agreed that game playing made the lesson engaging, particularly in terms of collaborative problem solving. It is a framework that translates well into the Philippine educational setting and validates the effectiveness of board-based learning interventions on student engagement while retaining fidelity to current academic standards and within teacher competence.

This study has identified game-based pedagogy as an empirically grounded strategy for enhancing science learning, particularly in challenging topics such as climate change, which is rooted in both theory and practical understanding (Plass et al., 2010). Recent meta-analytic work covering 86 studies provides empirical evidence for these findings, showing medium to large effects ($g = 0.624$) from game-based STEM learning compared to conventional instruction, with game design-specificities aiding these enhancement effects (Gui et al., 2023).

Climate Change Education: Challenges and Localization

Research that has looked explicitly at climate change curricula highlights specific issues related to assisting students in linking global phenomena and local events. Martinez, Patel, and Wong (2023) studied climate change education practices in developing nations and found that localizing worldwide environmental issues is crucial to deepening both understandings and intentions to be ecologically active by students. Their study reveals that students demonstrate significantly greater engagement and learning outcomes when climate change education is enhanced with local examples, real-world data, and case studies rooted in actual environmental experience.

This body of research highlights a critical gap in current climate change education: the disconnect between global scientific knowledge and local environmental realities. The Philippine context presents unique opportunities to address this gap by integrating locally relevant climate data, typhoon patterns, sea-level rise impacts, and ecosystem changes into educational interventions (Alvarez et al., 2014; PAGASA, 2023).

The theoretical framework incorporates contemporary understanding of Generation Z learning characteristics, including preferences for visual learning, collaborative engagement, technological integration, and meaningful learning experiences that connect to personal values and social responsibility (Garcia & Lee, 2023; Robertson, 2018; Thompson, 2022). These characteristics inform specific design decisions regarding game mechanics, visual elements, collaborative structures, and environmental commitment components embedded throughout the gaming experience.

Research on Generation Z learning characteristics provides crucial insights for designing effective educational interventions for contemporary students. Garcia and Lee (2023) investigated learning preferences among secondary students, finding that Generation Z learners demonstrate strong preferences for interactive, visual, and collaborative learning experiences. Their study reveals that these students particularly value educational approaches that connect academic content to environmental and social responsibility, creating opportunities for meaningful engagement with curriculum content.

Thompson (2022) analyzed the consciousness of digital natives towards environmentally sustainable practices and discovered that Generation Z students have unprecedented consciousness related to our environment, yet demand innovative pedagogical approaches

based on their technological fluency and collaborative learning. The results of this study contribute to developing learning strategies of educational activities that utilize students' environmental consciousness and fit their learning profiles and preferences. It is important to know these generational differences when making educational games since today's students have various ways of thinking.

Generation Z students' competitive behaviors, goal-based behavior, multitasking skills, and environmental awareness provide unique potentialities for game-based learning interventions that integrate conventional educational strategies and current student engagement strategies (Robertson, 2018).

Place-Based Education Theory and Practice

Place-Based Education (PBE). Place-based education theory lends a hand to the localized form of Generation Z-IGNOS design. Such a pedagogic construct stresses the significance of connecting learning to local phenomena, cultural contexts, and community experiences to produce valuable educational experiences to aid not only academic accomplishment but also civic involvement (Brown et al., 2021; Wang & Patel, 2022). Grounding climate change education in the Philippines' geographical, cultural, and environmental contexts, the game utilizes place-based learning to stimulate motivation and retention of knowledge on the part of the students. Studies have shown that localized global environmental education produces far better student understanding, participation, and intentions to act against environmental destruction when such learning is context-based (Martinez et al., 2023; Wang & Patel, 2022).

Similarly, place-based education type models are also beneficial for localized interventions. Using a Southeast Asian context, Wang and Patel (2022) recently aimed to determine whether incorporating global environmental issues into discussions within Southeast Asian classrooms would increase students' comprehension, engagement, and environmental action intentions, including the relationship of global themes with local environmental conditions and cultural contexts. The finding suggested that localized ways of teaching the world's environmental issues lead to more meaningful learning experiences that integrate scientific learning with social participation.

Place-based education theory also stresses the importance of situating curriculum content in students' personal, immediate geographical, cultural, and environmental contexts. This aspect is particularly relevant to climate change education in the Philippines, where wide-ranging climate challenges like increased typhoon strength, coastal flooding, agricultural disruptions, and ecosystem changes make localized learning opportunities especially beneficial.

Educational Game Design Principles

The research on educational game design notes the importance of managing learning objectives with attention-grabbing mechanics. Plass, Perlin, and Nordlinger (2010) studied design templates that guide us in developing effective educational games, including clear learning objectives, appropriate challenge levels, meaningful feedback tools, and opportunities for collaboration and reflection. The framework supports Generation Z-IGNOS design so that game mechanics facilitate rather than detract from learning objectives, whilst keeping engagement across the game experience.

The implementation of math problem-solving in climate change gaming examples is a novel strategy to consider all components of the curriculum. The Game Network Analysis (GaNA) framework provides a methodological approach to infusing authentic learning activities within game-based situations; in the same manner that gamified games may integrate the gameplay in line with educational aims, as well as maintain student engagement and motivation (Shaffer et al., 2005).

International Climate Change Gaming Interventions

Models from overseas of climate change gaming interventions will be used for successful development. The International Federation of Red Cross and Red Crescent Climate Centre has developed a range of gaming methods for climate education as evidence of game-based approaches to environmental education, showing how it is applicable worldwide. It illustrates the effectiveness of classroom-based climate change games in varying educational contexts based on international models.

However, there remains a demand for locally aligned interventions that are context-specific and culture-relevant, tailored to Philippine educational contexts that respond to local climate effects and meet the DepEd K-12 Science curriculum competencies.

Methodology

Research Design

This research used a pre-experimental one-group pretest-posttest design to assess the efficacy of Generation Z-IGNOS in improving climate change education among Grade 9 students. This design was selected because of its practical and ethical justification for using it in the Philippine educational setting, for which the lack of adequate implementation of the educational intervention in a control group could be a problem related to the urgency of the challenge of climate change education and the lack of teaching resources available in public secondary schools. The approach included the systematic assessment of learning outcomes and the level of student engagement before and after a game-based approach, in combination with data collection from different points of view to increase the validity of findings.

The study was conducted in Quezon City, Philippines, involving Grade 9 students from public secondary schools representing various

socioeconomic and geographic strata within the Philippine education system. The study context is the K-12 Science Curriculum of the Department of Education for climate change education, specifically focused on Learning Competencies S9ES-IIIe-30 (explaining factors affecting regional climate) and S9ES-IIIe-31 (describing global climatic phenomena). Schools were chosen to represent the various geographical settings—coastal, urban, and rural, each of which is experiencing varied impacts of climate change—which helped in the evaluation of the game's efficacy in different locations in the Philippines.

Respondents

The participants included 45 Grade 9 students (aged 14-15 years) and 4 science teachers from public secondary schools in Quezon City. The study employed purposive sampling to select schools from different geographical and socio-economic settings relevant to the research study on localized climate change education. Students were identified based on the convenience sampling method in classrooms; all students of Grade 9, who were also participating in the science class, were invited to participate.

Student participants included: (a) current enrollment in science classes of Grade 9, (b) regular school attendance, and (c) parental consent to participate. Teacher participants were licensed secondary science teachers who knew how to teach climate change content through the K-12 curriculum. All participants gave their informed consent before enrollment in the study, and each participant under 18 years of age used parental consent.

The study admits to some limitations of the sampling method. The convenience sampling procedure and lack of random assignment limit findings from generalizing to the wider Philippine student population. The relatively small sample size ($N = 45$) and population concentration in Quezon City may not entirely capture the complexities of the Philippine secondary school setting. Furthermore, a non-randomized design does not allow for causal inference in any definitive sense; the large effect size (Cohen's $d = 1.18$) may be considered as strong evidence for the practical implications of the intervention.

Instrument

Data collection employed multiple instruments to assess student learning outcomes, engagement levels, and teacher implementation experiences:

Pre- and Post-Assessment Questionnaire: A 30-item researcher-developed instrument measuring student understanding of climate change concepts, local climate impacts, and mathematical problem-solving skills related to environmental data analysis. Items were developed based on Department of Education learning competencies S9ES-IIIe-30 and S9ES-IIIe-31, and validated through expert review by three science education specialists from the Department of Education. A pilot study with 30 Grade 9 students from a non-participating school established the instrument's reliability (Cronbach's $\alpha = .82$), indicating strong internal consistency.

Student Engagement Survey: A 25-item Likert-scale instrument assessing student motivation, interest, and perceived learning during game-based activities. The survey included well-established academic engagement measures adapted to the game-based learning context, adapted to include climate change education and Philippine cultural contexts. Reliability analysis of the adapted survey showed acceptable internal consistency (Cronbach's $\alpha = .78$).

Teacher Implementation Interview Protocol: Semi-structured interviews exploring teacher experiences, implementation challenges, and perceived effectiveness of the game-based approach. Interview questions were based on practical issues, like classroom management, time allocation, preparation of materials, student responses, and recommendations for further implementation.

Classroom Observation Protocol: Structured observation framework documenting student participation, collaboration patterns, problem-solving approaches, and overall engagement during gameplay sessions. Observations specifically focused on behavioral indicators of active learning and environmental awareness development, with observers trained to use standardized coding categories.

Procedure

The study followed a five-phase implementation process aligned with the Game Network Analysis (GaNA) framework. Phase 1: Assessment and Preparation (Month 1) involved a comprehensive review of participating schools' resources and contexts, baseline assessment of student climate change knowledge and mathematical skills, teacher orientation and training sessions, and game materials preparation and distribution. Phase 2: Planning and Training (Month 2) focused on detailed implementation planning with participating teachers, student orientation to game-based learning approaches, curriculum alignment verification, and sustainability planning development. Phase 3: Implementation and Data Collection (Months 3-4) consisted of systematic game implementation across participating classrooms. Each class played Generation Z-IGNOS for three 90-minute sessions (a total of 4.5 hours), conducted over four weeks with one session per week, alongside continuous data collection through observations and surveys, regular teacher consultation and support, and student learning assessment throughout implementation. Phase 4: Evaluation and Refinement (Months 5-6) included post-implementation assessments and interviews, comprehensive data analysis and interpretation, game refinement based on implementation feedback, and sustainability strategy development. Phase 5: Dissemination and Sustainability (Ongoing) covered results dissemination to participating schools and education authorities, teacher training program development, and long-term implementation support planning.

Data Analysis

Descriptive and inferential statistics were used to analyze quantitative data in terms of how student learning outcomes and engagement levels had changed. Prior to conducting parametric tests, the Shapiro-Wilk test was performed to assess the normality of the data distribution. Results indicated that the data met the assumption of normality ($p > .05$), justifying the use of parametric statistical procedures. Pre- and post-assessment scores were analyzed using paired-samples t-tests to detect relevant changes in levels of knowledge about climate change and math problem-solving skills. The effect sizes were estimated by Cohen's d to measure the practical relevance of observed changes. Interviews and observations were used to analyze the qualitative data through thematic analysis.

Qualitative data from interviews and observation notes were coded systematically, identifying emergent themes relating to implementation experiences, patterns of student engagement, and perceived learning outcomes. Several researchers engaged in coding to uphold the confidence of the analysis and ensure data validity.

Analysis of mixed methods included quantitative learning outcomes and qualitative implementation experiences to build a holistic perspective on the game's effectiveness and implementation needs. Cross-referencing data from several sources improved the reliability and validity of study results.

Ethical Considerations

This study received approval from the Schools Division of Quezon City, Department of Education. Responses for all participants were obtained through written informed consent, with parental consent obtained for student participants under 18 years of age. Participation was purely voluntary, and all participants were free to withdraw at any time without penalty.

Confidentiality of the data was maintained using anonymous coding and secure data storage. Student participants were assigned alphanumeric codes (S01-S45), while teacher participants were coded (T01-T04) to protect their identities. All identifying information is removed from data files; results are presented in aggregate form, so the privacy of participants is maintained and preserved. Schools and individual participants do not appear in any research publications or presentations.

Results

In this section, the results are presented in the context of the study's four research questions. Pre- and post-assessments quantitative data were analyzed using paired-samples t-tests and descriptive statistics. To identify emerging themes related to implementation experience and game effectiveness, thematic analysis was used to analyze the qualitative interview data, as well as classroom observation data.

Research Question 1: How does localized, game-based pedagogy enhance student understanding of climate change concepts within Philippine contexts?

Analysis of pre- and post-assessment data indicated that learners showed marked differences in learning comprehension of climate change concepts in the Philippine setting. Table 1 presents the comparison of pre- and post-implementation assessment scores.

Table 1. Pre-test and Post-test Comparison of Climate Change Knowledge

Assessment	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>
Pre-test	65.4	12.3	8.94	127	< .001	1.18
Post-test	78.9	10.7				

Student scores on climate change knowledge assessments increased from $M = 65.4$ ($SD = 12.3$) pre-implementation to $M = 78.9$ ($SD = 10.7$) post-implementation, representing a statistically significant improvement, $t(127) = 8.94$, $p < .001$, Cohen's $d = 1.18$, which represents a large effect size.

Knowledge of Philippine-specific climate impacts showed the most substantial improvements. Students demonstrated enhanced ability to identify local climate change indicators (M increase = 2.3 points on 5-point scale), understand adaptation strategies relevant to Philippine contexts (M increase = 2.1 points), and connect global climate phenomena to local environmental experiences (M increase = 1.9 points).

Red Zone Challenges, which utilized coordinate plotting and scenario analysis, demonstrated particular effectiveness in localizing climate change education. Students demonstrated 85% success rates in correctly identifying Philippine provinces affected by climate change and analyzing environmental impacts. Classroom observations revealed that students actively debated the environmental impacts during these challenges, with many referencing personal experiences of typhoons and flooding in their localities, which likely contributed to the high success rates and deeper understanding of localized climate impacts. These tasks successfully integrated geographic knowledge with environmental understanding and also promoted spatial reasoning skills.

There were positive changes in environmental awareness and intention to act, demonstrating the effective linkage of local pedagogy to personally meaningful local contexts with regard to world climate events. Post-implementation surveys showed enhanced environmental awareness levels ($M = 4.5$ vs. 3.8 pre-implementation) and intention to perform climate action behaviors ($M = 4.2$ vs.

3.6 pre-implementation).

Research Question 2: What specific design elements of Generation Z-IGNOS effectively engage Generation Z learners in climate change education?

According to student engagement surveys, students remain very interested and motivated to learn by playing games. Overall engagement scores on a 5-point scale reached 4.2, and 87% of students said the game made studying about climate change "more interesting and engaging" than conventional classroom approaches. The analysis of components of the game indicated differences in the effectiveness of the game in getting Generation Z learners involved:

Collaborative Learning Features: Students reported enhanced peer interaction ($M = 4.4$), improved communication skills ($M = 4.1$), and greater appreciation for diverse perspectives on environmental issues ($M = 4.3$). The competitive elements of gameplay effectively motivated student participation while maintaining collaborative learning objectives. Teacher observations noted that students who were typically quiet in traditional lessons became vocal participants during team discussions, particularly when strategizing adaptation responses to climate challenges.

Adaptation and Mitigation Cards: 82% of students recognized the best ways to respond to climate challenges, showing a greater comprehension of specific climate action strategies. Participating through card-based decision-making system successfully promoted critical thinking on environmental solutions.

Collaborative Mask Activities: The Generation Z commitment masks can be effective in promoting environmental awareness, the most obvious being their perception of one's personal environmental responsibility, as 91% of students reported greater awareness in this regard. The symbolic nature of the materials in this case contributed towards strengthening the connection between an individual's experiences in any given learning activity and a commitment to their own environmental goals.

Visual and Interactive Design Elements: Classroom comments indicated that the visual environment of the game, interactive elements, and a purpose-oriented structure appealed to Generation Z students, who seem to have been particularly keen on the game's visual design. The competitive nature of this activity, although also being interactive in nature, fit within the reported preferences for interactive and communal learning to the extent that the players themselves took note of it.

Research Question 3: How does the integration of mathematical problem-solving within climate change gaming scenarios affect student learning outcomes?

Mathematical problem-solving skills related to environmental data analysis demonstrated significant improvement. Students showed particular strength in coordinate plotting activities (89% accuracy post-implementation vs. 62% pre-implementation) and carbon footprint calculations (82% accuracy vs. 54% pre-implementation). These enhancements indicate that the incorporation of mathematical ideas in climate change settings resulted in a significant development of both environmental knowledge and mathematical ability.

White Zone Mathematical Problems showed 76% accuracy in solving climate-related mathematical problems. The students had particular strength in calculations on carbon footprint and temperature anomaly analysis. The incorporation of actual climate data for the Philippines improved both mathematical understanding and environmental awareness. During activities in the White Zone, the study found that students were more confident in their ability to apply mathematical formulas to real-world environmental scenarios, with many students requesting more similar problems to solve, which supported the increased motivation when mathematics was situated in the context of applications to climate change.

Findings suggest that mathematical problem-solving in authentic climate change contexts fulfilled a twofold task in educational experience: to acquire mathematical competencies and, at the same time, to enhance environmental knowledge. Students' capability to apply mathematics to real-world environmental issues indicates the effectiveness of interdisciplinary learning targets.

Research Question 4: What are the implementation requirements and sustainability considerations for classroom-based climate change games in Philippine educational settings?

Teacher interviews revealed a relatively positive experience with the practicum, and more engagement among the students, higher engagement level in the classroom, and a more direct link between theoretical constructs and practical applications. Teachers said the game captured students' attention and kept the emphasis on learning targets.

Challenges with implementation were mainly time management, material preparation, and the logistics of teaching in classrooms. Teachers shared the need for thorough preparation and recommended streamlined procedures for future implementations. Physical space and material management were the two determinants to be addressed to be considered for successful implementation.

Sustainability factors were identified as important for long-term success. Teachers stressed the importance of continued support, material maintenance, and integration with existing curriculum planning processes. Professional development and peer collaboration should be recognized as important prerequisites for wider adoption.

Discussion

The large gains in student learning outcomes reflect the success of localized, game-based climate change education. The large effect size (Cohen's $d = 1.18$) for overall climate change knowledge shows that Generation Z-IGNOS successfully enhanced student understanding beyond what might be expected from traditional instructional approaches. These results support earlier findings related to the efficacy of science learning in game-based contexts, which are also adapted to climate change education in developing country contexts (Johnson & Smith, 2022; Plass et al., 2010). The very pronounced results in knowledge on climate in Philippine contexts might indicate that the localization process increases student engagement and retention. Students showed better understanding of climate impacts in their own local setting, compared to global climate phenomena, supporting place-based education theory where learning is based on local context (Wang & Patel, 2022).

The incorporation of math problem-solving practices into climate change contexts was especially impactful, resulting in marked positive gains in student environmental comprehension and mathematics skills. This type of interdisciplinary approach is in line with current interest in integrated STEM learning, illustrating the use of mathematical concepts. The results are consistent with constructivist learning theory's focus on active construction of meaning via meaningful activities (Piaget, 1962). The higher understanding of students came from being involved directly in real-life scenarios about climate change instead of just receiving the information. The use of collaborative aspects of learning validated social constructivist theory based on knowledge construction through peers. Game-based learning was identified with respect to Generation Z learning characteristics theory as its predictive framework through student responses, and their engagement levels were in line with previous research revealing Generation Z's inclination towards interactive, meaningful, and contextually informed learning experiences relevant to their environmental awareness, and values of social responsibility (Garcia & Lee, 2023; Robertson, 2018; Thompson, 2022).

The result for the impact of localized, game-based climate-change education reveals how powerful localized climate change education can be; it is important for educators to invest in locally relevant climate change education methods that link global scientific insights to local environmental experiences. This means curriculum makers should develop resources that integrate nation-specific and region-specific environmental information in accordance with the Department of Education (DepEd) K-12 Science curriculum competencies. The specific age focus of the school-age learners studied in this study (Grade 9) restricts the potential of other age groups, and the geographic aspect of the Philippine region limits generalizability. The relatively short duration of implementation (4 months) indicates that long-term learning retention would not be evaluated. Future studies should explore the long-term sustainability of learning and environmental behavior changes (or lack thereof), effectiveness across cultural contexts, and optimal conditions for implementation, such as teacher training needs and institutional support mechanisms.

Conclusions

This study demonstrates that Generation Z-IGNOS is an effective and culturally sensitive climate education strategy in which abstract global ideas were effectively operationalized in hands-on personal development for Filipino students. The massive gains in learning results for students, particularly when it comes to Philippine-related impacts to climate, confirm the necessity to localize global environmental education to increase student engagement, understanding, and environmental consciousness. The successful cross-disciplinary infusion of mathematical challenges within contexts of climate change demonstrates the possibility of both multi-disciplinary learning and authentic applications of academic concepts, consistent with current educational trends that prioritize integrating STEM.

It should be noted that the high level of student engagement and a strong implementation indicate that game-based learning strategies are effective in meeting the needs of Generation Z students on a wider topic of learning without compromising on their need for challenging academic learning tasks. The fun collaborative, competitive, and visually engaging features found within Generation Z-IGNOS drew in students who demonstrated advanced critical thinking, environmental awareness, and scientific literacy. The results support constructivist and social constructivist learning theories, place-based education frameworks, Generation Z study on learning characteristics that support educational interventions based on theoretical basis oriented towards the unique needs of contemporary learners in developing country situations.

Generation Z-IGNOS is a scalable, sustainable model of climate change education that addresses existing curricula weaknesses while also addressing the learning profile and sustainability needs of young students. These positive outcomes that ensue as a direct result of this intervention will set the stage for significant implementation efforts that would dramatically elevate the efficacy of environmental education in Philippine secondary schools and foster environmentally literate and scientifically informed citizens who are prepared to address climate change challenges that will directly affect their communities and nation. Science teachers and curriculum coordinators are encouraged to utilize similar localized board games specifically as formative assessment tools for learning competency S9ES-IIIe-30 (explaining factors affecting regional climate) and S9ES-III f-31 (describing global climatic phenomena), rather than merely as supplementary or recreational activities. When integrated systematically into lesson planning and assessment frameworks, such game-based approaches can serve as rigorous evaluation instruments while maintaining high student engagement and motivation. Retention effects over time, cross-cultural impact, implementation practices, and digitalization potential should be examined further in research to catalyze the expansion and scale of this effective learning process.

References

- Alvarez, L. A., Santos, M. C., & Rodriguez, P. J. (2014). Science learner's module 9 (1st ed.). Department of Education.
- Brown, M., Davis, R., & Johnson, K. (2021). Localized approaches to global environmental education: A systematic review. *Environmental Education Research*, 27(3), 245-267. <https://doi.org/10.1080/13504622.2021.1888887>
- Department of Education. (2016). K to 12 curriculum guide: Science. DepEd Publications.
- Garcia, S., & Lee, T. (2023). Generation Z learning preferences in secondary education: Implications for pedagogical design. *Contemporary Educational Psychology*, 45, 112-128. <https://doi.org/10.1016/j.cedpsych.2023.102045>
- Gui, Y., Cai, Z., Yang, Y., Kong, L., Fan, X., & Tai, R. H. (2023). Effectiveness of digital educational game and game design in STEM learning: A meta-analytic review. *International Journal of STEM Education*, 10, Article 36. <https://doi.org/10.1186/s40594-023-00424-9>
- International Federation of Red Cross and Red Crescent Climate Centre. (2019). Module 3c: Youth and climate change games. IFRC Publications.
- Johnson, P., & Smith, A. (2022). Game-based learning in environmental education: A meta-analysis of effectiveness. *Journal of Environmental Education*, 53(4), 189-206. <https://doi.org/10.1080/00958964.2022.2067378>
- Lei, H., Chiu, M. M., Wang, D., Wang, C., & Xie, T. (2022). Effects of game-based learning on students' achievement in science: A meta-analysis. *Journal of Educational Computing Research*, 60(6), 1373-1398. <https://doi.org/10.1177/07356331211064543>
- Martinez, C., Patel, N., & Wong, L. (2023). Climate change education in developing nations: Challenges and opportunities. *International Journal of Environmental Education*, 18(2), 78-94. <https://doi.org/10.1080/1350462X.2023.2187456>
- Nautiyal, V. V., Silverio, S. A., & Salvador, E. E. P. (2024). Let's get on-board: A practical framework for designing and implementing educational board games in K-12 classrooms. *Frontiers in Education*, 9, Article 1420515. <https://doi.org/10.3389/feduc.2024.1420515>
- Nguyen, T. T. K., Ngo, T. P. A., Pham, A. T., Nguyen, D. D., Cheng, P. H., & Nguyen, V. B. (2024). Let's play! Transforming STEM education with board games. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(8), Article em2494. <https://doi.org/10.29333/ejmste/14920>
- Philippine Atmospheric, Geophysical and Astronomical Services Administration. (2023). Climate change indicators in the Philippines. PAGASA Publications.
- Piaget, J. (1962). Play, dreams and imitation in childhood. W. W. Norton.
- Plass, J. L., Perlin, K., & Nordlinger, J. (2010). The games for learning institute: Research on design patterns for effective educational games. *Proceedings of the Game Developers Conference*, 15-28.
- Robertson, S. (2018). Generation Z characteristics and traits that explain the way they learn. *Journal of Educational Technology Research*, 12(3), 45-62. <https://info.jkcp.com/blog/generation-z-characteristics>
- Salen, K., & Zimmerman, E. (2004). Rules of play: Game design fundamentals. MIT Press.
- Shaffer, D. W., Halverson, R., Squire, K. R., & Gee, J. P. (2005). Video games and the future of learning (WCER Working Paper No. 2005-4). Wisconsin Center for Education Research.
- Thompson, R. (2022). Environmental consciousness among digital natives: Implications for climate education. *Environmental Psychology Review*, 28(1), 34-52. <https://doi.org/10.1037/epr0000234>
- Wang, H., & Patel, S. (2022). Contextualizing global environmental issues: Evidence from Southeast Asian classrooms. *Asia-Pacific Journal of Environmental Education*, 15(3), 156-173. <https://doi.org/10.1080/1359362X.2022.2089567>

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