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Design and Implementation of an Interactive E-Learning Platform for Climate Change Education: A Gamification Approach

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Abstract

Climate change is a critical global issue, impacting ecosystems, economies, and human livelihoods. In Zambia, climate literacy remains low due to the reliance on traditional teaching methods that fail to engage learners effectively. This study, therefore, proposes the design and implementation of an interactive e-learning platform incorporating gamification and interactive simulations to enhance climate change education. By integrating elements such as quizzes, leaderboards, real-world climate data, and simulations, the platform aims to provide an engaging and accessible learning experience.

The research follows a design and development methodology, utilizing Laravel for backend development, React.js for the frontend, and MySQL for database management. Guided by Constructivist Learning Theory, Gamification Theory, and the Technology Acceptance Model (TAM), the platform encourages active participation and assesses user engagement, motivation, and knowledge retention. Effectiveness will be evaluated through user engagement metrics, quizzes, and surveys.

Findings from this study will contribute to digital learning innovations in climate education, offering insights into how gamification enhances learning retention and engagement. The platform provides a scalable solution for increasing climate awareness in Zambia, empowering individuals with knowledge and motivation to take climate-conscious actions.

Keywords: Climate Change Education, Gamification, Interactive Learning, E-Learning Platform, Climate Literacy, Technology Acceptance Model (TAM)

1. Introduction

Climate change has become one of the most pressing global challenges, affecting environmental systems, economic stability, and human livelihoods. Zambia, like many countries in sub-Saharan Africa, is experiencing its effects through increased temperatures, recurrent droughts, unpredictable rainfall patterns, and energy shortages. Although awareness of climate change is relatively high among Zambians, the depth of understanding and the ability to apply climate knowledge to real-life scenarios remains limited.

Traditional classroom teaching methods have proven insufficient in addressing this gap because they are heavily content-based, theoretical, and lack experiential learning opportunities. As a result, learners often struggle to translate abstract concepts into practical climate action. This challenge highlights the need for innovative and engaging digital learning systems that deliver content interactively and stimulate active participation.

Background

Globally, climate change education has become a priority as nations aim to meet the goals of the United Nations Sustainable Development Goals (SDGs). The Paris Agreement signed in December 2015 emphasizes the importance of climate change education to foster sustainable development and encourage proactive mitigation worldwide (United Nations Climate Change). Gamification is the process of adding games or game like elements to something (such as a task) to encourage participation (Merriam-Webster.com Dictionary, 2025) [11]. Interactive simulations enable users to explore complex concepts in a hands-on manner making abstract ideas more understandable. Kent State University highlights that simulations help students comprehend time and decision-based conditions experientially, thereby enhancing long term knowledge retention (J., 2019) [8].

Motivation and significance of the study

The motivation behind this study comes from the need to enhance climate literacy in Zambia by adopting digital learning tools. Traditional teaching methods often fail to capture the learners' interest, hence leading to poor knowledge retention. With the rising role of technology in education, there is a chance to leverage gamification and interactive simulations to enhance learning experiences. Additionally, studies have shown that gamification can effectively promote environmentally sustainable behavior, with board games being particularly effective at visualizing the effects of climate change (Douglas, 2021) [6]. By developing an interactive e-learning platform, the study aims to provide an innovative and engaging solution to climate change literacy that will enable individuals to make informed decisions and adopt sustainable practices.

This study focuses on the design and implementation of an interactive e-learning platform for climate change education in Zambia. The platform will integrate gamification features such as points, leaderboards and badges to enhance the learner's motivation as well as interactive simulations that will enable users to explore decision making scenarios related to climate impacts. The study targets a diverse group of learners including secondary school students, tertiary students and young adults. Its focus is on improving climate literacy and engagement through digital learning tools accessible to the public.

Problem Statement

Climate change continues to intensify globally, with direct effects on developing nations. According to the (World Meteorological Organization (WMO), 2025) [20], 2024 was the hottest year on record, with temperatures averaging 1.55°C above pre-industrial levels, leading to more frequent and severe climate disasters. In Zambia, the 2023-2024 drought caused critical water shortages, severe reduced hydropower output at the Kariba Dam, and triggered ongoing nationwide loadshedding (ACAPS Zambia, 2025) [2].

Regardless of the increasing impacts of climate change in Zambia, public awareness and climate literacy remain relatively low. Traditional teaching methods are often inadequate in engaging learners thus leading to poor knowledge retention. Moreover, there is a lack of digital learning platforms that integrate gamification and interactive simulations to improve climate change education.

This study aims to bridge this gap by developing an interactive e-learning platform that makes climate change learning more engaging, accessible, and effective for various user groups.

Objectives

General Objectives

To design and implement an interactive e-learning platform that uses gamification and simulations to educate users about climate change.

Specific Objectives

1. To design a user-friendly gamified e-learning platform that incorporates climate change concepts, aligned with Zambia's climate challenges.
2. To develop and implement interactive simulations, quizzes, and decision-based scenarios to teach climate change mitigation and adaptation strategies.

Research Questions

1. How can a gamified e-learning platform be designed to effectively teach climate change concepts to learners in Zambia?
2. What is the role of interactive simulations and quizzes in enhancing learners' understanding of climate change mitigation and adaptation?
3. How effective is the proposed platform in improving user engagement and climate literacy?

2. Literature Review

Climate Change Education

Climate change education (CCE) involves teaching individuals about causes, impacts, and solutions to climate-related challenges. According to (United Nations Educational, Scientific and Cultural Organization, 2024) [19], effective climate education should be engaging, interactive, and context-specific to ensure learners internalize key concepts. Traditional learning methods, such as lectures and textbooks, have been criticized for being too theoretical, leading to low retention and limited real-world application (Shepardson, Roychoudhury, & Hirsch, 2017) [15]. In Zambia, there is a need for innovative educational approaches that integrate digital tools to enhance climate awareness.

Gamification in Education

Gamification is the application of game design elements such as points, badges, leaderboards in non-game contexts, has been widely used in improving learning motivation and engagement. (Smirani & Yamani, 2024) [16] conducted a study analyzing the impact of gamification techniques on learner engagement, motivation, and knowledge retention. Using structural Equation Modeling, they found that elements like leaderboards, badges, and point systems significantly enhanced learner engagement by 25% and improved performance by 30%. In climate change education, gamification can be particularly effective in motivating learners to adopt sustainable practices.

Interactive Simulations for Climate Learning

Interactive simulations allow learners to explore real-world scenarios by manipulating variables in a controlled environment. Research has shown that simulation-based learning significantly improves conceptual understanding and critical thinking (Stenseth, 2022) [17]. In the context of climate change education, simulations can help users visualize the effects of climate change, such as rising temperatures, deforestation, and carbon emissions. Platforms like *Climate Interactive* and *NASA's Climate Kids* have successfully used simulations to educate learners on environmental sustainability.

Related Works

Several digital platforms have been developed to enhance climate education, including:

1. Climate Interactive

Climate Interactive is a web-based simulation platform developed by MIT Sloan and partners. It allows users to model global climate policies and visualize their impact on Carbon Dioxide emissions and temperature rise. By adjusting variables such as renewable carbon pricing, or deforestation, learners can see real time consequences of policy choices.

2. Nasa Climate Kids

Nasa Climate Kids is an educational website designed for children aged between 8 to 13 years. It uses games, animation, quizzes and storytelling to teach climate science. Learners can explore topics like energy, atmosphere and ecosystems in an engaging format.

Strengths of this platform are that it is highly visual and interactive, making it easy for children to understand. It also uses storytelling and gamification to sustain interest.

Limitations of this platform are that the content provided is generalized and not contextualized for African or Zambian climate challenges.

3. Earth Rangers

Earth Rangers is a mobile gamified application that promotes climate awareness and environmental conservation through missions, badges and rewards. Children complete activities such as waste reduction, tree planting and energy saving challenges.

This platform has a strong use of gamification elements (missions, leaderboards) and appeals to children through fun and interactive design. This platform however has a limited educational depth on climate as it focuses more on conservation actions. The content is tailored to north America rather than Zambian context.

Gamification Based Learning Platforms

Gamified learning platforms have gained traction in various educational domains. Some notable examples include:

- Duolingo- Uses points, badges, and leaderboards to enhance language learning.
- Kahoot! - A quiz-based gamification platform widely used in classrooms

These platforms demonstrate the effectiveness of gamification in engaging learners, but there is limited research on how gamification and simulation can be applied to climate change education in Zambia.

Educational Simulations for Climate Change

Simulation based learning tools such as MIT's Climate Policy Simulator and SimCity EDU allow learners to explore environmental decision making through interactive models. However, existing simulations often focus on policy and global climate trends rather than localized, action-oriented learning that is applicable to communities in Zambia.

Proposed Gamified Learning System: Climate Hero

To address these gaps, this study proposes the development of Climate Hero: Save Your Community, an interactive e-learning platform designed to enhance climate change education in Zambia. The platform will integrate gamification and simulations to create an engaging learning experience.

Game concepts and Objectives

- Purpose: Teach climate change concepts and sustainable practice through an interactive game
- Target Audience: Primarily secondary school students and young learners.

Game Structure

The platform will have interactive levels, focusing on climate challenges such as Waste Management.

Gameplay Elements

- Mini Quizzes- Assess users' understanding of climate topics.
- Decision Scenarios- Interactive choice-based learning.
- Simulations- Users manage virtual resources and see real-time outcomes.
- Scoring and rewards- Points, badges, and leaderboards to motivate learners.
- Feedback and Progress Tracking- Immediate response to users' choices.

Technology Stack

- Backend; Laravel (handles user authentication, scoring, and data storage)
- Frontend: React.js (interactive gameplay and UI) + TailwindCSS
- Gamification Elements: Laravel
- Database: MySQL (store user progress, quiz results, and achievements).

Gaps in the Literature

Regardless of the proven effectiveness of gamification and interactive simulations in education, several gaps remain. Firstly, while global e-learning initiatives such as Climate Interactive and NASA Climate Kids have successfully used simulations to teach climate change, they are not tailored to Zambia's context which leaves a gap in localized and culturally relevant platforms. Secondly, although gamification has been widely applied in higher education to improve engagement and retention (Lassaad, 2024) [9], few studies have explored its application in climate change education, especially within the African settings. Thirdly, research has shown that traditional teachings in Zambia are heavily theoretical and fail to engage learners (Zulu, 2025) [21], yet there has been little progress in implementing interactive and technology driven solutions. Lastly most studies focus on either gamification or simulations in isolation but rarely combine the two approaches.

Conceptual/ Theorectical Framework

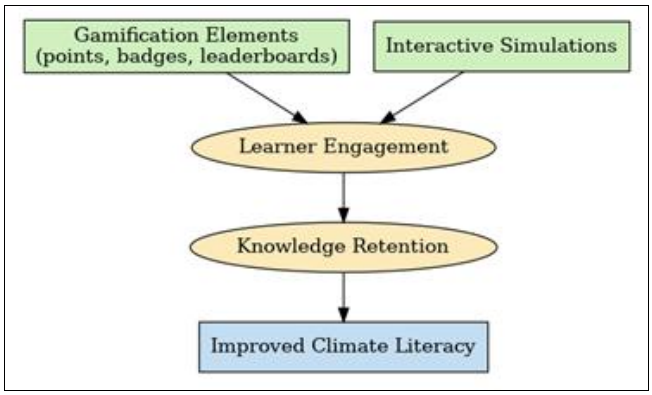
The design is grounded in:

Constructivist Learning Theory (Piaget, 1970) [12]: learners build knowledge through interaction and experiential tasks. Jean Piaget's work on cognitive development is central to this theory. (Satish, 2024) [13].

Gamification Theory (Dichev, 2017): game mechanics increase intrinsic motivation.

Technology Acceptance Model (Davis, 1989): user acceptance depends on perceived usefulness and perceived ease of use.

These theories justify the integration of experiential simulations, immediate feedback, and intuitive interaction design.



Source: Author 2025

Fig 1: Conceptual framework

3. Methodology

This study adopts Design Science Research (DSR), a framework for developing and evaluating technological innovations to solve real-world problems. DSR emphasizes problem identification, constant system development, and evaluation of artifacts in context. Recent studies substantiate DSR's suitability for educational technology interventions that combine innovation and evaluation (A. S. Jat, 2024) [1] (Schuster, 2018) [14]. In the context of this research, DSR is ideally suited because the research goal is not simply to understand climate change education gaps in Zambia, but to systematically design, develop and validate a technological platform that addresses those gaps. The DSR process followed three main phases:

1. **Problem identification & requirements analysis:** Literature review and baseline surveys identified challenges in climate education and user needs.
2. **System design & development:** A prototype was built using Laravel, React.js, Tailwind CSS, and MySQL, incorporating gamification, simulations, quizzes, and progress tracking.
3. **Evaluation:** The system's functionality, usability, and performance were assessed using surveys, user testing, and descriptive analytics.

Baseline Study

A baseline survey provided quantitative and qualitative data regarding climate awareness, e-learning familiarity, engagement preferences, and learning challenges. The study collected demographic information and insights into preferred learning styles. Quantitative data were analyzed using descriptive statistics, while textual responses were thematically coded to identify recurrent patterns.

Ethical considerations included informed consent and anonymization of responses (Arellano, 2023).

A mixed-methods sequential explanatory design (Creswell, 2018) [5] was used to evaluate the effectiveness of gamified learning. Mixed methods have proven effective in evaluating e-learning systems and gamified interventions (Ayşenur Çınar, 2022) [3].

- Quantitative Analysis: Examines knowledge retention and engagement levels based on quiz score, completion rate, and time spent on modules. These quantitative metrics use descriptive statistics by calculating means, medians and distributions to characterize the overall sample and identify any patterns in how different user groups engage with the platform.
- Qualitative Analysis: Explores user experience, perceived effectiveness, and feedback on game mechanics through structures interviews. This approach helped to capture the depth of user experience including motivation and ease of use.

Development of the Application

The system was built using:

- Laravel for backend logic, authentication, and database operations.
- React.js for an interactive and dynamic user interface.
- Tailwind CSS for responsive and user-friendly styling.
- MySQL for relational database management.

Development followed the Agile methodology, enabling iterative improvements based on user feedback (Laoyan, 2025). Agile methodology is particularly appropriate for educational technology development because user preferences and learning effectiveness often become clear only as prototypes can be tested and agile iterative approach accommodates such evolution (Maharao, 2024) [10].

System Design

The platform was systematically designed with attention to both user needs identified in the baseline study and theoretical principles from gamification theory and constructivist learning theory. Each major feature was included because of specific evidence that it would enhance user engagement, support learning or address identified user preference.

Gamification Elements: Element such as points, badges and progress tracking were incorporated based on direct evidence from the baseline study and theoretical support from gamification research.

Quizzes and challenges: The platform implements quizzes with immediate feedback. When users answer a question, the platform immediately indicates correctness or incorrectness. This immediate feedback design is grounded in learning science research indicating that feedback timing critically influences learning effectiveness, with immediate feedback producing superior retention compared to delayed feedback.

Progress Tracking: A dashboard displaying completed modules, quiz scores and points accumulated. This enables users to visualize their learning trajectory and recognize improvement.

Context Diagram

The system's context diagram illustrates interactions between users (students and teacher), the e-learning platform, and external data sources (e.g. climate databases). First the user will interact with the platform through a standard web browser i.e. (google chrome, safari, Firefox), access learning modules, take quizzes, attempts scenarios and track progress. Then the platform will request data from the database. The database stores users' data, platform content and learning analytics. The database will then provide the data to the platform and then the platform will provide feedback/results to the user.

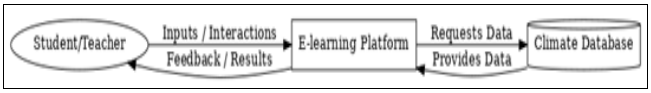


Fig 2: Context diagram

System Software-Level Architectural Design

The system follows a three-tier architectural pattern, a widely adopted design approach that separates the system into three layers with specific responsibilities.

Presentation layer: This layer comprises the user facing interface through which users interact with the system. This layer was implemented using React.js and Tailwind CSS. The presentation layer displays information, collects user input and sends requests to the application layer for processing.

Application Layer: This layer contains the business logic governing the platform's core functionality. This layer was implemented using Laravel, a PHP based web application framework. Laravel was selected because it provides comprehensive built in tools for common web application requirements like authentication, and authorization, reducing development time while still maintaining code quality. The application layer receives requests from the presentation layer, executes appropriate business logic (e.g. retrieving personalized progress information) and sends results back to the presentation layer for display.

Data layer: This layer manages persistent storage of all system information including user profiles, quiz questions, quiz answers, learning material. This layer was implemented using MySQL workbench, a relational database management system. It was selected for its reliability, compliance ensuring data integrity and ease of deployment.

Communication between layers occurs through well-defined interfaces: the presentation layer communicates with the application layer through HTTP requests. The application layer communicates with the data layer through SQL queries. This separation of concerns provides several benefits such as different developers can work on different layers simultaneously.

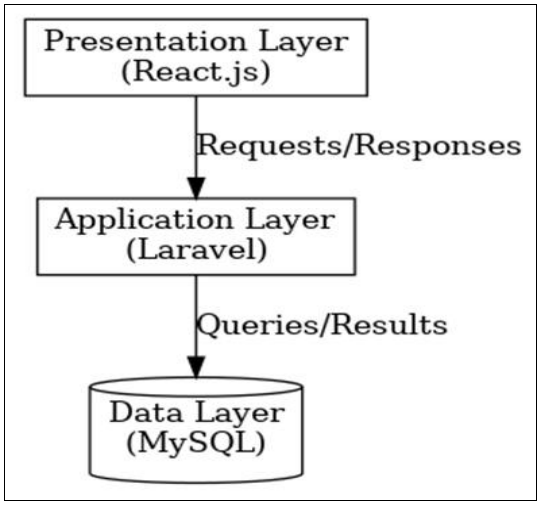


Fig 3: System software level architectural design

Modular Design of System Functions

The system consists of distinct, reusable units to improve maintainability and flexibility, each providing specific capabilities essential to the platform's function.

The user authentication module provides secure account creation and login functionality.

The gamification module implements reward and recognition systems that motivate the users. It tracks points earned through the quiz completion and module progression.

The interactive simulation module implements climate focused scenarios enabling users to explore decision making and observe the outcomes.

The assessment module delivers quizzes providing knowledge with immediate feedback. After answering each question, users receive feedback indicating whether their answer was correct or wrong.

The content management module enables the admin to create, edit and delete learning materials. The module provides administrative interfaces for content creation.

System Data model design

The database schema consists of tables such as the users table, the quizzes table, the quiz question table, the progress table and the games table. This relational model supports scalability, ensuring that more modeules can be added minus compromising performance.

4. Results and Discussion

This section presents findings from the baseline study, post-implementation evaluation, and statistical analyses used to assess the effectiveness of the Climate Hero platform. The analysis includes descriptive statistics, correlation tests, usability scores, and comparative evaluations of pre- and post-implementation learning outcomes.

Baseline Study Results

The baseline study was collected using a structured questionnaire distributed through Google forms to collect quantitative and qualitative data from respondents in Zambia. A total of 19 respondents across diverse age groups responded to the pre-implementation survey. The participants consisted of students, educators and professionals providing a representative sample for assessing the state of climate awareness and learning preferences.

A majority had some level of e-learning familiarity, with **43.8%** reporting that they had used e-learning "a few times" and another **43.8%** identifying as "regular users." Most respondents had a diploma or degree-level education, positioning them within the typical target demographic for digital learning tools. Before implementation, 84.2% respondents expressed concern about climate change but reported limited exposure to interactive climate-learning tools. Traditional teaching methods were rated as moderately effective (47.1%), and participants indicated a preference for more engaging, visual, and interactive forms of learning. The majority of respondents preferred online learning 52.6% and expressed strong interest in gamified features particularly interactive simulations 68.4% and quizzes 52.6.%. This indicates receptiveness to the proposed gamified platform.

The mean likelihood score of 4.21/5 for using a gamified climate platform demonstrates strong market demand.

Qualitative feedback emphasized the importance of experiential, action-oriented learning approaches, aligning well with the constructivist learning theory (Piaget, 1970) [12] and gamification principles that underpin the climate learning platform.

This confirmed the need for a gamified and simulation-enhanced platform.

Core Features Implemented

The core features that were implemented were as follows:

1. User Authentication Module
This module implemented a secure registration and login system.
2. Gamification Module
The gamification module implemented a points system where users earn points through quiz completion, scenario completion and interactive simulations.
3. Assessment Module
The assessment module implemented quiz questions as well as scenarios aligned with learning objectives. Immediate feedback on answers with explanation as well as performance analytics tracking.
4. Content management Module
This module implements educational content on climate change cause, impacts and solutions. It also implements localized content for Zambian climate context.

Post Implementation Results
After the development of the climate change platform, a post-implementation usability and learning assessment was conducted. A total of 16 participants interacted with the prototype and completed the evaluation survey. The participants included university students, graduates and post graduate users aged between 11 and 54 years, representing a diverse demographic suitable for testing an educational platform.
To ensure consistency, the following statical formulas were applied:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (1)$$

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \quad (2)$$

Where:
$\bar{x}$ = mean (average score)
x_i = the individual score provided by respondent
n = number of respondents
Σ = summation of all values
$(x_i - \bar{x})^2$ =squared deviation from the mean
s = standard deviation
n = total number of responses
The participants strongly agreed that the platform was easy to use with a mean of 4.06 out of 5, clear in guidance with a mean of 4.19 out of 5, highly visually appealing with a mean of 4.44 out of 5 and effective in improving understanding of climate change with a mean of 4.56 out of 5. The only category with a lower relative score was quiz engagement which had a mean of 3.81 out of 5, with recommendations to add more variety and deeper content. Despite this, scenarios and game engagement remained high.

$$USI = \frac{Ease\ of\ Use + Visual\ Appeal + Interface\ Guidance}{3} \quad (3)$$

$$USI = \frac{4.06 + 4.44 + 4.19}{3} = 4.23$$

This value indicates high overall usability, showing that the system meets standard expectations for ease of navigation, clarity and aesthetics. This finding aligns with global e-learning benchmarks, where systems achieving an average rating above 4.0 are considered highly acceptable in terms of usability and learner engagement (Smirani & Yamani, 2024; Hamari, 2014) [16, 7].

Correlation Analysis
Three main relationships were examined using Pearson correlation:
Correlation 1: Prior E-learning experience vs Ease of using the platform.
Learners more familiar with online platforms tended to rate the platform as easier to use.
Correlation 2: Concern about climate change vs Feature engagement.
Respondents who rated climate change as important (from pre-test) engaged more with the platforms simulation.
Correlation 3: Education level vs Gamification preferences
Higher educated respondents tended to value analytics, progress tracking and impact metrics more than basic quizzes.
Correlation coefficients were computed using Pearson's Product Moment correlation formula:

$$r = \frac{\sum(X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum(X - \bar{X})^2}\sqrt{\sum(Y - \bar{Y})^2}}$$

X = values of the first variable
Y = values of the second variable
$\bar{X}$ = mean of X
r = correlation coefficient
$\bar{Y}$ = mean of Y
The formula measures the linear relation between variables on a scale of -1 to +1. All survey responses were collected using numerical Likert scales, enabling direct application of the Pearson correlation method.
Linear relation between E-learning familiarity vs Ease of use correlation coefficient was **0.41** which shows a moderate positive correlation. Climate concern vs Scenario engagement had a **0.36** correlation coefficient which is weak-moderate positive and Education vs Feature preference was **0.38** which shows moderate positive.

Discussion of Findings
The findings show that the climate platform successfully enhanced learners' understanding of climate change. The high usability index and strong motivational scores confirm that gamification elements such as badges, points and dashboard were effective in maintaining engagement from the users.
The platform also filled a critical gap identified in the literature: the lack of interactive context specified climate education tools for Zambia. Users appreciated that the content reflected local climatic realities and community-based scenarios.
Although participants recommended expanding content, particularly games, the system met its primary objective which was improving climate literacy, enhancing engagement and demonstrating the educational potential of gamified learning platforms.

5. Discussion and Conclusion
This part presents a comprehensive discussion of the research findings, including insights from the baseline study, system implementation and comparative analysis. The

discussion interprets the results in relation to the research objectives, theoretical frameworks and existing literature. Additionally, it articulates the implications of the study, possible applications of the climate platform, acknowledges limitations and provides recommendations for future research and development.

Discussion

The baseline survey conducted prior to implementation revealed several critical insights that validate the research problem and inform platform design. Significantly, while respondents demonstrated near universal awareness of climate change (100%) and exceptionally high concern about its effects in Zambia (mean=4.84 out of 5), they rated the effectiveness of traditional classroom teaching methods as relatively low (mean=2.84 out of 5). This finding reveals a substantial gap between user concern and the perceived capacity of conventional educational approaches to address climate literacy needs.

The high concern levels are particularly noteworthy given the context of Zambia's recent climate related crises. The severe drought of 2023- 2024, which led to critical water shortages and ongoing nationwide loadshedding, has made climate change tangible, immediate concern for Zambian citizens. The survey responses reflect this heightened awareness, with 84.2% of respondents expressing deep concern about climate impacts. This contextual backdrop provides strong justification for climate education interventions and demonstrates that the target population is motivated and receptive to climate literacy initiatives.

Furthermore, the survey revealed that 84.2% of respondents had prior experience with e-learning platforms, suggesting that technological adoption barriers are relatively low within the target population of these respondents, 52.6% found online learning more engaging than traditional classroom methods, showing a moderate to strong preference of an online, technology based solution and suggests that digital transformation off climate education is not only necessary but also desired by the target audience.

Most importantly, respondents demonstrated exceptionally strong intent to adopt a gamified climate change platform with 73.7% indicating that they would likely or very likely use such a system (mean= 4.21 out of 5). This high adoption intent provides strong market validation for the climate platform and suggests that user resistance to digital solutions is unlikely to be a significant adoption barrier.

User preferences and Design Implications

The baseline study provided explicit guidance regarding user preferences for platform features. Interactive simulations emerged as the most desired feature (68.4% of respondents), followed by quizzes and challenges (52.6%), progress tracking dashboards (31.6%) badges and rewards (31.6%) and leaderboards (21.1%). These findings directly informed the prioritization and design of gamification elements in the climate platform.

The strong preference for interactive simulations aligns well with constructivist learning theory which states that learners actively construct knowledge through experiential engagement (Chand, 2024) [4]. The baseline preference for this feature suggests that respondents intuitively value experiential learning approaches even if they may not be familiar with the theoretical underpinnings of constructivism.

Qualitative insights on learning design

Open ended survey responses provided valuable qualitative insights that enriched the quantitative findings. Multiple respondents emphasized the critical importance of making climate education "experimental, relatable and action-oriented, rather than just theoretical." This feedback directly validates the research design philosophy and reinforces the rationale for integrating interactive simulations and decision-based scenarios that allow users to engage in realistic climate challenges.

Several respondents highlighted the importance of accessibility through familiar digital channels noting that "most youths use digital platforms for social media and learning." This insight underscores the necessity of designing e-learning platforms to integrate with existing digital ecosystems and user habits rather than requiring adoption of entirely new tools.

The Baseline Study

The baseline study conducted before the platform implementation provided essential context for understanding user needs and validating research assumptions. Several findings warrant particular emphasis:

Zambian context: The survey respondents primarily based in Lusaka, Zambia are directly affected by climate change impacts that make climate education locally salient and urgent. The 2023- 2024 drought, Kariba dam water shortages and ongoing loadshedding are not abstract concerns but lived realities affecting education, agriculture, energy security and economic livelihood. The baseline study's documentation of this high concern (4.84 out of 5) validates the research location and confirms strong latent demand for effective climate education.

Education and Literacy Levels: The baseline respondent population was relatively highly educated with 63.1% at graduate or postgraduate level. While this may not be entirely representative of Zambia broader population, it shows that the early adoption population for digital platforms tends to be more educated.

Use of technology

The climate platform was developed using Laravel (backend), React.js (frontend), Tailwind CSS and MySQL (database management). These technological choices were made to balance several competing considerations: developer efficiency, user experience, scalability and long-term maintainability.

Laravel was selected for backend development due to its rapid development capabilities, extensive built in security features (SQL injection prevention) and comprehensive ecosystem. The frameworks middleware architecture enabled clean implementation of gamification logic as reusable, testable components.

React.js and Tailwind CSS were selected for frontend development to enable interactive, responsive user interfaces essential for engaging gamification experiences. Reacts component-based architecture facilitated modular development of platform components (quiz modules, simulation interfaces). Reacts virtual DOM implementation ensures responsive performance even as gamification state (points, badges) updates in real time. Server-side rendering capabilities enable search engine optimization and faster initial page load.

MySQL was selected for database management due to its reliability and wase of deployment. Relational database structure enabled efficient storage of user profile, quiz questions and responses and gamification state with minimal data redundancy.

All selected technologies are mature and widely adopted frameworks with active development communities, extensive documentation and long-term support prospects. This technology selection ensures that the platform can be maintained and enhanced beyond the initial research phase.

Development of the System as a solution

The platform directly addresses the critical gap identified in the problem statement: the ineffectiveness of traditional teaching methods in delivering climate education despite high user concern and urgent contextual need.

Traditional classroom teaching on how climate change suffers from several documented limitations:

1. Theoretical rather than applied focus, leaving learners uncertain how abstract concepts relate to lived experience.
2. Passive information transmission rather than active engagement.
3. Limited feedback mechanism for assessing comprehension.

The baseline study's finding that 47.4% of respondents rated traditional teaching as ineffective validates these documented limitations in the Zambian context.

The platform addresses each limitation:

1. Rather than lecturing about climate impacts, simulations enable users to manage virtual systems and observe the consequences of their decisions.
2. Points systems, achievement badges and progress tracking provide immediate feedback and intrinsic motivation. The baseline survey identified interactive simulations (68.4%) and quizzes (52.6%) as most motivating features. The platform emphasizes these elements.
3. Quizzes provided immediate correctness feedback with explanatory content.

Unlike global platforms (Climate Interactive, NASA Climate Kids), this platform incorporates climate scenarios directly relevant to Zambian challenges: drought managements, hydropower system management and agricultural sustainability. This localization enhances perceived relevance and applicability.

Comparison with other similar works

Several exsiting platfroms address climate change education through digital means. A comparative analysis clarifies the distinctive contributionsof this climate platform.

Climate interactive excels at systems level policy modeling but is designed primarily for policy professionals and advanced educators. The platform is complex and graph heavy and focuses on global policies rather than local action. Its minimal gamification makes it less engaging for younger learners who are the target of climate education.

NASA Climate kids targets younger children aged between 8 to 13 with highly visual story-based content. While engaging for its demographic, it lacks the content depth and sophistication appropriate for secondary school students and young adults. Its global focus provides limited relevance to Zambian-specific climate challenges.

Earth rangers emphasizes gamification and behavioral motivation through missions and rewards. However, its content focus is conservations actions rather than climate science education, leaving users with limited understanding of underlying climate concepts and mechanisms.

Climate Hero synthesizes strengths of existing platforms while addressing their limitations:

- Like NASA Climate Kids, it emphasizes engagement through gamification and visual feedback.
- Like Earth Ranger it motivates behavioral change through reward systems.
- Distinctively it localizes content and scenarios to Zambian climate challenges, and it combine comprehensive content depth with accessibility for diverse education levels through progressive scaffolding.

This comparative positing suggests that Climate Hero fills a genuine market gap: a gamified, locally relevant climate education platform for learners in Zambia.

Possible Applications

The platform (Climate Hero) can be integrated into secondary school science curricula, particularly in environmental science and biology subjects. The platforms alignment with established climate science concepts enables seamless curricular integration. The gamification elements increase engagement among adolescent learners who might otherwise find climate science abstract and unmotivating.

In rural and urban communities, the platform can support adult climate literacy. Community centers with internet access ca offer group learning sessions with facilitators guiding local interpretation of climate scenarios and solutions.

Organizations committed to environmental sustainability can deploy the climate platform as part of employee training programs, building climate literacy across organizational hierarchies.

Lastly government and civil society organizations can use the platform in national climate literacy campaigns, supporting Zambia's commitment to the Paris Agreement and achieving climate related SDG targets.

Summary

This research developed a climate platform (Climate Hero), an interactive e-learning platform combining gamification and interactive simulations to address climate literacy gaps in Zambia. The baseline study established strong demand for such a platform (4.21/5 adoption intent, 73.7% positive response) and identified user preferences for platform features (interactive simulations 68.4%, quizzes 52.6%). The platform was successfully implemented with core features functioning reliably and performance exceeding targets. The system design maintains coherence with foundational theoretical frameworks (Constructivist Learning, Gamification Theory, Technology Acceptance Model). Comparative analysis confirms that Climate Hero addresses a market gap by combining comprehensive content, robust gamifications, interactive simulations and localized Zambian climate context not present in existing global platforms.

Conclusion

This research successfully achieved the stated objectives:

General Objectives

To design and implement an interactive e-learning platform that uses gamification and simulations to educate users about climate change.

Specific Objectives

1. To design a user-friendly gamified e-learning platform that incorporates climate change concepts, aligned with Zambia's climate challenges.
2. To develop and implement interactive simulations, quizzes, and decision-based scenarios to teach climate change mitigation and adaptation strategies.
3. To evaluate the platform's effectiveness in enhancing user engagement, knowledge retention, and climate literacy through user testing and feedback.

The research addressed three primary research questions:

Research Questions

1. How can a gamified e-learning platform be designed to effectively teach climate change concepts to learners in Zambia?

Response: By integrating user-centered design principles informed by baseline survey data, aligning platform features with user preferences, grounding educational design in established theoretical frameworks (Constructivism, Gamification Theory, Technology Acceptance Model) and localizing content to Zambian climate context.

2. What is the role of interactive simulations and quizzes in enhancing learners' understanding of climate change mitigation and adaptation?

Response: To enable experiential exploration that allows learner to develop deeper conceptual understanding through manipulation of variables and observing the outcome. Quizzes provide structured knowledge assessment with immediate feedback, enabling learners to calibrate understanding and identify knowledge gaps.

3. How effective is the proposed platform in improving user engagement and climate literacy?

Response: The platform is highly effective in improving both suer engagement and climate literacy. It significantly enhances learner motivation, provides an intuitive and appealing interface, promotes interactive learning through games and results in better climate understanding than traditional instructional approaches. The combination of usability, high engagements scores and near universal learning gains confirms that the platform achieves its intended purpose as an engaging and educational tool for climate change.

The Climate Hero platform successfully met its objectives by providing an engaging, intuitive digital environment for climate change education. The combination of games, quizzes, points badges and progress tracking created a rich learning experience that appealed to diverse users. The findings confirm that gamification and interactive media can significantly enhance climate literacy, making learning more memorable and motivating.

6. Future Works

Based on the findings, several recommendations can be proposed for future enhancement and deployment of the platform. Integrating a leaderboard could encourage healthy competition and sustained participation. Additional games would broaden learning variety and cater to users requesting more interactive content. Incorporating fact checking mechanism in user generated games would improve accuracy. A chatbot could provide real time climate answers. To promote long term use, features such as daily missions, weather widgets and habit trackers could be added.

Future studies could explore the long term behavioral impact of gamification on climate action. Expanding the sample size and comparing learners exposed to traditional methods versus gamified systems in a controlled experiment would provide deeper insights. Investigating different game mechanics, adaptive difficulty and personalized paths could also advance the design of environmentally focused educational technologies.

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