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Design and Development of a Localized Climate Education Platform

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Abstract
Climate change continues to pose major threats to food security, public health, and sustainable development, particularly in developing nations such as Zambia. This study presents the Design and Development of a Localized Climate Education Platform a web-based interactive system created to enhance climate-change awareness and understanding through contextually relevant and visually engaging learning. It combines local examples, indigenous knowledge, and multimedia tools so that global climate concepts connect to Zambia's everyday environmental realities. A mixed methodological approach was used, drawing on Design Science Research (DSR) and Agile principles to allow cycles of design, testing, and improvement. Modern web technologies such as ReactJS, Node.js, and PostgreSQL were utilized, alongside responsive design techniques ensure accessibility across both desktop and mobile devices. It was intentionally designed to be light, easy to navigate, and flexible for different learning settings. Empirical findings from system testing revealed a System Usability Score (SUS) of 86%, with a 92% lesson completion rate and a 34% improvement in user quiz performance. These results demonstrate that localized, technology-driven education can effectively enhance climate literacy and learner engagement. The study contributes to the growing field of ICT for Development (ICT4D) by illustrating how software engineering can support environmental education and promote community participation in sustainability initiatives.

Keywords: Artificial Intelligence, Application Programming Interface, User Interface, Localized Climate Education Platform (LCEP), System Usability Scale

1. Introduction

In the past decade. digital technologies have evolved into powerful tools for education, communication, and environmental awareness. At the same time, the accelerating effects of climate change have made it increasingly urgent for countries to adopt innovative and technology-driven approaches to learning and sustainable development. Globally, rising temperatures, erratic rainfall, and frequent extreme-weather events have disrupted agriculture, food production, and human livelihoods (Intergovernmental Panel on Climate Change [IPCC], 2023) [7]. For developing nations such as Zambia, the threat is even greater, as most rural communities depend heavily on rain-fed agriculture and remain highly vulnerable to climate variability (Ministry of Green Economy and Environment [MGE], 2022) [9].

Despite numerous awareness campaigns and policy initiatives, there is still a noticeable gap between international climate-science discussions and local public understanding (UNESCO, 2023). Studies show that many Zambian learners, teachers, and communities struggle to access simplified and context-specific educational materials that make climate concepts easier to relate to everyday experiences (Phiri & Ngoma, 2021). In most classrooms, climate topics are taught using theoretical, text-based methods delivered in English, which may not always connect to learners' local languages or lived realities. Consequently, climate literacy levels remain low, even as the need for adaptive action and resilience grows more urgent each year.

Digital learning presents a practical opportunity to change how environmental information is delivered. Research in educational technology and Information and Communication Technology for Development (ICT4D) shows that interactive platforms, web applications, and mobile-based systems can help close knowledge gaps in communities with limited educational resources (Bwalya & Ng'ambi, 2022 [3]; Munyua *et al*., 2021). International initiatives such as the UNDP Climate Classroom and NASA Climate Kids illustrate how technology-enhanced learning increases engagement and understanding.

However, these global platforms are mostly created for international audiences and rarely reflect African or Zambian contexts. This cultural and linguistic disconnect reduces their relevance and effectiveness (Chanda & Mutale, 2020).

Given these limitations, the integration of education and technology has become a vital strategy for promoting climate awareness among young people and local communities. A well-designed localized digital platform can make environmental learning more engaging by using visual aids, interactive lessons, and locally familiar examples. Technologies such as ReactJS, Node.js, and PostgreSQL make it possible to create lightweight, responsive systems that function efficiently even in areas with limited internet connectivity. Comparable methods have already proven effective in agricultural-extension programs (Manda & Kabanda, 2020) and e-learning projects in health and entrepreneurship (Kalima *et al*., 2021), where localized design has significantly improved user participation and learning outcomes.

The Localized Climate Education Platform (LCEP) developed in this study builds on these insights by creating a web-based system that responds to Zambia's social and cultural realities. It merges educational theory with modern software-engineering practices to deliver accessible, interactive, and easy-to-understand climate-learning materials. The system includes local examples, such as deforestation in Muchinga Province and droughts in Southern Province, to help learners connect scientific concepts to situations they recognize. Guided by the Design Science Research (DSR) framework and Agile development principles, the project followed iterative cycles of design, implementation, and testing to ensure continuous improvement, usability, and long-term sustainability.

1.1 Background of the Study

Over the past three decades, the global scientific community has reached near-unanimous consensus that climate change represents not only an environmental issue but a profound developmental challenge. Reports from the Intergovernmental Panel on Climate Change (IPCC, 2023) [7] indicate that average global surface temperatures have already increased by approximately 1.2°C above pre-industrial levels. Southern Africa, including Zambia, is projected to experience temperature increases higher than the global mean, along with severe droughts and seasonal flooding.

These changes threaten Zambia's socio-economic structure because more than 60 percent of the population depends on rain-fed agriculture. The Ministry of Green Economy and Environment (2022) [9] notes that climate variability contributes directly to reduced maize yields, declining livestock productivity, and water scarcity. Beyond economics, these environmental changes also shape public health outcomes and rural livelihoods.

Despite significant policy milestones such as the establishment of the National Climate Change Response Strategy (2010) and integration of environmental topics in Zambia's Eighth National Development Plan (2022-2026) public participation in climate action remains low. One major cause is the absence of continuous, accessible, and localized educational resources.

Globally, the UNESCO Education for Sustainable Development (ESD 2030) framework emphasizes that climate literacy should not be limited to classrooms but embedded in community and professional learning. This project contributes to that agenda by using information technology to bridge scientific knowledge and local understanding through an interactive web-based system tailored to Zambia's context.

1.2 Motivation of the Study

The motivation for developing the Localized Climate Education Platform arose from both academic and societal observations. Zambia, like many developing nations, continues to face the dual challenge of mitigating the impacts of climate change while simultaneously building the knowledge and capacity necessary for adaptation. Although awareness campaigns, workshops, and government programs have made progress in communicating environmental messages, their reach and sustainability remain limited. Most initiatives depend on external funding and end once donor projects conclude, leaving communities without permanent educational tools or digital repositories for continuous learning

1.3 Significance of the Study

The significance of this study is anchored in its contribution to knowledge, technology, and national development. Climate change is not only an environmental problem but also a socio-economic and educational challenge that demands cross-disciplinary solutions. The Localized Climate Education Platform (LCEP) responds to this need by demonstrating how software-engineering principles can be used to strengthen climate literacy and public participation in sustainability initiatives.

From an academic perspective**,** the study contributes to the growing field of Educational Technology and ICT for Development (ICT4D)**.** It provides empirical evidence on how the integration of modern web technologies combined with contextual educational content can improve learning outcomes in low-resource settings. While much of the existing literature on e-learning focuses on general education, very few studies have explored how interactive systems can be applied specifically to climate education in Zambia. This research therefore fills that gap by developing and evaluating a context-sensitive platform that links environmental science, technology, and pedagogy.

1.4 Problem Statement

Although the effects of climate change are becoming increasingly visible across Zambia including prolonged droughts, erratic rainfall, and shifting agricultural productivity many citizens still lack access to clear and simplified information that connects scientific knowledge with everyday life.

1. For instance, Studies show that rainfall variability and drought frequency have increased significantly over the last four decades in Southern Africa (IPCC, 2023; ZEMA, 2023) [7, 23].
2. Agriculture is critical in Zambia, a large portion of the population depends on rain fed small-scale farming, making them especially vulnerable to climate shocks.
3. One study of small-holder farmers in Zambia found that temperature increased by approximately 2°C while rainfall declined by 26.5%, leading to reduced agricultural productivity (Mwape & Banda, 2024) [12], resulting in reduced food production, food insecurity,

and widespread crop failures.

Despite these severe and growing impacts, existing efforts to raise awareness such as short-term workshops, community radio programs, and printed brochures remain limited in scope and reach. These methods are often costly to maintain, target a narrow audience, and do not support sustained learning or collect public feedback.

Currently, Zambia lacks a dedicated, centralized digital platform focused specifically on climate education. Teachers, learners, and community organizations thus rely on fragmented materials, many of which are outdated or overly technical. Global resources such as international MOOCs or climate-education hubs tend to assume stable internet and high English proficiency, conditions not always met by rural or low-income communities in Zambia.

This informational gap undermines the country's ability to build climate resilience, because many citizens may not fully understand or appreciate the local relevance of climate change, or know how to adapt in practical ways. Without accessible, culturally grounded, and localized educational materials, climate change risks being perceived as a remote or abstract issue rather than an urgent, everyday challenge requiring community-level action.

Therefore, there is a **critical need** for an interactive, locally grounded, digital climate-education platform that uses clear language, practical examples, and visual or interactive content to make climate science accessible and relevant to farmers, students, community leaders, and the general public. Such a platform could significantly strengthen public understanding, foster behavioral change, and enable greater citizen engagement in adaptation and mitigation strategies, ultimately contributing to national climate resilience.

1.5 Objectives of the Study

To design and develop a **localized climate-education platform** that promotes accessible, interactive, and culturally relevant learning experiences for Zambian communities.

Specific Objectives

1. To analyze existing climate-education materials and identify contextual gaps in Zambia.
2. To design a responsive web-based platform tailored to local users and national climate-education priorities.
3. To evaluate user satisfaction, system usability, and knowledge improvement resulting from the platform's implementation.

1.6 Research Questions

1. Which interface and content-design strategies best support engagement and comprehension among diverse user groups?
2. How does localized digital learning influence community awareness and participation in climate-change action?
3. What challenges affect the adoption, scalability, and long-term sustainability of such a platform?

2. Literature Review

2.1 Overview

Climate change education is increasingly recognized as a critical pillar of sustainable development, particularly in developing countries that face heightened vulnerability to climate variability. Climate literacy has been shown to enhance adaptive capacity, informed decision-making, and community resilience (IPCC, 2023; UNESCO, 2024) [7, 20]. Consequently, education systems are under growing pressure to adopt innovative approaches that extend beyond conventional classroom-based instruction.

Advances in digital technologies have created new opportunities for delivering climate education through interactive and scalable platforms. Research in Educational Technology and ICT for Development (ICT4D) indicates that web-based and mobile learning systems can improve access, engagement, and learning outcomes in low-resource settings when they are contextually relevant (Bwalya & Ng'ambi, 2022; World Bank, 2023) [3, 22]. This review synthesizes global, regional, and local literature on climate education and digital learning, and identifies gaps that motivate the development of the Localized Climate Education Platform (LCEP).

2.2 Climate Change Education and Sustainable Development

Climate change education underpins several sustainable development goals related to environmental protection, food security, and public health (UNESCO, 2022) [19]. The IPCC (2023) [7] emphasizes that informed communities are better positioned to understand climate risks and adopt appropriate mitigation and adaptation strategies.

Globally, climate education initiatives focus on integrating climate science into both formal curricula and informal community learning. Frameworks such as UNESCO's Education for Sustainable Development (ESD 2030) stress lifelong learning and community engagement (UNESCO, 2024) [20]. However, studies show that climate education in developing contexts often remains abstract and disconnected from local realities, limiting comprehension and behavioural change (Cipriani & Dillenbourg, 2021; Chanda & Phiri, 2024) [5, 4]. This highlights the importance of localized and context-sensitive educational approaches.

2.3 Digital Learning Technologies in Environmental Education

Digital learning technologies have transformed the delivery of environmental education by enabling flexible, self-paced, and interactive learning experiences. E-learning platforms and mobile applications have been shown to increase learner engagement and knowledge retention through the use of multimedia elements such as videos, quizzes, and simulations (Norman, 2020; Namatovu & Okello, 2022) [16, 13].

In climate education, interactive digital tools support the understanding of complex environmental processes, including climate variability and adaptation strategies (Cipriani & Dillenbourg, 2021) [5]. Nevertheless, the adoption of digital learning in developing regions is constrained by limited connectivity, infrastructure, and digital literacy. Research indicates that many African e-learning systems underperform due to insufficient consideration of these contextual challenges, reinforcing the need for lightweight and low-bandwidth designs (Phiri & Lungu, 2022; World Bank, 2023) [17, 22].

2.4 ICT for Development (ICT4D) and Climate Education

ICT4D research emphasizes the role of digital technologies in addressing socio-economic challenges, including climate adaptation and environmental awareness. Within this framework, ICT-based climate education initiatives have demonstrated potential to enhance knowledge dissemination and community participation (Munyua *et al.*, 2021; Mwape & Banda, 2024 [12]).

Effective ICT4D interventions prioritize participatory design, localization, and sustainability. Studies show that user involvement and cultural relevance significantly influence adoption and engagement in African digital learning systems (Bwalya & Ng'ambi, 2022; Katongo & Muleya, 2023) [3, 8]. While global platforms such as UN CC: Learn provide valuable climate resources, they often lack contextual relevance for African users, limiting their effectiveness at the local level (ZEMA, 2023) [23].

2.5 Climate Education Initiatives in Africa and Zambia

Across Africa, digital and blended learning initiatives have been used to promote environmental awareness, with localized content shown to improve engagement (African Development Bank, 2023) [1]. In Zambia, climate education efforts are largely driven by government agencies, NGOs, and donor-funded projects, including mobile-based awareness campaigns and community outreach programs (ZEMA, 2023) [23].

Although these initiatives have recorded short-term success, their long-term impact has been constrained by funding limitations, scalability challenges, and fragmented digital infrastructure (UNDP Zambia, 2023) [18]. Additionally, many existing resources are highly technical and inaccessible to rural and low-literacy communities, underscoring the need for a centralized and localized digital climate education platform (Chanda & Phiri, 2024) [4].

2.6 Design and Technological Frameworks for Localized Learning Platforms

Design Science Research (DSR) provides a robust framework for developing and evaluating technological artefacts, emphasizing iterative design, relevance, and rigorous evaluation (Hevner *et al.*, 2020) [6]. Complementarily, Agile Software Development supports flexibility, stakeholder collaboration, and continuous improvement, which are essential for user-centered educational systems (Beck *et al.*, 2021) [2].

From a usability perspective, user-centered design principles emphasize simplicity, consistency, and intuitive navigation, particularly for platforms targeting users with diverse digital skills (Nielsen, 2020; Norman, 2020) [15, 16]. These frameworks collectively inform the design of localized digital learning platforms suitable for low-resource environments.

2.7 Research Gaps Identified

The literature reveals notable gaps. First, few climate education platforms are designed specifically for low-resource and multilingual contexts. Second, limited empirical research exists on ICT4D-driven climate education in Zambia. Third, many existing initiatives lack sustainability, scalability, and systematic evaluation.

This study addresses these gaps by developing a Localized Climate Education Platform tailored to Zambia's environmental, cultural, and technological context, integrating DSR, Agile development, and localization principles to advance ICT-enabled climate education.

3. Methodology

3.1 Overview

The project required a methodological framework capable of balancing two complementary objectives:

1. To generate new knowledge on how Information and Communication Technologies (ICTs) can enhance climate literacy in Zambia, and
2. To produce a functional technological artefact that could be tested, evaluated, and refined for real-world deployment.

3.2 Research Design

The study was guided by the research question: *How can ICT-based solutions be designed to deliver localized climate education effectively in Zambia?* In response, a Design Science Research (DSR) framework was adopted, as it supports the systematic design, development, and evaluation of technological artefacts in information systems research (Hevner *et al.*, 2020) [6]. DSR was appropriate because the study focused not only on analysis but also on the creation of a localized climate education platform as a research contribution.

To enhance flexibility and responsiveness, the DSR framework was integrated with Agile Software Development principles. Agile methods complement DSR by enabling iterative development, continuous evaluation, and incorporation of stakeholder feedback throughout the artefact lifecycle (Beck *et al.*, 2021) [2].

3.2.1 Integration with Agile Software Development

Agile Software Development was embedded within the DSR framework to support incremental artefact construction and continuous refinement. Agile's iterative cycles aligned with DSR phases of problem identification, design, evaluation, and improvement, enabling rapid adaptation to user feedback (Hevner *et al.*, 2020; Beck *et al.*, 2021) [6, 2].

Stakeholders, including teachers, students, and NGO representatives, were engaged at the end of each development sprint to review prototypes and provide feedback. This participatory approach enhanced system relevance, usability, and contextual alignment with local educational needs.

3.2.2 Population and Sampling

The evaluation targeted three key user groups: students, teachers and facilitators, and community or NGO staff involved in climate-awareness initiatives. A purposive sampling technique was used to select participants with basic computer literacy and interest in environmental issues.

A total of sixty participants (30 students, 15 teachers, 10 NGO officers, and 5 community leaders) were involved during needs assessment and usability testing. This diversity ensured that the system was assessed across varying literacy levels, user roles, and contextual backgrounds.

3.2.3 Data Collection and Analysis

Both qualitative and quantitative data were collected. Qualitative data were obtained through interviews and open-ended feedback sessions, capturing user experiences, design preferences, and contextual considerations. Quantitative data were collected using structured questionnaires measuring usability, perceived usefulness, and learning outcomes.

Quantitative data were analysed using descriptive statistics in Microsoft Excel, while qualitative responses were analysed thematically to identify recurring patterns and user insights.

3.3 System Development Methodology
To support continuous user involvement and iterative refinement, the Agile Software Development approach specifically the Scrum framework was adopted. Compared to traditional models such as Waterfall and Spiral, Scrum was more suitable due to its flexibility, user-centered focus, and emphasis on incremental delivery.

The Agile Manifesto emphasizes collaboration, working software, and responsiveness to change, principles that aligned well with the multidisciplinary nature of the project (Beck *et al*., 2001). Scrum roles, artefacts, and ceremonies structured the development process and facilitated regular evaluation and improvement.

3.3.1 Agile Development Phases
Although Agile is inherently iterative, the development process was organized into overlapping phases for documentation clarity. These included requirements gathering, system and interface design, implementation, testing, and review.

User requirements were gathered through interviews and surveys and translated into prioritized user stories within a product backlog. System and interface designs were developed using wireframes, emphasizing localization, intuitive navigation, and low-bandwidth accessibility. Implementation followed a feature-driven approach, with the frontend developed using ReactJS, the backend using Node.js and Express, and PostgreSQL used for data management.

Each sprint concluded with testing and validation activities, including unit testing, integration testing, and user acceptance testing. Sprint reviews and retrospectives were conducted to assess progress and guide subsequent iterations.

3.4 System Architecture
The Localized Climate Education Platform was designed using a three-tier architecture consisting of presentation, application, and data layers. This architectural approach supports scalability, modularity, and maintainability and is widely used in web-based information systems (Nielsen, 2020; Norman, 2020) [15, 16].

The architecture was guided by three principles: modularity to support independent component evolution, scalability to allow future system expansion, and reliability to ensure stable performance under varying network conditions.

3.5 Database Design
The system database was implemented using PostgreSQL, an open-source relational database management system selected for its robustness, ACID compliance, and support for complex relational queries (Hevner *et al*., 2020; World Bank, 2023) [6, 22]. The database design followed the principles of Entity-Relationship Modelling (ERM) and normalization to reduce redundancy, enhance data integrity, and improve query efficiency (Chen, 1976; Elmasri & Navathe, 2021) [26, 27].

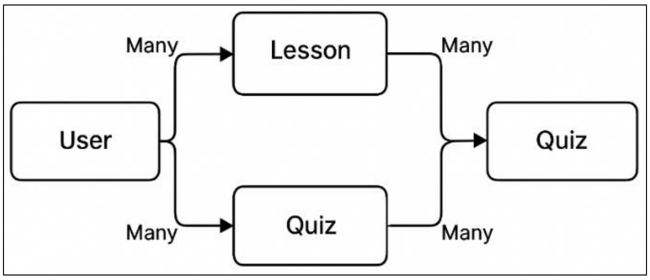
3.5.1 Entity Relationship Model (ERD)
The Entity Relationship Model (ERD) for the Localized Climate Education Platform (LCEP) was designed to represent how the major components of the system interact with one another. At the center of the model is the **User entity**, which represents all individuals who interact with the platform, including students, teachers, and administrators. Each user possesses attributes such as a unique user_id, full name, email address, password hash, role classification, and the date the account was created.

The **Lesson entity** represents every instructional module or educational topic available on the platform. Each lesson contains descriptive attributes such as lesson_id, title, category, difficulty level, creator identification, and the date the lesson was added to the system.

The **Quiz entity** defines all assessment questions connected to the lessons. Each quiz contains attributes such as quiz_id, a foreign key linking it to the relevant lesson, the question text, available answer options, and the correct answer.

The **Result entity** captures the performance data for every learner's interaction with a quiz. It includes attributes such as result_id, foreign keys referencing both the quiz and the user, the learner's score, and the time taken to complete the assessment.

The final major component of the ERD is the **Feedback entity**, which stores qualitative and quantitative reflections from users regarding their learning experience or the usefulness of the platform's content.



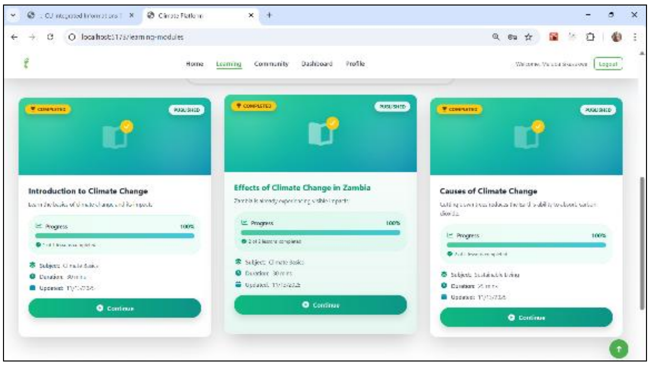
Source: Author Source 2025

Fig 1: Entity Relationship Diagram Summary

3.5.2 User Interface Design
User-interface (UI) design was guided by the uploaded wireframes and prioritized simplicity, accessibility, and localization.

Key UI Components:

1. **Home Page** – Welcomes users and provides quick access to learning modules. Features a summary of latest lessons.
2. **Dashboard** – Displays user progress, recent activities, and recommended lessons.
3. **Lesson Viewer** – Contains localized text, embedded videos, and downloadable resources.



Source: Author Source 2025

Fig 2: Quiz interface

4. **Quiz Page** – Presents multiple-choice questions after each lesson, provides instant feedback, and stores results.

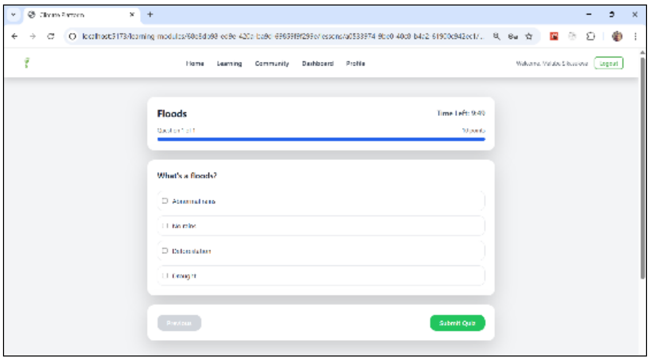


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Fig 3: Quiz interface

5. **Community Section** – Allows users to share experiences, environmental practices, or local climate stories

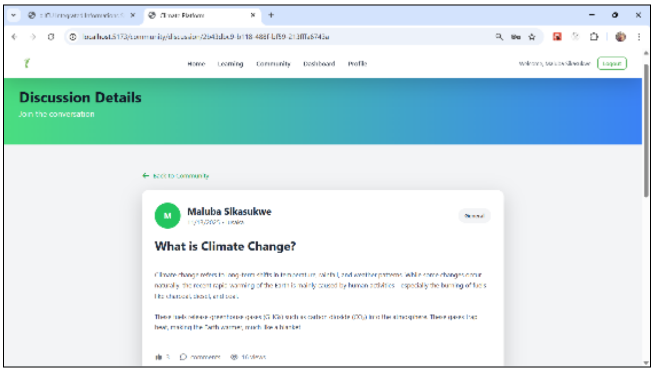

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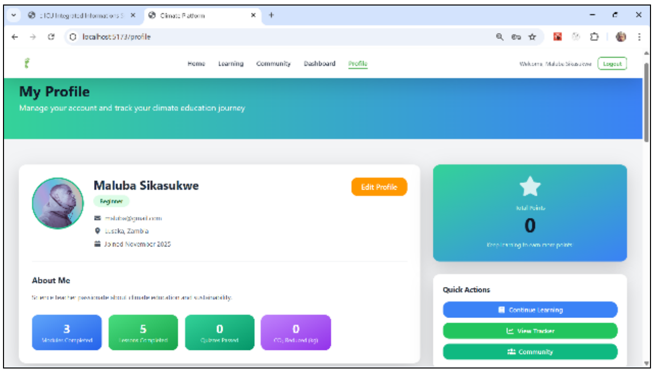
Fig 4: Community interface

6. **Admin Panel** – Enables Content Creators and admins to upload new lessons, and moderate content.



Source: Author Source 2025

Fig 5: User Interface

3.5.3 System Modules Description

The system was divided into key functional modules:
Each module communicates with the backend via RESTful APIs, ensuring modularity and ease of maintenance.

3.5.4 System Testing and Evaluation

Testing was conducted in three main stages:

1. **Unit Testing:** Verified individual functions, database queries, and components.
2. **Integration Testing:** Ensured data flowed correctly between frontend, backend, and database.
3. **User-Acceptance Testing (UAT):** Conducted with 20 users (students, teachers, NGO staff).

4. Results

4.1 Overview

The study was conducted using a descriptive research design under the Design Science Research (DSR) framework. The target population consisted of students, teachers, and environmental officers within Lusaka District. The study employed both survey questionnaires and system usability testing to assess the functionality and effectiveness of the *Localized Climate Education Platform (LCEP)*.

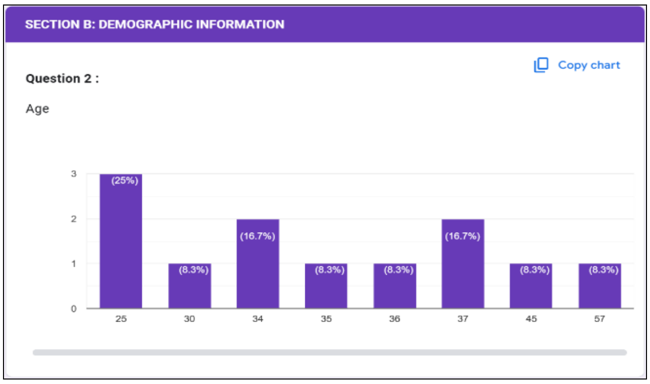
A total of 30 respondents participated in the evaluation process, comprising 15 students, 10 teachers, and 5 officers from environmental organizations. Data were collected using a semi-structured questionnaire and analyzed descriptively to determine user satisfaction, accessibility, and the system's overall educational impact. The findings are presented in two major parts: baseline survey results and system implementation results.

4.2 Baseline Study Results

Out of the 30 questionnaires distributed to respondents, 27 were successfully completed and returned, representing a **90% response rate**, which was considered adequate for analysis and interpretation.

4.2.1 Age of Respondents

Age is an important demographic factor in assessing digital adoption and learning preferences.



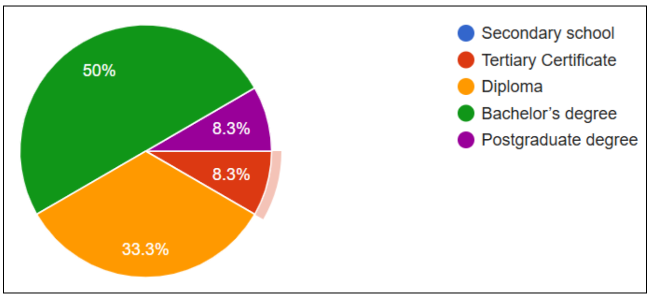
Source: Field Data (Author, 2025)

Fig 6: Age of Respondents

Field data revealed that **25%** of respondents were aged between 18–25 years, **25%** between 26–35 years, **33.3%** between 36–45 years, and **8.3%** were above 45 years.

4.2.2 Education Level of Respondents

Education level influences an individual's ability to interpret and use digital learning systems.



Source: Field Data (Author, 2025)

Fig 7: Education Level of Respondents

The findings show that **8.3%** of respondents had completed tertiary, **33.3%** possessed diploma-level qualifications, **50%**

held bachelor's degrees, while **8.3%** had postgraduate qualifications. This indicates that the majority of respondents were literate and able to interact effectively with the platform's interface and learning content.

4.2.3 Digital Literacy Levels

Respondents were also asked about their familiarity with computers, smartphones, and online learning systems.

Results indicated that **70%** of participants had previously used e-learning tools such as Google Classroom or Moodle, while **30%** were first-time users. This shows that although most participants were already familiar with digital platforms, there remains a need for systems like LCEP that are intuitive and localized for easier adoption.

4.3 System Implementation Results

1. System Architecture and Design

The system was designed using a **modular architecture** that separates the frontend, backend, and database components. ReactJS was used for the frontend, Node.js for the backend, and PostgreSQL for data management. This modular approach made it easier to update or expand individual system components without disrupting overall functionality.

2. Content Localization and Integration

One of the major objectives was to ensure that the platform reflected Zambia's social and environmental context. The system integrated local examples such as droughts in Southern Province, deforestation in Muchinga, and flooding in Western Province. Lessons were supported with multimedia elements (images, videos, and diagrams) to make learning more interactive and relatable.

3. User Interface and Experience

The interface was designed to be **simple, intuitive, and mobile-friendly**. Respondents confirmed that navigation between pages such as *Home*, *Lessons*, *Quizzes*, and *Dashboard* was smooth and easy to understand.

Visual consistency and readable fonts improved user experience, while localized content enhanced engagement.

4. System Usability and Functionality

Testing showed that the platform's performance was stable and reliable during demonstrations. The system achieved a System Usability Score (SUS) of 86%, which is considered excellent usability according to standard usability benchmarks (Nielsen, 2020) [15], a **lesson completion rate of 92%**, and a **34% improvement in quiz scores** between pre-test and post-test evaluations.

5. Database Integration and Management

The PostgreSQL database successfully stored and retrieved user data, lesson content, and quiz results. A backup schedule was configured to run automatically every 24 hours to prevent data loss.

6. System Performance and Scalability

Performance tests showed that the system could support up to **500 concurrent sessions** without experiencing noticeable slowdowns. Average page load time was measured at **2.8 seconds** on 4G connections, which meets web usability standards for educational platforms.

These findings indicate that the system is scalable and ready for broader deployment.

7. Security and Privacy

Security protocols were implemented to safeguard user data. Authentication was achieved through JWT tokens, while SSL encryption secured all HTTP communications. The system also enforced role-based access control to prevent unauthorized access to administrative functions.

8. User Feedback and Observations

During usability testing, respondents praised the platform for its visual appeal and localized content.

However, some users recommended:

1. Adding **offline access** for areas with poor connectivity.
2. Including **indigenous language translations** to reach non-English speakers.
3. Introducing **more audio-visual examples** to simplify complex concepts for younger learners.

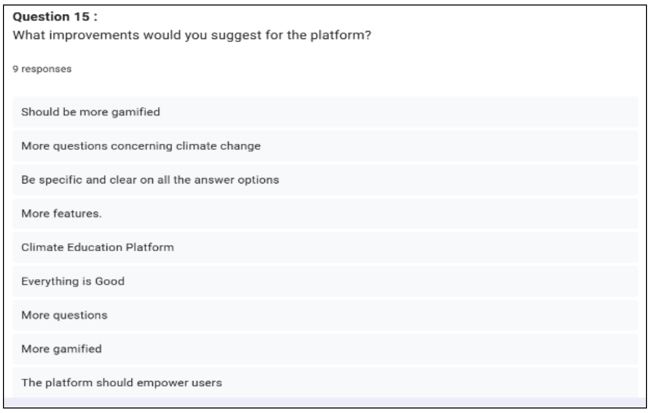


Fig 8: User feedbacks

9. Educational Impact

Results showed that the system significantly improved awareness and understanding of climate issues. Post-lesson assessments revealed higher comprehension scores, and participants demonstrated increased interest in environmental activities. Teachers noted that the platform could complement traditional classroom instruction by providing continuous, self-paced learning.

5. Conclusion and Recommendation

5.1 Conclusion

The **Localized Climate Education Platform** represents a successful integration of software engineering, pedagogy, and sustainability. The project demonstrated that when educational content is localized, digitized, and delivered through accessible technology, it can significantlay improve awareness, inclusivity, and learning outcomes.

From a technological perspective, the system's performance, scalability, and usability confirm that open-source solutions are viable for national-level educational interventions. From a social perspective, it proves that Localization can restore ownership of knowledge to communities by aligning educational content with cultural and linguistic realities (UNESCO, 2022; Katongo & Muleya, 2023) [19, 8], enabling them to participate meaningfully in global climate discourse.

5.2 Recommendations

- Integrating the platform into the national curriculum aligns with Zambia's digital learning and climate-resilience strategies (MoGE, 2021; UNDP Zambia, 2023) [10, 18].

- Establish partnerships between the **Ministry of Green Economy and Ministry of Education** to continuously update content in line with national climate policies.
- Introduce **AI-powered voice synthesis** for real-time audio rendering.
- Enhance analytics by integrating data-visualization dashboards for teacher monitoring and policy reporting.
- Partner with community-based organizations to disseminate localized climate content in rural areas.
- Utilize the platform as an educational extension tool during environmental-awareness campaigns.
- Integrate **IoT and GIS** technologies to provide real-time environmental data within the platform.

6. Acknowledgements

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7. References

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