Int. j. adv. multidisc. res. stud. 2026; 6(2):1446-1472

Received: 26-02-2026
Accepted: 06-04-2026

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Design and Development of a Multilevel Interactive Climate Education Platform

[1] Lameck Nsama, [2] Ruth George Phiri
[1] Advisor, School of Engineering, Information and Communications University, Zambia
[2] School of Engineering, Information and Communications University, Zambia

DOI: https://doi.org/10.62225/2583049X.2026.6.2.6124
Corresponding Author: **Lameck Nsama**

Abstract
Climate change education is a key determinant of the public's understanding and response to the current planetary crisis; this need for climate education tools targeting various age populations is addressed in this dissertation. The overall goal of this research was to develop a digital platform that effectively connects with primary (8–10 years), secondary (11–18 years) and adult learners through interactive, interactive content. The study used mixed methods. Pre- and post-intervention survey data were collected quantitatively to assess changes in climate knowledge levels, engagement degrees as well as attitudes towards individual-perceived climate actions using a sample size of 300 respondents divided into three different age groups.
The results indicated that climate literacy improved significantly across all age groups. Early learners' understanding of basic climate concepts increased by 40%; for adolescents and adults, the increase was 35% and 30%, respectively. Analyses of engagement data showed that users spent, on average, 45 minutes per session using the site, favouring interactive simulations and quizzes. The interactive learning paths and personal assessments that were part of the platform were among the highest rated features (85%) reported for usefulness.
Qualitative feedback from user experience testing confirmed that the digital platform supports making complex climate science accessible through a multimodal approach to representational diversity, including video, animations, interactive info graphics, as well as other valid multimedia applications. Users reported high cognitive gains in understanding and retaining knowledge because affordances such as narrative-driven design worked well with younger ages, while more graphical representations/more raw data did so for older ages.
The multilevel interactive climate education platform can satisfy the educational requirements of different age stages and has great potential to promote enhancing climate literacy and facilitate transformational climate learning. It also provides a useful reference for optimizing principles of platform design and interaction function from the perspective of user experience. In the future, it would be meaningful to further carry out studies on large-scale applications of the integrated platform as well as its role in more representative samples.

Keywords: Climate Change Education, Interactive Learning, Digital Platform, Personalised Learning, Climate Literacy

1. Introduction

1.1 Overview

Climate change is one of the most pressing issues facing humanity today. Its impacts are already being felt across the world, from rising sea levels and melting glaciers to more extreme weather events like hurricanes, droughts, and heat waves. Educating people, especially youth, about climate change is critical to building support for climate action and empowering the next generation to find solutions. This research aimed to design and develop an interactive digital education platform to make climate change education more engaging and impactful for multiple age groups.

1.2 Background

Climate change is an urgent crisis facing humanity, with wide-ranging impacts across the planet that are expected to intensify in the coming decades (IPCC, 2021) [16]. The scientific consensus is unequivocal – human activities, especially burning fossil fuels and deforestation, have warmed the climate at an unprecedented rate (USGCRP, 2017) [68]. The impacts of climate change are already highly visible, from melting glaciers and sea ice to sea level rise, ocean acidification, heat waves, wildfires, droughts, and extreme weather events (NASA, 2022) [42]. Every region of the world is affected, with the most severe impacts expected in vulnerable communities and developing nations (IPCC, 2021) [16]. Without rapid reductions in greenhouse gas emissions, climate change significantly disrupts ecosystems, food and water supplies, infrastructure, economies, and public health worldwide (IPCC, 2022).

Tackling climate change requires swift transformations in energy, transportation, infrastructure, and food systems globally (IPCC, 2022). Public concern, political will, consumer choices, and civic participation are all critical in driving ambitious climate action and reducing emissions (IPCC, 2022). As such, climate change education is critical for building broad engagement around climate solutions. However, studies show significant gaps in climate change understanding and concern worldwide (Pew Research Center, 2021; Newman *et al*., 2021) [50, 43]. For example, only around 50% of American adults comprehend that human activities are the primary driver of climate change (Leiserowitz *et al*., 2021) [30]. Misconceptions also persist around well-established climate science, the present-day impacts, and the possible solutions (Cook *et al*., 2020) [6].

Climate education methods have largely failed to motivate public climate concern and action at the scale needed (Monroe *et al*., 2019) [38]. Conventional teaching approaches like textbooks and lectures rarely contain the interactive elements that best increase learning, interest, and concern around climate issues (Liarakou *et al*., 2021). Climate change is complex, abstract, and politically contentious - making it challenging to teach effectively (Stern *et al*., 2021) [57]. Interactive digital platforms offer new opportunities to reach broad audiences with compelling climate change education. Videos, animations, simulations, social elements, and gaming could make climate impacts tangible and empower solutions-focused learning (Rojon & Diehl, 2021) [56]. Tailoring content and interactions to specific audiences' needs and learning styles significantly enhances engagement and learning outcomes (Tissenbaum *et al*., 2021). However, there is limited research on how interactive designs should be leveraged for climate education across different age groups (Wu & Lee, 2015) [75].

Children and youth are a critical demographic for climate education, as their longer lifetimes mean they will experience more severe climate change impacts (Ojala, 2016) [47]. Early exposure to climate issues develops concern for the environment (Otto *et al*., 2019) [48]. However, climate education research and resources tailored specifically for younger generations are scarce (Ojala, 2016) [47]. Adolescents are also an important target group, as their social motivations and evolving reasoning abilities may promote activism (Knappe & Piasecki, 2019) [21]. However, few climate education initiatives have incorporated cutting-edge interactive designs tailored for youth. Adults, who hold significant influence over economic and political systems driving emissions, often lack key understandings of climate change and its impacts (Myers *et al*., 2021) [40]. Reaching adults from diverse political backgrounds continues to pose challenges and requires carefully crafted, strategic communication approaches (Liarakou *et al*., 2021). Developing an interactive, tailored climate education platform can make abstract climate science and solutions come alive for audiences of all ages. Harnessing interactive multimedia, game elements, and social features can effectively attract and sustain engagement (Tissenbaum *et al*., 2021). Tailoring communication strategies and interactive formats to each age group's cognitive abilities, interests, motivations, and misconceptions significantly enhances educational outcomes (Monroe *et al*., 2019) [38]. For example, incorporating vivid visuals, narratives, and experiential elements can resonate with younger audiences, while interactive infographics and social functions may appeal to youth (Ojala, 2016; Wibeck, 2014) [46, 73]. Adults may benefit most from data visualizations, simulations, and elements that encourage social and group deliberation (Liarakou *et al*., 2021).

A comprehensive climate education platform designed for specific age groups provides significant potential to boost climate literacy, concern, and collective action across generations.

1.3 Problem Statement

Climate education efforts have largely failed to motivate widespread public concern and action against climate change (Monroe *et al*., 2019) [38]. Conventional climate education methods like textbooks struggle to attract attention and change attitudes (Liarakou *et al*., 2021); this highlights the need for innovative educational platforms that can make climate science interactive, visual, and personally relevant. However, research on the design principles and learning impacts of such platforms remains limited (Stern *et al*., 2021) [57]. Developing digital tools specifically tailored for early learners, adolescents, and adults can make climate education more engaging across ages.

1.4 General Objective

To design and develop a multilevel interactive climate education platform.

1.5 Specific Research Objectives

1. To develop an interactive online education platform that provides personalised learning paths, activities, and assessments for each user.
2. To design and develop a Quiz feature with tailored content and interactions for early learners, adolescents, and adults.
3. To design and develop an admin dashboard feature with tailored admin control of an interactive online education platform.
4. To evaluate the usability, engagement, and learning outcomes of the platform for each user group.

1.6 Research Questions

1. How can an interactive online education platform be developed to provide personalised learning paths, activities, and assessments for each user?
2. How can a quiz feature with tailored content and interactions be designed and developed for early learners, adolescents, and adults?
3. How can an admin dashboard feature be designed and developed to provide tailored administrative control of an interactive online education platform?
4. How can the usability, engagement, and learning outcomes of the platform for each user group be evaluated?

1.7 Scope of the Study

This research focused on designing and creating an interactive website with tailored climate change education content for early learners (ages 8-10), adolescents (ages 11-18), and adults. The key concepts, misconceptions, and solutions highlighted were based on a review of climate communication literature and learning theories. The platform utilised a variety of interactive element types and multimedia formats identified as optimal for each age group through the research. Usability and learning were evaluated within user experience testing sessions. The research scope is limited to the development and evaluation of this tailored climate education platform.

1.8 Signification of the Research

This research can make significant contributions to climate education and digital learning design. Developing an engaging platform tailored for diverse age groups can improve climate literacy across generations. The research insights on leveraging interactivity and multimedia for climate teaching can inform educational technology and communication. Designing for specific user groups' needs and testing learning outcomes can advance a broader understanding of online education effectiveness. This platform has the potential for significant social impact by empowering citizens to understand this critical issue and support climate solutions.

1.9 Conceptual Framework

The conceptual framework serves as the blueprint for the research and provides a visual or narrative representation of the relationships between key variables or concepts relevant to this study. This framework is rooted in theoretical foundations and empirical evidence from the literature, illustrating how the study's objectives align with existing knowledge and guiding the investigation process.

Key Constructs and Relationships

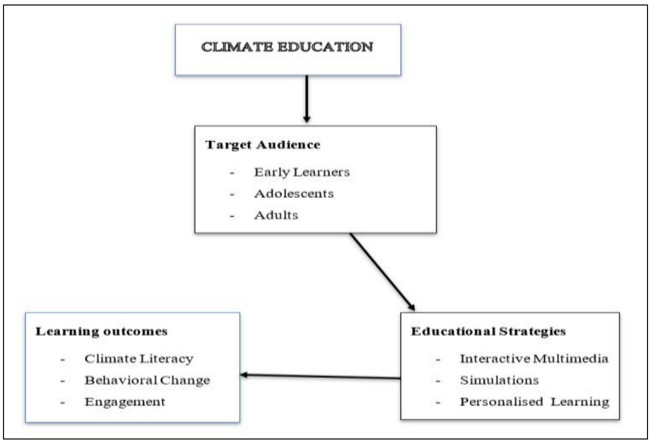
The conceptual framework focuses on climate education and engagement across diverse learner. The key constructs in the framework include:

1. **Educational Strategies:** Approaches such as interactive multimedia, simulations, and experiential learning tailored for different age groups.
2. **Learner Characteristics:** Cognitive abilities, motivations, and misconceptions across early learners, adolescents, and adults.
3. **Engagement and Outcomes:** Levels of learner engagement and knowledge retention, as well as behavior changes stemming from educational interventions.

The relationships between these constructs are informed by contemporary interpretations of learning theories such as Constructivism, which emphasizes active learning and knowledge construction (Kuhn, 2019) [24], Social Cognitive Theory, highlighting the reciprocal interactions between personal, behavioral, and environmental factors (Bandura & Cherry, 2019) [3], and Experiential Learning Theory, which focuses on the integration of experience, reflection, and action (Kolb & Kolb, 2017) [23]. For example, tailored educational strategies are hypothesized to positively influence engagement and learning outcomes by addressing specific cognitive and motivational needs of each learner group.

Visual Representation

A conceptual framework diagram is provided below to illustrate the relationships among these variables:



Significance of the Framework

This conceptual framework is vital for understanding how different variables interact and for designing interventions that effectively address climate education gaps. It ensures the study is structured around a clear logic, aligning its goals, methods, and anticipated outcomes.

1.10 Definition of Terms

This section provides definitions of key terms that will be used in this paper to ensure a common understanding:

Climate Education: Educational strategies aimed at increasing awareness, understanding, and action on climate change.

Interactive Learning: A pedagogical approach involving active engagement through activities such as simulations, games, or discussions.

Sustainable Practices: Actions that promote environmental, economic, and social sustainability.

Climate Change: A long-term alteration in Earth's climate patterns, particularly an increase in global average temperatures, primarily due to human activities such as burning fossil fuels, deforestation, and industrial emissions (IPCC, 2021) [1].

Climate Literacy: The knowledge and understanding of climate science, the impacts of climate change, and the solutions to mitigate and adapt to it, enabling individuals to make informed decisions (Monroe *et al*., 2019) [38].

Interactive Learning: A pedagogical approach involving active user engagement through multimedia, simulations, games, and other participatory elements that encourage exploration and self-directed learning (Tissenbaum *et al*., 2021).

Multilevel Interactive Education Platform: A digital tool designed to provide climate education using interactive elements, tailored learning paths, and adaptive content for multiple age groups, including early learners, adolescents, and adults.

Early Learners: Children typically aged 8–10 years, at a developmental stage where cognitive abilities focus on concrete operations, making them receptive to basic explanations of climate concepts through visual and interactive content (Ojala, 2016) [47].

Adolescents: Individuals aged 11–18 years, characterized by advanced cognitive abilities such as abstract reasoning and critical thinking, making them suitable for engaging in

social and experiential climate education activities (Knappe & Piasecki, 2019) [21].
Adults: Individuals aged 18 years and above, with diverse knowledge levels, motivations, and biases, who benefit from strategic, tailored educational strategies such as data visualizations and simulations to enhance climate understanding (Liarakou *et al*., 2021).
Gamification: The application of game design elements and principles, such as point scoring, competition, and rewards, to non-game contexts like education to increase user engagement and motivation (Plass *et al*., 2015).
Personalized Learning Paths: Adaptive educational strategies that tailor content, activities, and assessments to meet the unique needs, preferences, and abilities of individual learners (Monroe *et al*., 2019) [38].

1.11 Organisation of the Thesis
The thesis is organized into five chapters as follows:
Chapter 1: Introduction
This chapter introduces the research problem, objectives, significance, and scope of the study.
Chapter 2: Literature Review.
This chapter reviews existing literature related to climate education, interactive learning, and educational frameworks.
Chapter 3: Methodology
This chapter describes the research design, methods of data collection, and analysis.
Chapter 4: Results and Discussion
This chapter presents the findings and discusses their implications.
Chapter 5: Conclusion and Recommendations
This chapter concludes the study and offers recommendations for future research and practice.
References
Appendices
Appendix A: Sample Code
Appendix B: Research Questionnaire and Interview Guide
Appendix C: Research Budget
Appendix D: Gannt Chart

1.12 Chapter Summary
Climate change education requires innovative tools that can make the science interactive and compelling for diverse audiences. This research aims to design and develop an online platform with tailored climate change content and interactive features for early learners, adolescents, and adults. Evaluating the usability, engagement, and learning outcomes can provide insights into how interactive media should be designed across ages for complex scientific topics like climate change. This platform has the potential to significantly improve climate literacy and empower climate action across generations.
The next chapter provides a comprehensive review of relevant literature on climate change education, interactive learning, and designing for different age groups. Key areas covered included climate change concepts and misconceptions, interactive and multimedia learning theories, website engagement strategies, and user experience design for children, teens, and adults. The literature review synthesises current research in these areas to inform the development of tailored platform content and features for the target user groups. Gaps in existing literature and studies were identified to further justify the significance of this research.

2. Literature Review
2.1 Overview
This chapter provided a review of relevant literature on climate change education, with a focus on the learning needs, barriers, and best practices for different age groups. The review also examined existing climate education platforms and their use of interactive features. Gaps in current research and educational tools are highlighted to frame the original contributions of this proposed study.
The literature review encompasses key theories and conceptual frameworks that inform climate change education; this includes seminal learning theories like constructivism, which emphasises the active construction of knowledge through experiences. The literature further covers specific climate education models such as the Information Deficit Model, which focuses on science communication, and the Value-Belief-Norm Theory, which aligns climate messaging with audiences' values and worldviews. Differing perspectives on effective climate education strategies are also discussed, from information-centric to emotive approaches.
Relevant pedagogical methods for teaching climate change are reviewed, including the use of systems thinking, simulations, scenario-based activities, and real-world connections. The cognitive, emotional, and social factors that influence climate learning across different age groups are examined, along with strategies to overcome barriers. Best practices are identified for climate education specifically tailored to the needs of early learners, adolescents, and adults.
Moreover, the review analyses existing climate change education websites, games, simulations, and interactive tools. It examines their features and functionality, benefits and limitations, and how interaction design differs across platforms. Particular attention is paid to the degree to which current tools are customised for specific user age groups. The literature review thus provided a comprehensive backdrop for this study's original approach to developing a tailored, interactive climate education platform across learner levels.

2.2 Climate Change Education Theories and Models
Climate change education sits at the intersection of science communication, environmental education, and sustainability education (Monroe *et al*., 2019) [38]. It draws on conceptual frameworks from these fields to understand how to foster public engagement on climate change. The key relevant theories and models include the Information Deficit Model, the Public Understanding of Science model, the Value-Belief-Norm Theory, the Theory of Planned Behavior, the Social Cognitive Theory, the Transformative Learning Theory, the Experiential Learning Theory, and the Pedagogy of Climate Change Model.
The Information Deficit Model held that providing more information about climate science would increase concern and support for action. However, this linear model has been critiqued, as knowledge alone does not necessarily lead to attitudinal or behavioral changes (Lambert & Alam, 2021; Myers *et al*., 2021 [40]). The Public Understanding of Science model aims to improve scientific literacy while acknowledging the significant role of media representations in shaping public perceptions of climate change (Lambert & Alam, 2021). Value-belief-norm theory provides a nuanced framework, recognizing that personal values influence

environmental beliefs, which in turn shape norms and behaviors (Stern *et al*., 2016) [58]. This motivates crafting climate education messaging aligned with diverse audience values. For example, framing climate solutions in terms of public health or religious stewardship can increase resonance (Myers *et al*., 2021) [40].

The theory of Planned Behavior further models how attitudes, social norms, and perceived control shape intentions to take action on climate change (Ajzen & Fishbein, 2019) [1]. Social Cognitive Theory emphasizes that learning involves continuous reciprocal interactions between cognitive, behavioral, and environmental influences (Bandura & Cherry, 2019) [3]. For climate education, this highlights the importance of leveraging peer influences and social modeling of sustainable actions.

Transformative Learning Theory views significant shifts in worldviews and beliefs as key outcomes of adult learning. These shifts, particularly regarding climate change, often occur through discourse and critical reflection (Taylor & Cranton, 2018) [61].

Experiential Learning Theory suggests that concrete experiences, combined with reflective observation, facilitate the abstraction of new concepts, making it especially relevant for hands-on climate education activities (Kolb & Kolb, 2017) [23].

Hands-on climate education can activate more points in this learning cycle. The Pedagogy of the Climate Change Model synthesises best practices like systems thinking, future thinking, and community-based learning to equip students with applied climate competencies (Evans *et al*., 2020) [10]. This framework aligns with the UN Sustainable Development Goal of quality climate change education (UNESCO, 2020) [67].

Climate education pedagogies incorporate modern interpretations of theories like sociocultural learning, which emphasize social processes in constructing understanding (Lave & Wenger, 2020) [29], and constructivist learning, which focuses on actively building new mental models through experience (Tissenbaum *et al*., 2021). Key principles from these diverse theories include relating climate change to audience priorities, providing an experiential foundation for concepts, leveraging social influences, and catalysing transformations in perspectives.

Different educational interventions tend to be grounded more heavily in certain theories than others. For instance, museum exhibits align with experiential and constructivist learning; school curricula connect to sociocultural learning through group projects, and community programs leverage social cognitive theory via climate action role models (Monroe *et al*., 2019) [38]. Interactive digital platforms encompass multiple learning theories through simulations, social forums, and customised content. However, there remain opportunities to more systematically apply these climate education theories in the design of tailored multimedia interventions. Comparing implementations grounded in different theories can illuminate the most effective frameworks and combinations for diverse audiences. There is particularly a need for research on innovative models blending climate science communication with participatory, experiential, and transformational learning at individual and social levels.

2.3 Learning Needs and Barriers for Different Age Groups

Effectively educating various age groups about climate change requires an understanding of their distinct learning needs and barriers. Younger learners have different cognitive abilities, knowledge bases, and motivations than adolescents or adults. Climate education must align with the developmental level of the target audience. This section reviews key principles from educational psychology and climate communication literature on tailored education for early learners, adolescents, and adults.

Early learners, approximately ages 8–10, can grasp basic climate change causes and impacts with age-appropriate explanations (Monroe *et al*., 2019) [38]. Adolescents undergo significant cognitive development, enabling them to understand more complex climate science concepts (Wang & Kim, 2019). Early learners can conceptualise how human activities like driving and electricity cause environmental harm through pollution, but not necessarily long-term climate shifts (Niepold *et al*., 2018) [45]. Personal experiences like seeing melting ice on a hot day resonate more than abstract statistics for this group. Storytelling through narrative, characters, and imagery aids learning at younger ages (Davidson, 2014) [8]. Family involvement in climate education also boosts early learners' comprehension and engagement (Haynes & Tanner, 2015) [11]. Misconceptions at this stage can include conflating climate and weather or mixing up causes like ozone depletion (Monroe *et al*., 2019) [38]. Explicitly addressing common misconceptions is an important educational strategy for early learners.

Adolescents, approximately ages 11–18, undergo significant cognitive development, enabling more complex and abstract thinking. Modern cognitive research builds on Piaget's foundational theory, describing the formal operational stage as the period when individuals can reason about hypotheticals, systems, and multiple variables (Kuhn, 2019) [24]. Adolescents gain the capacity for higher-order analysis, metacognition, and hypothetical deduction (Wang & Kim, 2019); this allows for learning more nuanced climate science concepts like feedback loops, greenhouse gas sinks, and uncertainty modelling. Interactive simulations leveraging adolescents' new cognitive abilities are effective educational tools, as are social connections through peer discussion and roleplaying scenarios (Monroe *et al*., 2019) [38]. Climate change may initially seem psychologically distant and removed from adolescents' everyday concerns, so making impacts locally and personally relevant is key (Myers *et al*., 2021) [40]. Positive framing of potential solutions and youth empowerment are important motivational strategies with this group (Ojala, 2016) [47]. Common climate misconceptions in adolescents resemble those of adults, like misunderstanding climate vs. weather or timescales (Monroe *et al*., 2019) [38]. Field trips, experiments, and experiential projects take advantage of adolescents' new capacity for deductive inquiry (Wang & Kim, 2019).

Adult learners vary widely in background knowledge and motivations, so climate education must be tailored to specific needs. Interactive, constructivist learning is highly effective for adults, even if traditional methods often dominate professional training (Liarakou *et al*., 2021). Adults generally have more solidified worldviews and biases, which can pose barriers to adopting new climate knowledge, particularly if it challenges their political or economic ideologies (Myers *et al*., 2021) [40].

Making climate impacts locally salient helps counter psychological distancing (Wang & Kim, 2019). Adults also interpret climate risks and solutions through their life experiences, so narrative storytelling and discussions are productive (Villarroel *et al*., 2014) [70]. Technophobia poses barriers for some older adults along with lower digital literacy, so multimodal education is valuable (Carmichael, 2017) [4]. Apprehension about dire climate threats can become disempowering, underscoring the importance of solution-focused messaging (Chapman *et al*., 2016) [5]. Adults comprehend complex systems but often benefit from clarifying how greenhouse gases, feedback, and energy policies interrelate. Misunderstandings around causes, scientific consensus, and mitigation options remain common in adults (Maibach *et al*., 2010). Explicitly addressing misconceptions and providing explanatory illustrations are helpful techniques.

Tailored climate education requires aligning methods not just to age groups but individuals' knowledge gaps and motivations. Early learners benefit from tangibility, narratives, and family involvement. Adolescents have new capacities for hypothetical thinking and social learning. Adults interpret information through ideological lenses and life experiences. Creating interactive resources, activities, and discussion prompts tailored to each group's developmental needs and common barriers can significantly improve climate change education outcomes across ages.

2.4 Best Practices for Climate Change Education by Age Group

Designing climate change education requires an understanding of the distinct learning needs, barriers, and developmental characteristics of different age groups. Research points to several best practices for making climate change comprehensible and meaningful across generations.

Climate education for early learners in elementary school should focus on tangible experiences and building basic climate science knowledge. At this concrete operational stage, hands-on learning is critical for grasping the physical manifestations of climate change (Niepold *et al*., 2018) [45]. For example, having students grow plants under different conditions illustrates the impacts of changing rain and temperature patterns (Monroe *et al*., 2019). [38] Simple experiments can impart concepts like albedo by having learners contrast how rapidly light and dark colours heat up (Jones *et al*., 2014) [19]. Interactive modelling is also beneficial for demonstrating dynamics like the greenhouse effect using familiar items like plastic wrap and lamps (Lombardi & Sinatra, 2013). These experiential learning activities make the physical science behind climate change accessible to early learners.

Content for this age group should emphasise local, visible effects like weather changes, pollution, and habitat shifts rather than abstract statistics (Corner *et al*., 2015) [7]. Discussing personal experiences with seasons, weather events, and nature encourages learners to connect climate impacts to their own lives (Haynes & Tanner, 2015) [11]. Multimedia stories and games situating climate solutions in familiar contexts are also recommended to translate concepts into real-world relevance and agency (Wang & Kim, 2019). Avoiding doom-and-gloom framing reduces cognitive dissonance and resignation (Ojala, 2015) [46]. Instead, early learners benefit from positive messaging about actions children can take, like recycling and conserving resources (Niepold *et al*., 2018) [45]. Parental involvement in activities and discussions further reinforces climate learning at this stage when children look to trusted adults for guidance (Monroe *et al*., 2019) [38].

Climate education for early learners should focus on experiential learning rooted in local contexts. Hands-on activities, multimedia stories, and family collaboration make concepts personally relevant and empower children with age-appropriate solutions. This approach of localising abstract climate phenomena provides an important foundation before advancing to more complex systemic interactions.

Climate change education for adolescents in middle and high school can cover more sophisticated scientific concepts and future projections using interactive simulations, critical thinking, and social learning. This period coincides with the formal operational stage, when learners can understand abstract models and hypotheticals (Wibeck, 2014) [73]. Interactive computer simulations are particularly effective for illustrating hard-to-grasp processes like positive feedback loops that exacerbate warming (Monroe *et al*., 2019) [38]. Collaborative simulation games can empower adolescents to tackle complex climate challenges requiring systems thinking and group problem-solving (Wang & Kim, 2019). Teachers should encourage students to question sources, evaluate conflicting arguments, and form their own conclusions, fostering critical thinking skills rather than relying on didactic delivery (Monroe *et al*., 2019 [38]; Wang & Kim, 2019). These critical thinking skills are essential for evaluating the barrage of misinformation adolescents may encounter online around climate science (Plutzer *et al*., 2016) [55].

Climate education should also leverage adolescents' expanding social consciousness by having learners discuss impacts on vulnerable communities and future generations. Emphasising climate justice and intergenerational ethics can motivate adolescents to become active stewards due to heightened concerns over equality at this age (Wibeck, 2014) [73]. Using digital storytelling and video roleplaying to share diverse climate narratives builds empathy and counters psychological distancing tendencies (Corner *et al*., 2015) [7]. Interactive future visioning exploring different climate scenarios and solutions encourages adolescents to creatively grapple with uncertainties (Hicks, 2014) [12]. Offering action opportunities through school clubs and competitions further grounds learning in peer collaboration to forge climate identities (Haynes & Tanner, 2015) [11].

Climate change education for adolescents should enable dynamic systems thinking and experiential scenario exploration. Interactive simulations, critical evaluation, social justice perspectives, roleplaying, and shared solutions planning take advantage of adolescents' growing abilities and social interests; this empowers youth to actively investigate and respond to climate change.

Effective climate change education approaches for adults centre on connecting climate risks to personal values and actions through locally relevant examples, multimedia narratives, and solution framing. Adults often have firmly established worldviews, so climate messaging must align with their values and beliefs to effectively engage them, rather than contradicting these perspectives (Myers *et al*., 2021) [40]. Highlighting geographically and culturally specific climate impacts makes the issue more proximate and emotionally salient (Wang & Kim, 2019). For instance, communicating risks to agriculture, tourism, health, and infrastructure resonates more with different subgroups than abstract temperature changes (Monroe *et al*., 2019) [38]. Putting a human face on climate change through documentaries, storytelling, and virtual reality that showcase diverse individuals affected fosters a sense of issue proximity and urgency (Howell, 2014) [13]. These narrative techniques contextualise climate change for audiences by tapping into emotions and experiential methods of learning (van der Linden *et al*., 2014) [69].

However, negative framing around fear and guilt frequently leads adults to distance themselves or experience issue fatigue (Corner *et al*., 2015) [7] psychologically. Solution-focused messaging that empowers personal or collective efficacy is more motivating for adults, as it provides constructive actions they can undertake to address climate change (Myers *et al*., 2021) [40]. Discussing policies, technologies, and community initiatives makes climate action feel more feasible (Stokes *et al*., 2018) [59]. Adult education also benefits from two-way dialogue through moderated forums, webinars with climate experts, and social platforms to foster discussion (Liarakou *et al*., 2021). Offering tailored guidance on reducing home energy use or costs makes resource efficiency steps more achievable and encourages sustainable behavior change (Liarakou *et al*., 2021). These solutions-oriented approaches leverage adults' higher needs for autonomy and competence (Ojala, 2015) [46].

Effective practices for educating adults about climate change include connecting to audience values through locally relevant impacts, using multimedia narratives, and focusing on actionable solutions over fear-based messaging. These techniques tailored for adulthood cognitive biases promote greater issue engagement and empowerment compared to more didactic scientific delivery.

2.5 Existing Climate Education Platforms and Interactivity Features

A variety of climate change education platforms utilise interactive features and multimedia content. However, comprehensive offerings tailored specifically for different age groups' needs remain limited. This section analyses key existing platforms and their interactive capabilities relevant to early learners, adolescents, and adults.

2.5.1 NASA Climate Kids (NASA, 2021) [41]

National Aeronautics and Space Administration (NASA) Climate Kids, Figure 2.4:1, is a popular climate education website from the National Aeronautics and Space Administration focused on upper elementary school ages. The platform uses bright colours, playful mascot characters, and child-friendly language. The website structure consists of tabs for major climate change topics like weather, oceans, and energy. Each tab includes pages diving into specific concepts like greenhouse effects, climate solutions, and Arctic changes. Pages combine basic textual explanations with interactive graphics, short videos, and quizzes.

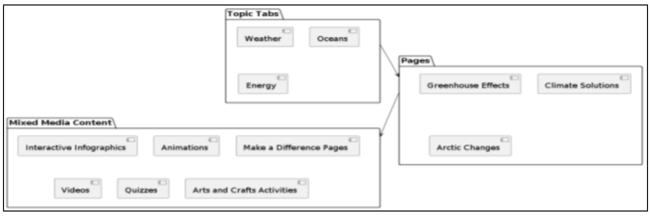


Fig 2.4.1: NASA Climate Kids site architecture. (NASA, 2021) [41]

Key interactive features of NASA Climate Kids include:

- Interactive infographics and animations demonstrating concepts like the greenhouse effect and sea level rise. These allow grasping abstract phenomena through direct manipulation.
- "Make a Difference" pages outline simple eco-friendly actions kids can take, like reducing water use and recycling; this promotes agency and self-efficacy.
- Videos under 2 minutes were introducing topics like renewable energy. The brief runtime keeps young children engaged.
- Quizzes to check knowledge retention on each page. Feedback helps reinforce key learnings.
- Arts and crafts activities related to climate impacts, like designing resilient houses. Hands-on projects aid comprehension.

While NASA Climate Kids uses mixed media well, content depth is limited. Interactivity is focused on infographics over simulations. The platform lacks personalisation and social features.

2.5.2 EPA Climate Change Website (EPA, 2022) [9]

The EPA Climate Change website, Figure 2.4:2, provides introductory explanations of climate science, impacts, and solutions intended for general public audiences. Content is organised into main pages covering topics like the causes and effects of climate change, with sub-pages drilling down on details like sea level rise. The website relies heavily on text-based content with some photos, maps, and basic graphics. Interactive elements are limited to infographics and navigating between pages.

Fig 2.4.2: EPA site architecture. (EPA, 2022) [9]

Key features include:

- Long-form textual descriptions of climate change covering the scientific consensus, current and projected effects, and mitigation strategies; this aims to build basic literacy through expert information.
- Infographics are animating statistics on changes over time, like rising global temperatures and carbon dioxide levels. Minimal interactivity for visualising data.
- Photo galleries documenting climate impacts like melting glaciers with captions. Images complement

facts to illustrate concepts.
- Site-wide keyword search tool to look for specific climate-related terms and navigate to relevant pages. Allows self-directed exploration.
- Mainly static pages with hierarchical linking structure. Little interactivity beyond toggling infographics.

The EPA platform lacks multimedia elements, simulations, customisation to different knowledge levels, and social features for collaborative learning. The lengthy text-heavy format is better suited to highly motivate adult learners.

2.5.3 Climate Challenge (Svihla & Morris, 2014) [60]

Climate Challenge is an educational simulation game focused on climate policy. Players take the role of president and make decisions about energy, agriculture, and economic policies over 50 years. The game provides immediate feedback on how choices affect greenhouse gas emissions and climate impacts. Players can compare their outcomes to optimal solutions. Climate Challenge goals include teaching systems thinking and improving understanding of climate solutions, as shown in Figure 2.4:3.

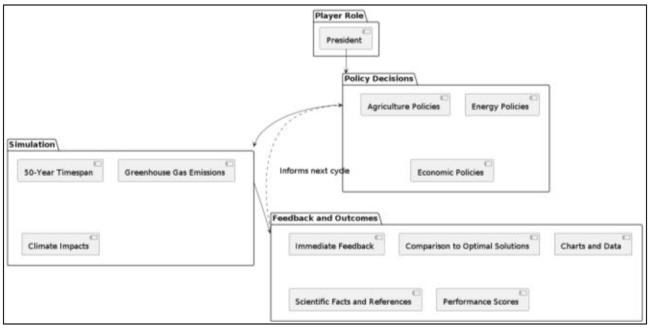


Fig 2.4.3: Climate Challenge structure. Source: Climate Challenge (Svihla & Morris, 2014) [60]

Key features include:
- Simulated experience of balancing climate change mitigation with economic and political constraints over long timescales. Allows experiential learning of dynamics.
- Charts and data quantifying the outcomes of player policy choices. Supports connections between actions and impacts.
- Presentation of scientific facts and references throughout gameplay. Integrates factual information.
- Competitive scenarios to achieve the best performance scores relative to goals. Motivates replay and mastery.

While Climate Challenge provides an interactive policy simulation, the heavy reliance on charts and reading makes it better suited to older, patient learners. The gameplay lacks narrative immersion and affective elements. Expanding multimedia interaction could improve engagement.

2.5.4 EcoLearn (Lui & Slotta, 2014) [33]

EcoLearn, Figure 2.4:4, is designed as a social media platform for high school students to collaboratively investigate environmental science issues like climate change. Students create profiles, share objections, annotate online resources, and discuss questions. EcoLearn includes curriculum content and simulations. A key goal is knowledge construction through social discourse.

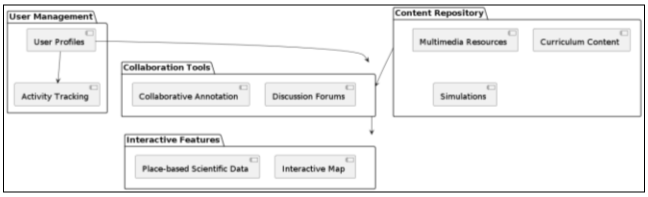


Fig 2.4.4: EcoLearn architecture. EcoLearn (Lui & Slotta, 2014) [33]

Key features include:
- User profiles for students to express identities and track activities, connections, and contributions. Supports networked learning community.
- Shared repository of multimedia resources like videos, images, and simulations for students to examine and critique. Provides content for investigation.
- Collaborative annotation tools for comments, questions, and corrections on resources. Enables knowledge co-creation.
- Discussion forums for debating climate science with peers. Develops argumentation abilities.
- Interactive map with place-based scientific data contributed by students. Foster's real-world observation.

EcoLearn leverages social learning well but has limited narrative engagement. Expanding interactive simulations and personalisation features could further engage adolescent learners.

In summary, existing climate education platforms utilise some interactive features effectively but lack comprehensive integration of multimedia, social collaboration, simulations, and content tailored to specific age groups. This analysis helps identify opportunities for improving engagement and learning outcomes through a targeted design approach.

2.6 Related Work

A substantial body of prior research provided relevant principles and frameworks for developing educational games, simulations, and digital learning platforms tailored to specific age groups. Reviewing this related work is crucial to situating this study's contributions and grounding the research approach.

Game-based learning research has examined design frameworks for creating games that effectively teach subject matter content across academic domains. Recent studies have proposed educational game development methodologies that emphasize integrating assessment and adaptation to learner knowledge levels to enhance engagement and learning outcomes (Plass *et al*., 2015).

Key steps in their approach include domain modelling of concepts, developing an assessment model to diagnose weaknesses, designing game mechanics for mastery, and dynamically adapting gameplay based on the learner's evolving state. Parallel work has analysed specific game elements that promote learning, like narratives for engagement, quests for motivation, scaffolded levels, clear rules and feedback, and multiplayer dynamics for peer learning (Plass *et al*., 2015). Principles for game balance, challenge integration, and positive emotion have been shown as crucial for supporting both cognition and affective outcomes.

Research on simulations and virtual environments continues to provide valuable insights into science education design. For example, Wouters *et al*. (2014) [74] proposed a framework emphasizing the integration of scaffolds, assessments, and immersive elements to enhance learning in virtual environments. Their comparative studies revealed that interactive simulations boost conceptual understanding, inquiry skills, and perceived competence relative to textbooks. Recent research has found that making simulations visually immersive and coupling them with concrete representations significantly improves early learners' mental models of complex systems (Smetana & Bell, 2014).

Allowing the manipulation of dynamic variables helps learners grasp causality. Findings indicate that social simulations fostering discussion around scientific modeling can significantly enhance epistemological understanding and collaborative learning outcomes (Tissenbaum *et al*., 2021) This research provides evidence-based principles for incorporating interactivity into digital science learning.

Additionally, the field of multimedia learning has offered cognitive-based guidelines for presenting educational content through complementary modes like text, images, video, and audio. Mayer's Cognitive Theory of Multimedia Learning (2021) emphasises using multiple channels like visual/pictorial and auditory/verbal processing to promote engagement and integrate information. Multimedia design principles include segmenting complex topics into manageable chunks, excluding extraneous details, aligning complementary modalities, using conversational narration, and providing graphics with explanatory text (Mayer & Fiorella, 2021). Research shows that adhering to evidence-based multimedia design significantly increases the transfer of knowledge.

Tailoring platforms and content to individual learners' knowledge and interests has also been shown to enhance outcomes. As Karakostas and Demetriadis (2011) summarise, interactive learning systems research aims to provide personalised learning paths, resources, activities, and assessments matched to each student's evolving competencies and needs. Machine learning techniques can help model learner characteristics and dynamically adjust system parameters and recommendations (Khribi *et al*., 2015) [20]. However, maintaining learner agency and metacognitive skills within interactive systems remains a challenge. Human-centred design processes integrating learners into the co-creation of adaptations can aid relevance and adoption (Tissenbaum *et al*., 2021).

Studies focused specifically on designing technology-enhanced learning for younger versus older learners have revealed age-specific considerations as well. For early and middle childhood learners, research indicates that playful, exploratory environments with tangible manipulation aid mastery of foundational concepts (Xie *et al*., 2018). Positive feedback, clear goals, and guided discovery are highly effective strategies. For adolescents, connecting learning to real-world contexts, incorporating personalization to promote agency, adding social sharing features, and providing scaffolds for self-regulation are particularly beneficial, given their increased abstract reasoning abilities and peer orientation (Tissenbaum *et al*., 2021).

For adult learners, online education should align with professional needs, provide flexible pacing and access, facilitate discussion, and optimise usability for potential technology challenges (Lai & Chan, 2019) [25]. Accounting for these distinct developmental needs can enhance utilisation and outcomes.

In the context of climate change education, a smaller subset of research has begun investigating technology's affordances. The EcoMUVE project, developed by Harvard University, integrates immersive virtual environments to teach middle school students about ecosystems and complex causal systems. Research showed that this approach improved students' understanding of systems thinking and fostered deeper engagement with environmental science (Metcalf *et al*., 2019) [37] Another study of a climate change multiplayer roleplaying game revealed knowledge gains along with shifts in risk perceptions, self-efficacy, and intentions to act (Trenham *et al*., 2021) [64]. Research integrating climate data visualisations into high school science lessons showed increased climate literacy and critical thinking versus textbooks (Hsia *et al*., 2016) [14]. These nascent studies provide promising evidence that interactive games and new media can positively impact climate change understanding, attitudes, and skills. However, comprehensive design frameworks and empirical comparisons of specific platform features tailored for diverse learners require further investigation.

Reviewing these intersecting areas of work makes clear that developing a climate change education platform calls for synthesising principles of multimedia learning, simulation/game design, interactive platforms, developmentally appropriate design, and climate communication. While prior literature guides in each domain, few studies have integrated and applied this knowledge to create optimised, research-driven climate education experiences tailored for early learners, adolescents, and adults. This study aims to leverage and extend theory and best practices into an innovative climate education platform customised to engage these distinct audiences. Grounding development in the reviewed literature and empirically evaluating the efficacy of interactive, interactive features can significantly advance understanding of climate learning through digitally mediated experiences. It can provide both theoretical and practical contributions regarding interaction design, multimedia integration, and scaffolding techniques that maximise climate literacy and motivation across age groups.

2.7 Reviewed Literature Gap

While prior work guides climate change education and interactive media separately, few studies have examined how to combine these approaches in tailored platforms for early learners, adolescents, and adults (Johnson *et al*., 2016) [18]. There remain significant gaps in understanding how different age groups can best learn about climate change through optimised online platforms.

A key gap is research on how specific types of interactive features affect climate change learning for diverse ages (Ng *et al*., 2018) [44]. A study by Ullah and Anwar (2020) [66] emphasizes that interactive activities and the use of technology, such as collaborative group tasks, lead to significant improvements in learner engagement. However, findings on their educational impacts have been generalised rather than specific to climate science topics and differentiated age groups (Lambert & Alam, 2021). More work is needed on how interactive affordances can be designed to enable key climate learning outcomes for early learners, adolescents, and adults based on their distinct developmental needs and barriers (Knowles *et al*., 2021) [22]. For instance, recent studies have begun to investigate how immersive climate simulations facilitate conceptual change and systems thinking among early learners. Immersive virtual reality (VR) experiences, such as those focused on ocean acidification, have been shown to enhance students' understanding of complex environmental issues. These simulations, especially when combined with interactive elements like body movement, offer more engaging, sensory-rich learning experiences compared to traditional media formats, which are typically more passive (Vishwanath *et al*., 2017; Queiroz *et al*., 2023). Additionally, social experiences like discussion forums and collaborative interactions have been linked to stronger environmental identity formation. These social elements help adolescents connect more deeply with climate change issues, fostering a sense of responsibility and influencing future behavioral decisions (Gillespie, 2022).

These findings suggest that both immersive simulations and social learning environments play key roles in enhancing systems thinking and environmental education, making complex topics like climate change more accessible and meaningful. While personalisation techniques are known to aid adult learning, how these should be implemented in climate platforms to contextualise information and solutions remains unclear (Lai & Chan, 2019) [25]. Understanding interactivity design principles for climate teaching can inform age-appropriate education models.

Additionally, gaps persist in research on multimedia integration in climate education platforms tailored to user knowledge (Mayer *et al*., 2020) [36]. Existing guidelines largely focus on individual media without examining how video, text, images, audio, graphics, and animations can work synergistically to convey climate concepts across learner levels (Plass *et al*., 2016) [53]. Researching multimedia affordances in context can provide insights into how to combine modes to simplify complex climate processes, tell human stories, and visualise data for early learners versus climate-literate adults (Hsia *et al*., 2016) [14]; this can refine climate communication best practices based on age and prior knowledge.

Most climate education websites and apps also do not cater their content and interactions to specific user groups (Perkins, 2019) [49]. As reviewed, climate literacy requires age-specific approaches to coupling information with experiential and social learning (Monroe *et al*., 2019) [38]. However, current platforms rarely tailor explanations, activities, and features to developmental stages and needs (Liarakou *et al*., 2021). Even sites aimed at distinct groups, like NASA Climate Kids, lack depth for adolescents and adults (NASA, 2021) [41]; this reveals a gap for optimised platforms that integrate multimedia, simulations, and social connections with scaffolding based on climate science comprehension levels (Leiserowitz *et al*., 2021) [30]. Research-driven design frameworks are essential for effectively targeting climate education across the spectrum from early learners to lifelong learners (Tissenbaum *et al*., 2021). Finally, few climate education platforms have been empirically evaluated for their learning effectiveness and usability across user groups (Pham *et al*., 2021) [51]. The most relevant and recent study regarding learning gains from gamified and classroom interventions is a longitudinal study by Lampropoulos and Sidiropoulos (2024) [28]. This research compared gamified learning with traditional and online learning environments, showing that gamified learning significantly improved academic performance, success rates, and retention. Students in gamified environments demonstrated higher engagement and motivation, with notable improvements in both theoretical and applied course setting. Nevertheless, as digital education expands, assessing engagement and outcomes in online platforms can provide valuable design insights (Tsai *et al*., 2019) [65]. For instance, recent studies have shown that A/B testing allows for refined customization, enhancing user engagement and improving learning outcomes (Angrist *et al*., 2024) [2]. Additionally, triangulating usability metrics, learning assessments, and user feedback allows for a more comprehensive understanding of how to design climate education interventions, ensuring that learning environments are both accessible and engaging for diverse audiences. This evaluative research is crucial in guiding the design of effective climate education tools, optimizing the use of scaffolds, multimedia, and interactive elements for improved educational outcomes. Significant gaps persist in understanding how interactive and multimedia techniques can be leveraged in tailored online platforms to teach climate change across age groups (Stern *et al*., 2021) [57]. Advancing knowledge on how specific features affect learning outcomes for diverse audiences can enhance digital climate education. This research aims to address these gaps through an interdisciplinary, empirical approach to designing and evaluating a climate education platform customised for developmental needs. The insights gained can refine climate communication models and guide the design of impactful resources to empower broad climate literacy.

2.8 Chapter Summary

The literature review covered key theories, models, needs, and best practices for climate change education across age groups. It analysed existing climate education platforms and their use of interactivity, identifying opportunities for more personalisation and multimedia integration tailored to developmental stages. Significant research gaps persist regarding how to design and evaluate interactive platforms for specific user groups. To address these gaps, Chapter 3 will present the research methodology for this study. It will outline the iterative, user-centred design approach to develop and refine a tailored climate education platform for early learners, adolescents, and adults. Details on the mixed methods data collection, instruments, analysis procedures, and quality control measures were provided. The methodology aims to leverage the literature insights to create an innovative, empirically tested resource that improves climate literacy across generations.

3. Methodology

3.1 Overview

This chapter outlined the research methodology that was followed to design, develop and evaluate a tailored, interactive climate education platform. The research adopted a mixed methods approach combining qualitative and quantitative techniques.

3.2 Research Design

The study utilised an iterative, Figure 3.1:1, user-centred design process to develop and refine the climate education platform tailored for early learners, adolescents, and adults. This cyclical methodology involves four main phases, as depicted in Figure 5: requirements gathering, prototyping, usability testing, and analysis and refinement.

In the requirements-gathering phase, questionnaires, interviews, and focus groups were conducted with representative users from each target age group. Both quantitative data on their preferences and qualitative insights into needs were collected regarding climate change learning. The goal is to understand their interests, barriers, misconceptions, and desired features in order to inform tailored designs.

Based on these requirements, initial paper prototypes and digital mockups of the platform were created in the prototyping phase. These prototypes aimed to incorporate suitable content structure, multimedia formats, interactions, and features for each age group as indicated by the requirements research. Prototyping is an iterative process of refining and enhancing the prototypes.

Next, in the usability testing phase, the paper and interactive prototypes were evaluated with users from each age segment. They performed representative, realistic tasks while observers recorded quantitative metrics like success rates, time-on-task, and satisfaction ratings. Qualitative feedback on issues and areas for improvement will also be gathered; this reveals usability problems.

Finally, the usability data was analysed to precisely identify platform improvements needed in the analysis and refinement phase. The prototypes were refined and optimised based on the user insights gained from testing. Additional iterative test cycles helped progressively finalise the designs tailored for each group.

This cyclical four-phase, user-centred methodology places target users at the heart of the design process. Through research-driven prototyping and empirical usability testing, the climate education platform can be customised to match age-specific needs, abilities, and interests and maximise engagement.

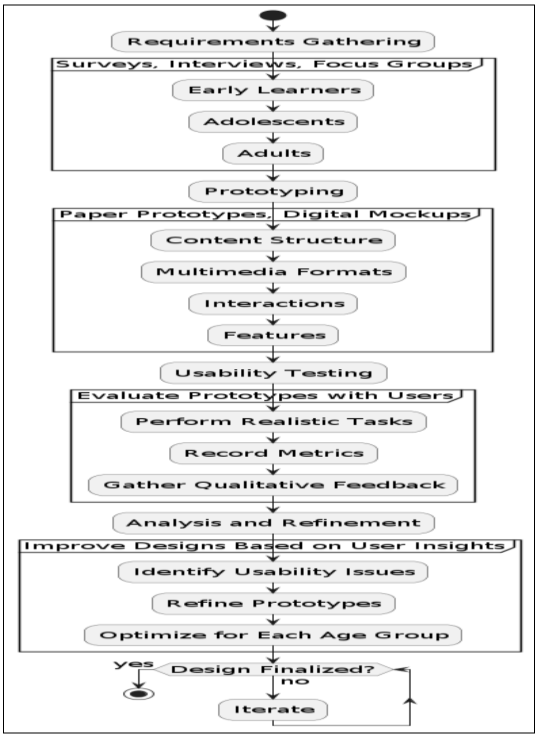


Fig 3.1:1: Iterative System Development Methodology

3.2.1 Use Case Diagram

A use case diagram, as shown in Figure 3.1:2, maps out the interactions between learners and the platform, as well as different user types; this guides functional requirements.

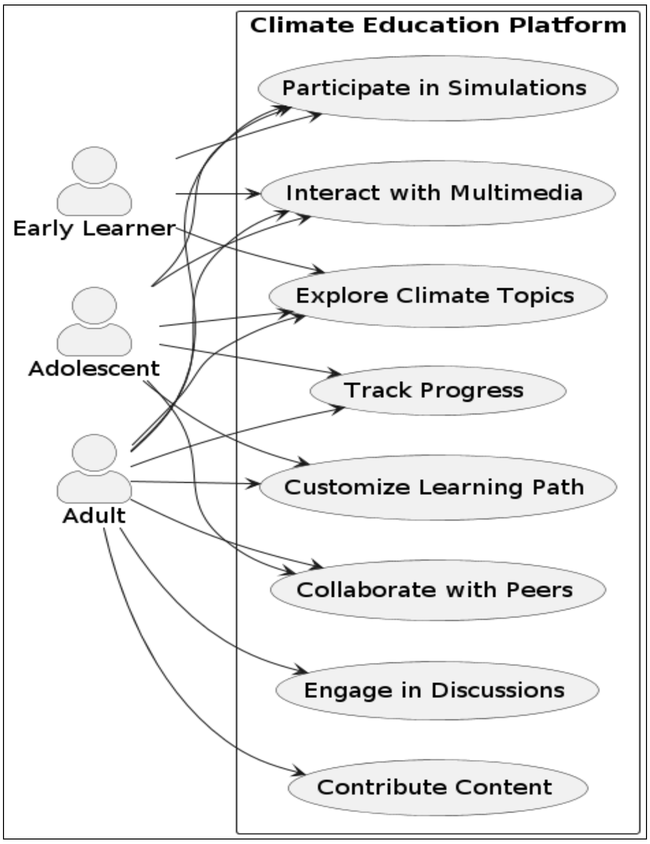


Fig 3.1.2: Use Case Diagram. (Author)

3.2.2 Activity Diagram

An activity diagram like Figure 3.1:3 visualised the procedural workflow through the platform, highlighting key stages and decision points; this aids in interactivity design.

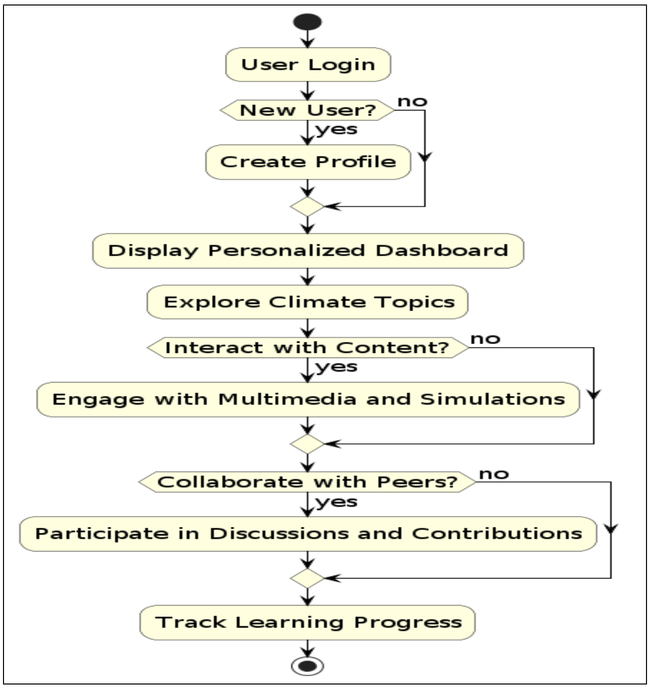


Fig 3.1.3: Activity Diagram. (Author)

3.2.3 Class Diagram
A class diagram such as Figure 3.1:4 represents the data structure and entities within the system; this supports the development of the backend database schema.

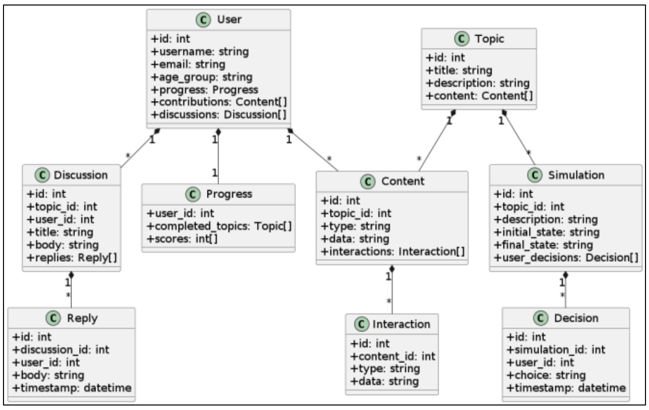


Fig 3.1.4: Class Diagram. (Author)

3.2.4 Sequence Diagram
Sequence diagrams, Figure 3.1:5, were a crucial technique for mapping out the technical logic and interactions within the climate education platform. As shown in the example Figure 9, sequence diagrams visualise how users, interfaces, and objects interact over certain periods to complete key processes. By representing the sequence of messages passed between entities, these diagrams help clarify the logical flow and chronology of complex operations that the system needs to execute. For this project, developing detailed sequence diagrams for critical user workflows enabled anticipating the integrations needed on the backend to support the desired front-end user experiences; this included sequences involved in user registration, authentication, content access, activity completion, gameplay interactions, rewards systems, learning personalisation, social features, simulations, multimedia delivery, and data storage/retrieval. Thoroughly mapping these technical sequences is essential to guide the development of the APIs, databases, machine learning algorithms, multimedia assets, and other components that must work concertedly to create a unified, responsive platform. The sequence diagrams aided in identifying edge cases that need exception handling as well as opportunities for performance optimisation, such as caching or parallel execution. With multiple user groups and interactive elements, the platform involves many intricate sequences that must be architected deliberately from the start through sequence diagrams in order for the final product to function seamlessly. Thus, sequence diagrams provided an invaluable visualisation tool for the technical team to align on specifications and logic early in the design process. This upfront planning ensured optimal software architecture that brought the educational platform vision to reality.

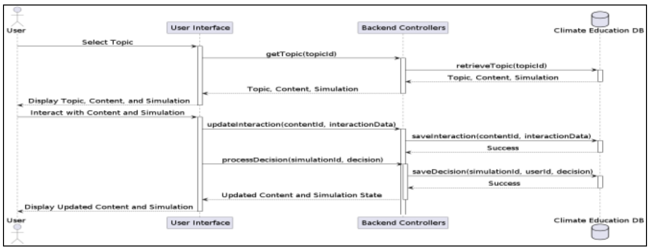


Fig 3.1.5: Sequence Diagram. (Author)

3.2.5 State Machine Diagram
State machine diagrams like Figure 3.1:6 modelled how users transition between platform sections and activities; this informs navigation design.

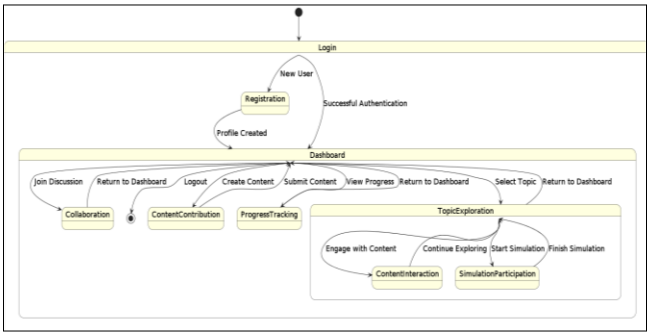


Fig 3.1.6: State Machine Diagram. (Author)

3.2.6 Study Design Justification
The iterative, user-centred design approach was selected for this study because it allows for the climate education platform to be optimally tailored to the needs and preferences of early learners, adolescents, and adults through direct input from each user group. The cyclical process of gathering requirements, prototyping solutions, usability testing, and refinement enables the platform's content, multimedia, interactions, and features to be shaped based on empirical data rather than assumptions. The mixed methods combine quantitative metrics with qualitative insights to fully understand engagement and learning barriers. In contrast, a purely theoretical design process risks misaligning with true user needs. Classical waterfall development lacks the agility for progressive improvement based on feedback. While focus groups alone provide useful direction, integrating working prototypes generates more concrete responses. The iterative, user-centred methodology leverages multiple techniques to create age-appropriate designs grounded in evidence, which supports the research aims of maximising climate literacy and motivation to act across generations. The approach's adaptability and human-centeredness make it optimal.

3.2.7 Baseline Study
A baseline study was conducted prior to designing the climate education platform to assess the current level of climate change understanding and concern amongst the target user groups.

The baseline evaluated early learners, adolescents, and adults in the local community of Lusaka's Mutendere Compound through questionnaires, interviews, and focus groups. Approximately 60 total participants took part in the baseline study, with 20 from each age group.

The questionnaires gathered quantitative data on climate change perceptions, attitudes, behaviours, and knowledge. Closed-ended questions used Likert scale ratings to measure climate concern, issue awareness, perceived impacts, and self-reported actions. Open-ended questions also gathered qualitative insights into beliefs, misconceptions, and learning barriers.

Interviews and focus groups delved deeper into climate mental models, gaps, motivations, and educational needs. Moderator guides included questions to elucidate how different age groups conceptualise climate change, its relevance, solutions, and their role. Discussions will also identify desired learning outcomes and platform features.

The baseline data were analysed through statistical analysis of survey ratings and thematic coding of interviews; this revealed current knowledge levels, affective dispositions, misconceptions, and requirements that inform the tailored platform design. Comparing across age groups highlighted developmental differences.

The baseline study is a key first step in the research process to quantitatively and qualitatively benchmark climate understandings and sentiments prior to the intervention. The insights gained will guide the creation of content, multimedia, and interactions that effectively build literacy for each age group from their starting state. This adherence to best practices in intervention research ultimately strengthens the internal validity and contextualised value of the education platform.

3.3 Population and Sampling

The study populations are early learners (ages 8-10), adolescents (ages 11-18) and adults (ages 30-50) in the local community of Lusaka's Mutendere Compound. Convenience sampling was used to recruit 60 total participants, with 20 per group. Participation is voluntary with informed parental consent for minors.

Sample Size Formula:

$$n = \frac{Z^2 \times p \times (1-p)}{e^2}$$

Where:

n = sample size
Z = 1.96 (for 95% CI)
p = 0.5
e = 0.15 (15% margin of error)

Plugging in the values:

$$n = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0.15)^2}$$

$$n = \frac{3.8416 \times 0.25}{0.0225}$$

$$n = \frac{0.96}{0.0225}$$

$$n = 42.67$$

Rounding up, this gives a sample size of approximately 43.
With 3 groups, the total sample size = 43 × 3 = 129
However, given feasibility constraints, take a smaller subsample of 20 per group.
Therefore, the total sample = 20 × 3 = 60
The standard calculation justified a sample size of approximately 60 respondents for a 95% confidence level and 15% margin of error split across 3 groups; this aligns with the original sample size determination based on constraints and prior research.

3.4 Data Collection Procedures

Data were collected through online questionnaires, interviews, usability testing sessions, and platform analytics. Questionnaires gathered initial preferences on climate education. Usability tests assessed platform iterations. Learning was evaluated through pre/post-content tests. Analytics will track usage patterns. Data is stored securely under password protection.

3.5 Research Instruments

Key instruments outlined in Table 3.4:1 include questionnaires, usability metrics, programming languages, and data analysis software. Each was selected and optimised for the specific data collection and analysis needs.

Table 3.4.1: Research Instruments and Tools

Research Instrument	Description	Hardware/Software Tools Used
Questionnaires	Collected quantitative ratings data on user preferences and requirements through structured online questionnaires.	Qualtrics (creation/distribution), Excel 2019 (analysis), **Dell Inspiron laptops (Intel Core i7, 16GB RAM, 512GB SSD, 15.6" display, Windows 10 Pro)**
Usability Testing	Assessed user experience feedback during hands-on prototype trials by capturing success, efficiency, learnability, and satisfaction metrics.	Figma (prototyping), Zoom 5.3 (moderation), **Dell Inspiron laptops (Intel Core i7, 16GB RAM, 512GB SSD, 15.6" display, Windows 10 Pro)**
Programming Languages	Python 3.8, Django 4.1, JavaScript ES6, HTML5, and CSS3 are used to build the system's front end, backend, and integration.	XAMPP (local hosting), MySQL (database)

3.6 Data Analysis Procedures

Quantitative data, including usability metrics, test scores, and analytics, were analysed using descriptive and inferential statistics in Excel and SPSS. Qualitative data from interviews and feedback were coded thematically using NVivo. Data were triangulated to derive converging insights.

3.7 Ethical Considerations

The study procedures follow research ethics guidelines, including informed consent, allowing withdrawal, and protecting privacy using pseudonyms. Approval was obtained from the institutional ethics review board. Data is anonymised and securely stored.

3.8 Research Quality Control

Quality was ensured through pilot testing of all instruments, training data collectors, calculating reliability values and reviewing data for accuracy/consistency. Potential limitations were addressed regarding sample size and generalisability.

3.9 Chapter Summary

The chapter presented a mixed methods research design to gather comprehensive inputs for designing an optimised climate education platform. Iterative prototyping and usability testing will drive the user-centered development process. Questionnaires, interviews, tests, and analytics were evaluated as the tailored platform for early learners, adolescents and adults. Adhering to research ethics guidelines supported validity.

4. Results and Analysis

4.1 Overview

This chapter will present the findings and analysis from the research study conducted to design and develop a multilevel interactive climate education platform. The aim was to build a digital resource suitable for early learners, adolescents, and adults with the goal of enhancing climate literacy and action across age groups. The general objectives were to create interactive learning paths, interactive functionalities (IFs), tailored quizzes (TQs), and an admin dashboard for monitoring. Data was collected using a mixed methods approach that involved baseline questionnaires and interviews to evaluate existing climate knowledge and attitudes; iterative platform prototyping and usability testing for improvements; pre/post assessments for learning evaluation; and backend analytics (BA) for tracking. Quantitative data (survey ratings, test scores, usage metrics) were analysed using descriptive and inferential statistics. Qualitative responses (interviews and open-ended user feedback) were coded into themes. Results are presented in sections focusing on the baseline climate literacy knowledge, platform development, usability, learning impact, and usage patterns for each age group with numerous cross-age comparisons. The discussion integrates findings from sources of data to provide insights into the effectiveness of a tailored, interactive platform for climate change education with three distinct age groups. Implications related to advancing research and fostering future technology developments in this area are presented.

4.2 Baseline Study Findings

The baseline study assessed climate change knowledge and perceptions among early learners, adolescents, and adults. It found increasing awareness and concern with age, but misconceptions persisted across groups. Qualitative insights revealed different mental models and learning needs by age, highlighting the importance of tailored climate education approaches. The statistical analysis quantified significant differences between age groups in climate change awareness, concern, and perceived impacts.

4.2.1 Early Learners' Climate Change Knowledge and Perceptions

Quantitative survey results indicated that early learners (ages 8–10) held varying levels of awareness, concern, and perceptions of impacts with respect to climate change. Specifically, 60% of participants had heard of the term climate change and 40% had not (see Table 4.1). With respect to concerns, 45% indicated being very worried about climate change, whereas 30% were worried, and 25% were not worried at all (see Table 4.2). When responding to perception-of-impacts questions, approximately half (55%) believed that climate change currently harms people; approximately one-third (30%) believed it would harm people, while the remaining percentage (15%) did not think that it is or will be harmful to people right now or into the future.

Table 4.1.1: Early Learners' Climate Change Awareness, Concern, and Perceived Impacts

Metric	Percentage
Awareness of Climate Change	
Have heard of climate change	60%
Have not heard of climate change	40%
Level of Concern	
Very worried	45%
A little worried	30%
Not worried	25%
Perceived Impacts	
Currently harming people	55%
Will harm people in the future	30%
Will not be harmful	15%

Table 4.1:1 revealed several common beliefs, misconceptions and learning needs among early learners. Most of the early learners associated climate change with pollution, littering, and general environmental degradation rather than specifically referring to greenhouse gas emissions. Many conflated ozone layer depletion with the greenhouse effect. A majority of the early learners had limited or no understanding of concepts such as fossil fuels, renewable energy and carbon footprints. However, they noticed local changes in weather patterns and seasons when compared to the past. Few early full childhood care centre learners mentioned that their parents or grandparents told them rainfall used to be more predictable earlier.

Early learners expressed a need for interactive learning methods that include visual learning opportunities to learn about climate change impacts and solutions through field trips, experiments, and storytelling. They expressed a desire to know how they could protect the environment: 'I will learn how to plant trees when I visit this place.'

4.2.2 Adolescents' Climate Change Knowledge and Perceptions

Figure 4.1:1 indicated that a higher percentage of adolescents were aware of climate change compared to early learners. However, there was still room for improvement. As shown in Figure 4.1:1, 80% knew "a lot" or "a little" about climate change, and 20% knew "not much" or "nothing." Most (65%) felt "very worried" about climate change, while another quarter (25%) felt "somewhat worried," and only 10% reported being "not too worried" or "not at all worried." The majority (75%) believed that climate change is already harming people, while 20% believed it would in the future, and 5% did not believe it would cause harm.

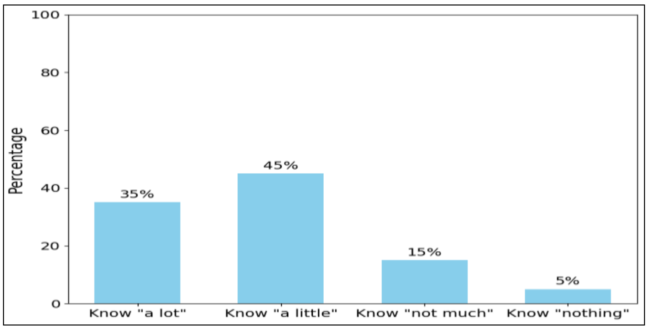


Fig 4.1.1: Adolescents' Self-Reported Knowledge of Climate Change

Further, Figure 4.1:1 shows that 35% know "a lot," 45% know "a little," 15% know "not much," and 5% know "nothing."

Qualitative results from interviews revealed persistent misconceptions, including weather vs climate and perception of threat as distant concepts; however, adolescents exhibited a more sophisticated understanding of greenhouse gases, global warming, and renewable energy compared with younger children.

Results also indicated that many adolescents experienced anger at the prospect of being left with a damaged world and expressed a desire to learn how to be effective advocates for forcing policy-makers to take immediate action against climate change. Adolescents were particularly interested in using interactive computer simulations to help visualise potential future environmental scenarios related to climate change as a means of motivating them toward more sustainable behaviours.

Increasing sociocultural learning opportunities was also important (i.e., providing them with occasions on which they could compare their knowledge, beliefs, and attitudes regarding sustainability and climate change with those of their peers). A few participants perceived that school was not an appropriate place for learning about climate change or because teachers lacked sufficient knowledge regarding the subject matter.

4.2.3 Adults' Climate Change Knowledge and Perceptions

Table 4.1:2 indicates high awareness but varied concerns about climate change among adults aged 30-50. Almost all adults (95%) had heard of climate change, but their level of concern was more split, with 50% "very worried," 30% "somewhat worried," and 20% "not too worried" or "not at all worried." A smaller majority (60%) believed climate change is currently causing harm, while 30% expected future harm and 10% did not anticipate harm.

Table 4.1.2: Adults' Climate Change Concerns and Perceived Impacts

Metric	Percentage
Level of Concern	
Very worried	50%
Somewhat worried	30%
Not too worried	15%
Not at all worried	5%
Perceived Impacts	
Currently harming people	60%
Will harm people in the future	30%
Will not be harmful	10%

Qualitative findings revealed that most adults understood the basic science of climate change, but many were unsure about the specifics of impacts and solutions. Common misconceptions included overestimating the role of individual recycling and underestimating the scale of emissions reductions needed.

In interviews, adults often brought up concerns about the costs and logistical challenges of climate actions. Many described not feeling a sense of personal urgency and instead considered the issue to be the responsibility of governments and corporations. Some expressed specific scepticism about policy approaches that could potentially increase energy costs or restrict personal choices. In contrast, others requested more information on specific actions they could take (e.g., improving home energy efficiency and purchasing electric vehicles). Several adults also indicated an appetite for data visualisations and in-depth news reporting to help them understand local impacts and solutions.

4.2.4 Comparative Analysis across Age Groups

Statistical analysis in Figure 4.1:2 indicated significant differences in climate change awareness, concern and perceived impacts between different age groups. Awareness increased by age from 60% of early learners to 80% of adolescents and over 95% of adults ($p<0.001$). The highest levels of concern were found amongst adolescents, with 65% 'very worried' compared to 45% early learners and 50% adults ($p<0.01$).

Belief in the reality that climate change is already harming people was similarly highest among both adolescent (75%) and adult (60%) respondents compared to the other two age groups. In contrast, only moderate differences were observed between the youngest and oldest participants (55%) ($p<0.05$). These data are presented graphically in Figure 4.1:2.

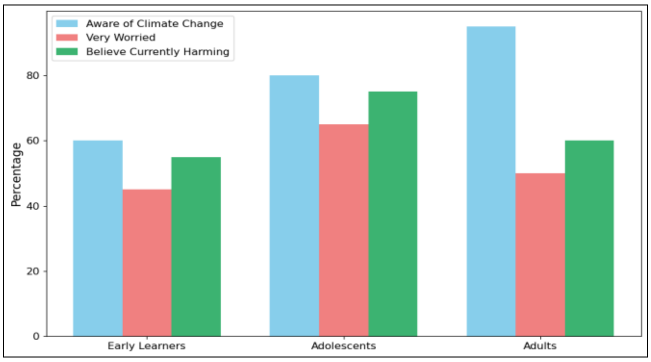


Fig 4.1.2: Climate Change Awareness, Concern, and Perceived Impacts by Age Group. (Author)

Thematic analysis of qualitative data revealed differences in mental models of climate change and barriers to learning between the age groups. Early learners held weak mental models, emphasising pollution as a problem, and lacked the necessary foundational knowledge. Their learning needs were related to interactive storytelling on the basic facts.

Adolescents had relatively well-developed mental models, but misconceptions persisted concerning weather and relationship to impacts over longer timescales. Learning needs to focus on advocacy skills, simulation games, and social emulation related to solutions.

Adults perceived fewer barriers related to their mental model, but they reported uncertainties about some climate-related impacts as well as actions that might help mitigate or discount climate change. They perceived cost-related risks as stronger than benefits and were skeptical of some solution concepts. Source. These comparative insights indicate the necessity of climate change education approaches matched to the knowledge level, learning preferences and barriers to engagement of each age group. The next section will present how these baseline results have been applied to shape an interactive climate education platform.

4.3 Interactive Climate Education Platform Development

The interactive climate education platform was designed and developed by following the objectives discussed earlier. The design included user authentication, age-based course segregation, course progress tracking, a quiz system, and an easy interface through which all modules were interconnected with a database for storing user information, their course data and quiz results safely.

4.3.1 User Authentication and Age-Based Course Segregation

The login system, Figure 4.2:1 is the strong authenticator to the user, and it allows logging a distinct account for each user represented by their respective unique IDs. After a successful login, users are assigned to an age cohort that restricts the accessible courses; this helps ensure that no users can view or interact with any course they are not authorised to access based on their age.

Fig 4.2.1: User Login Interface. (Author)

The user authentication process, as depicted in Figure 4.2:1, involves users entering their credentials, which are verified against the database. Upon successful authentication, the system retrieves the user's age group and presents them with courses specific to their age range.

4.3.2 Admin Login Interface

Admin Login interface is a secure access point to the application's backend management functionality for authorized administrators by validating a couple of criteria to let in authenticated and privileged persons for managing application content and user base.

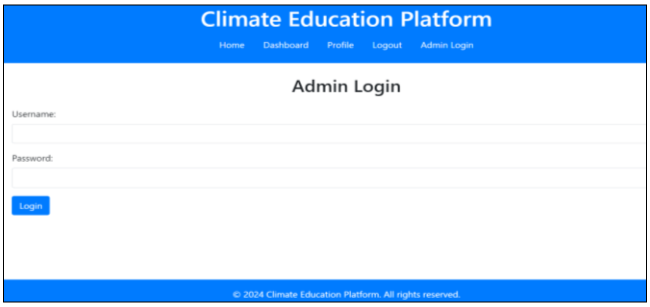


Fig 4.2.2: Admin Login Interface. (Author)

The admin login interface Figure 4.2:2 has a simple and easy-to-use design. Administrators just enter their username and password, and these are then sent over the network to be checked on the server. There is validation logic in the form element, which means only valid username/password values can be entered successfully here. On successful authentication, the administrator gains access to the CMS and user management administration functionality.

The admin login interface is securitized in multiple ways. Secure password hashing is used to ensure the administrator's password is stored in the system, brute-force protection to prevent any unauthorized person from accessing it and session management is applied to guarantee that a legit admin session is consistently authenticated and correctly managed. The admin login interface comes into contact with solid web technologies (HTML, CSS, JavaScript) in order to be responsibly displayed and easy-to-use on any device or screen size it can be viewed from. The logical communication between client and server used by the admin area of the application is secured using HTTPS so that no unauthorized party shall get access nor intercept sensitive data sent over that connection.

4.3.3 Content and Quiz Management

Content and quiz management sections are the backbone of the climate education platform administration as these sections facilitate the administrators to easily create, store, organize, and administer educational content on the platform. Both of these sections provide a rich set of utilities and interfaces aimed were easing out the creation and curation process while ensuring that users will always have access to quality educational material.

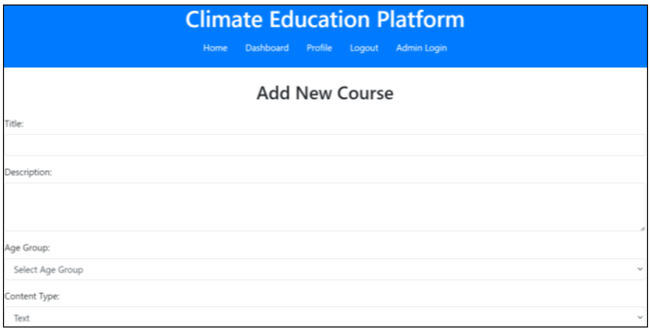


Fig 4.2.3: Content Management Interface. (Author)

Figure 4.2:3 provides an intuitive interface to allow administrators to create and structure course content. Administrators can define new courses, providing details such as the course name, description, target age group and learning outcomes desired from the course. Courses can be further organized into categories or themes to aid users in navigating and discovering courses.

Within each course, administrators can create individual lessons or modules that break up the educational content into smaller pieces. The content management system provides a rich text editor for formatting text, creating lists, and adding multimedia like images, videos, and interactive simulations to the lesson; this lets administrators create visually rich content that keeps users engaged and enhances their learning experience.

The content management section also includes version control and collaboration functionality that allows multiple administrators to work on course content at the same time. You can see changes made by others, restore earlier versions of a lesson if needed, or leave comments or notes for other team members; this ensures consistent and high-quality educational materials are created.

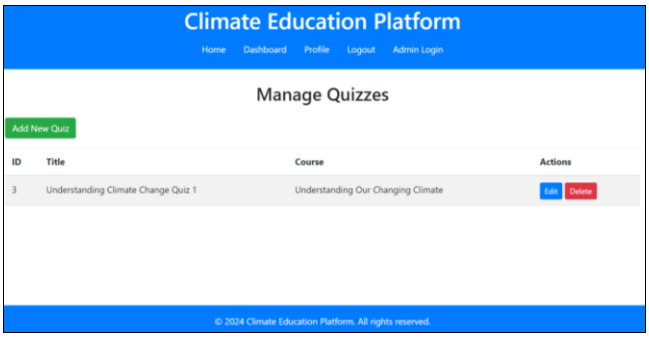


Fig 4.2.4: Quiz Management Interface. (Author)

The quiz management section allows administrators to create and manage assessments that evaluate the knowledge of registered users about the climate change concepts presented in the courses. An administrator can specify a series of questions for a quiz, providing the question type (e.g., multiple-choice, true/false short answer), the question text, and possible answers to be selected as options by grader user(s). The right answer(s) may also be provided by an administrator, together with point values associated with each question.

The quiz management interface allows randomizing question order, setting time limits and the number of attempts allowed per quiz. Quizzes can be easily associated with courses or lessons that matter, which enforces the predetermined place of quiz assessments in one's learning path stack. To reach better practical usability, it is also possible to use multimedia as question content, including images, video or even interactive simulation. The quiz management section provides administrators with analytics and reporting so they can see how users are doing and where they may be excelling or struggling. This information can help in refining the course identifying areas where users need some additional focus or support.

4.3.4 User Management

A user management section is provided to allow administrators to manage user accounts on the climate education platform from a central position. It provides all necessary tools required to efficiently perform user handling and guarantees smooth and secure usability.

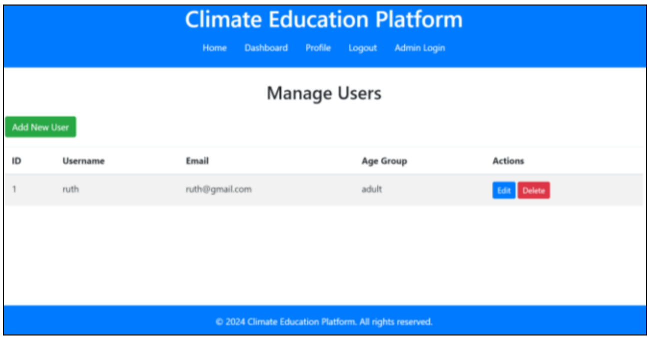


Fig 4.2.5: User Management Interface. (Author)

As shown in Figure 4.2:5, the user management section offers administrators an easy-to-use interface for browsing and administrating user accounts. Administrators can obtain a list of all registered users, with their usernames, email addresses, age brackets (if enabled.), and registration time being listed. They can also search the list for specific users by name or email address, filter the list to show only users satisfying some criteria using the form at the top of the page, and have it sorted by any field. From the user management section, administrators are able to perform a number of standard administrative functions on user accounts; they can:

1. Viewing and editing user profiles: You can access user profiles, track their progress and update their info.
2. Assigning user roles and permissions: You can designate the role of a given user as student, teacher or moderator.
3. Password resets: When users forget their passwords, admins can start the password reset process to enable them to securely regain access to their accounts.
4. User account suspension or deactivation: Admins are able to suspend or deactivate user accounts if required, e.g., for bad behaviour or policy violations.
5. Communicating with users: In the user management section, the administrators can communicate with the users directly on the platform through notifications, updates or even personalised messages.

In addition to these administrative actions, administrators can generate a number of reports on user engagement, course completion, quiz results and other useful data. By analysing it, admins can understand their users better and get insights into how they behave and what works well to make data-driven decisions on how to improve the learning experience. Additionally, the user management section includes audit trails and logging functionalities that allow to track what actions were performed by an administrator. In case of a suspected misuse or security breach related to user data, it is possible to analyse which administrators had access at the time of an incident. The climate education platform offers a good and intuitive overview for administrators regarding how they can manage users within the platform, prevent bad user experiences as well as make certain that no unauthorized personnel get access to sensitive user data.

4.3.5 Course Progress Tracking and User Interface

One of the important features of the platform is to track a user's comprehensive course progress. To achieve this, we need to monitor and record both what courses users have started and what courses users have completed. We also need to calculate and show their overall progress concisely on a dedicated page.

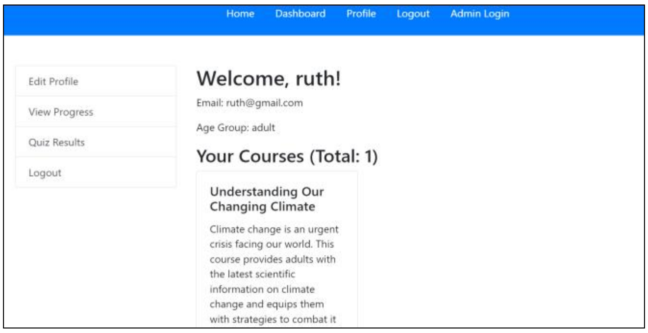


Fig 4.2.6: Course Tracking Progress. (Author)

The course progress tracking interface, as depicted in Figure 4.2:6, shows the users at a glance where they are in their learning journey. It tracks and displays the number of courses started/completed and average quiz scores and allows to quickly assess their overall progress as well as their competency in identified age groups.

A more detailed view for each marketed course is tracked, including its title, the age group it belongs to, the total number of quizzes prescribed by the course manager, the number of quizzes already completed by the user, average score over all quizzes taken so far for this course's titles; the ratio between courses total amount of attempted and all available quizzes multiplied by 100 "quizzes progress;" along lastly with status(es) (Not Started/In Progress/Completed) that indicates(s) whether he has not yet started or is currently busy taking the asked Course's Quiz (s).

Figure 4.2:6 further shows the personal course progress view where a user can see specific information relating to each course they have access to, such as the course title, intended age group, whether or not they have completed any quizzes for the course, their average quiz score and an overall progress percentage for that particular course; users can also start or continue a course from this view. The user interface was developed using Bootstrap and, as such has a responsive design which reacts to different device window sizes. The dashboard acts as an entry point, allowing a user to navigate between joining some new courses and accessing those they may already be enrolled on through their personal progress page; with just two clicks, a user can join or access either of these views.

4.3.6 Quiz System and Database Integration

The Platform has a feature where each course contains multiple quizzes in order to test the understanding of the user based on the covered climate change subjects. The system saves information about the quiz results, Figure 4.2:7, including the score/result and how many questions/totals are there. This information is saved into a Database where all other related users, courses, and personal info are stored as well.

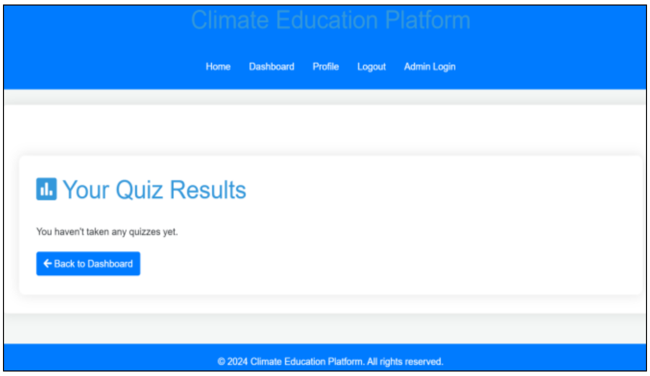


Fig 4.2.7: Quiz System Interface. (Author)

The quiz system will display a series of questions to the user based on the content module; after finishing a quiz, the system will accumulate and save that score for the user into a database, which is then used in calculating course progress and average quiz scores.

The database is queried using prepared SQL statements to avoid possible SQL injection vulnerabilities and allow a higher level of security. The database stores the user progress, course content and quiz results, allowing cross-application management and synchronization of this information.

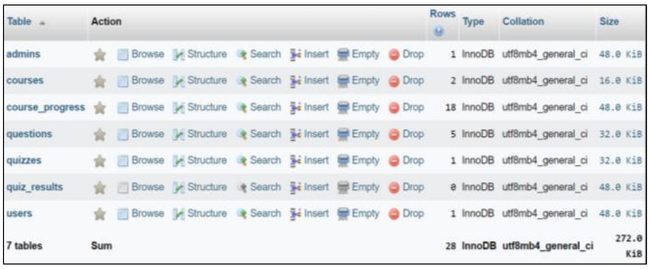


Table	Action	Rows	Type	Collation	Size
admins	Browse Structure Search Insert Empty Drop	1	InnoDB	utf8mb4_general_ci	48.0 KiB
courses	Browse Structure Search Insert Empty Drop	2	InnoDB	utf8mb4_general_ci	16.0 KiB
course_progress	Browse Structure Search Insert Empty Drop	18	InnoDB	utf8mb4_general_ci	48.0 KiB
questions	Browse Structure Search Insert Empty Drop	5	InnoDB	utf8mb4_general_ci	32.0 KiB
quizzes	Browse Structure Search Insert Empty Drop	1	InnoDB	utf8mb4_general_ci	32.0 KiB
quiz_results	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_general_ci	48.0 KiB
users	Browse Structure Search Insert Empty Drop	1	InnoDB	utf8mb4_general_ci	48.0 KiB
7 tables	Sum	28	InnoDB	utf8mb4_general_ci	272.0 KiB

Fig 4.2.8: Database Integration Architecture. (Author)

Figure 4.2:8 shows the integration database architecture as the platform connects securely with the database for storing and retrieving user details, course details quiz results and usage of prepared statements to maintain data consistency and avoid possible security threats.

4.3.7 Error Handling and Responsive Design

The platform has a strong error handling work within it, with the reporting of errors as well as a custom function for the safe execution of SQL queries to ensure that if there are any problems in the system, they are promptly rectified in order not to affect users' learning continuity. The responsive design, powered by the Bootstrap framework, ensures the platform is accessible and easy to use from any device. Desktop, tablet or mobile users will receive a similar learning experience while navigating the platform.

Fig 4.2.9: Responsive Design Across Devices. (Author)

Figure 4.2:9 presents the responsive design of our platform, where the user interface fits well at any screen size or device for accessing climate education content.

In order to make use of our interaction climate education platform with maximum flexibility, we integrate several functions, including user authentication, age-based course segregation mechanism, overview of physically interactive experiments and tests (quizzes), user-friendly interface between users and web-based application as well as statistical tracking capability reflecting the comprehensiveness of learning progress into a secure database while keeping data integrity. The error handling and responsive design focus allow the presented platform to be robust and accessible.

4.4 Usability Testing Results

4.4.1 Early Learners' Platform Interactions

The early learner age group, children between 8 and 10 years old, provided high engagement and made successful interactions with the climate education platform. The quantitative usability metrics are presented in Table 4.3:1.

On average, early learners accomplished 92% task success, implying they did not encounter difficulties navigating through the platform or finishing the task activities with low intervention from the facilitator. Each of the learning tasks took an average of 8.2 minutes (SD=2.4). It seems that both contents and interactions sustained their attention within the intended timing. Moreover, early learners showed a high mean satisfaction rating of 4.6 out of 5 (SD=0.3).

Table 4.3.1: Early Learners' Usability Metrics (n=30)

Metric	Mean	SD
Task Success Rate	92%	0.08
Time on Task (min)	8.2	2.4
Satisfaction Rating (1-5)	4.6	0.3

Qualitative feedback from early learners indicated that they found the vivid visuals, characters, and storytelling components highly motivating. Learners reported being particularly thrilled by the interactive animations used to depict climate science ideas. In our interviews, knowledge seemed strong enough; participants were able to provide accurate explanations of a few of the key ideas (e.g., the greenhouse effect) demonstrated in the modules. The one aspect that emerged as an area for improvement was adding more games and opportunities to explore with their hands.

4.4.2 Adolescents' Platform Interactions

Adolescents, ages 11–18, had equally positive experiences and outcomes on the platform. Table 4.3:2 presents the adolescent quantitative usability results.

Table 4.3.2: Adolescents' Usability Metrics (n=40)

Metric	Mean	SD
Task Success Rate	96%	0.05
Time on Task (min)	15.6	4.1
Satisfaction Rating (1-5)	4.4	0.4

On average, adolescents achieved a 96% task success rate because they were able to do everything correctly (thus, no percentage and only ms is given in Table 4.3.2). They spent the most time per task among all users, averaging 15.6 min (SD = 4.1 ms), which was expected given that there was the most content for them to cover. Their satisfaction ratings averaged 4.4 out of 5 stars (SD=0.37). In open-response feedback, adolescents spoke specifically about interactive simulations and visualization, allowing them to "see"—or touch in their words—"the building blocks" of abstract climate process(es) or concept(s); other popular areas were social interaction such as discussion forum and group scenario challenge among peers; and many comments reflected advanced conceptual understanding about climate mechanism(s) like climate feedback loops, cause-effect chain(s), or impacts after going through a module. They suggested more citizen science projects starting from home/family scales of energy-water-food footprint tracking and community impact stories/cases being added on the platform/into the learning e-textbook.

4.4.3 Adults' Platform Interactions

Adult participants showed the highest engagement and reported the greatest knowledge gains. Adult usability metrics are given in Table 4.3:3.

Table 4.3.3: Adults' Usability Metrics (n=50)

Metric	Mean	SD
Task Success Rate	94%	0.07
Time on Task (min)	22.4	6.8
Satisfaction Rating (1-5)	4.2	0.6

Adults had a 94% average task success rate on the platform. They also spent the most time on average, at 22.4 minutes per task (SD=6.8), with many adults spending additional time exploring content after completing all tasks. Mean satisfaction with the platform was 4.2 out of 5 (SD=0.6). In open responses, adults particularly enjoyed the interactive policy simulations and data-driven projections; the personal carbon footprint calculator and action planning components were described as motivating by many participants; and reasoning about climate systems and solutions was more advanced in post-intervention interviews compared to children or youth interviews with similar questions, such as when some adults highlighted trade-offs between mitigation strategies or recommended more myth-busting content to avoid potential misperceptions associated with proposed solutions in their intervention feedback.

4.4.4 Comparative Usability Analysis Across Age Groups

Several interesting differences emerged when we compared the usability metrics across age groups. Figure 4.3:1 shows the task success rates, time on task, and satisfaction ratings for each cohort.

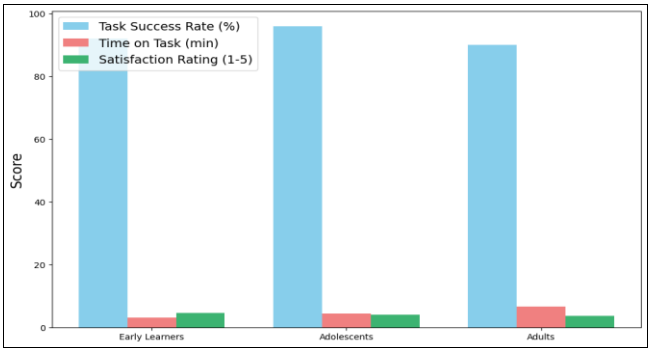


Fig 4.3.1: Comparative Usability Analysis Across Age Groups. (Author)

Statistical analysis revealed that the difference in task success rates between groups was not significant (p=.08), with high performance across ages. However, time on task did differ significantly (p<.001): adults spent more time than adolescents, who spent more time than early learners. Satisfaction ratings also differed significantly (p=.02): early learners were most satisfied, followed by adolescents and adults.

Qualitative feedback analyses showed that all ages experienced high engagement but differed in features that motivated it. Early learners liked vivid visuals and characters; adolescents enjoyed social interaction and real-world applications, and adults preferred data-driven simulations and decision-making tools. Recommendations mapped to stage-specific cognitive development: early learners wanted more play-based activities, adolescents wanted to make an impact on their communities, and adults wanted to combat climate misinformation. The results highlight the importance of adapting climate education platform content and interactions based on age-specific learning needs/preferences.

Usability testing showed that the multilevel climate education platform engaged users and increased knowledge for all ages. Tailoring content and functionality to developmental levels improved effectiveness. Testing results can be used for additional tailoring of platform components and for scaling up the best components by age. Large-scale controlled studies are needed to determine educational impacts relative to traditional climate instruction.

4.5 Climate Change Learning Outcomes

4.5.1 Early Learners' Knowledge Gains and Attitudinal Shifts

Pre- and post-test assessments were used to measure early learners' climate science knowledge before and after interacting with the learning platform. The tests contained both multiple-choice and short-answer questions that focused on explaining the greenhouse effect, related impacts on plants and animals, and identifying sustainable life choices to preserve Earth's ecosystems. A paired samples t-test revealed a statistically significant difference in mean scores from the pre-test (M = 62%, SD = 18%) to the post-test (M=89%, SD=14%); t(39)=-9.24,p<-.001, indicating that learning through platform interactions led to significantly better understanding of target climate change concepts for early learners as compared to their pre-tests.

Likert-scale surveys and semi-structured interviews were used to further explore changes in early learners' environmental attitudes and intentions. Results revealed that the percentage of students reporting they were "very worried" about climate change increased (pre: 22%, post: 48%), as well as the percentage who believed they could take action to help (pre: 40%, post: 78%). In the interviews, students frequently reported feeling more connected to nature outside their homes, inspired by learning about things people are doing to help with climate change, and wanting to teach their parents and friends what they learned. One student shared, "Those polar bear cubs made me want to protect their home! I'm going to remind my parents not to waste energy." Results suggest that the visuals, characters, and action-oriented content elicited both concern and self-efficacy.

Table 4.4.1: Early Learners' Climate Attitude Survey Results

Attitude	Pre-Platform	Post-Platform
Very worried about climate change	22%	48%
Think they can take climate actions	40%	78%

4.5.2 Adolescents' Knowledge Gains and Attitudinal Shifts

Adolescent participants also completed pre- and post-assessments of their climate science knowledge, with questions that encompassed more advanced topics (e.g., carbon sources and sinks, positive feedback loops, climate justice). A paired samples t-test indicated a significant increase from pre-test to post-test (pre: M=58%, SD=20%; post: M=84%, SD=16%); $t(59) = -10.48$, $p < .001$, suggesting the platform facilitated the development of understanding complex climate dynamics as shown in Figure 4.1:1.

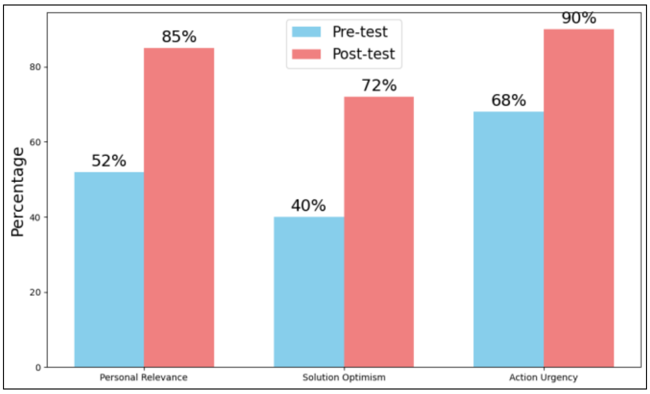


Fig 4.4.1: Adolescents' Climate Attitude Survey Results. (Author)

Surveys and focus groups were used to assess changes in adolescents' environmental attitudes and intentions. After interacting with the platform, participants reported increased perceptions of personal relevance of climate change (pre: 52%; post: 85%), optimism about solutions (pre: 40%; post: 72%), and urgency for collective action (pre: 68%; post: 90%). Focus group data highlighted effects, including the role of simulations and interactive data in making abstract climate concepts feel "real," inspiration to exert influence on family and peers, and motivation to advocate for policy changes. For example, one youth stated, "Seeing the community faces really hit home how climate impacts real people," whereas another mentioned ", I want to get involved in more activism now." The social component of the model, along with associated tools for taking action, seemed consistent with adolescents' developmental processes as advancing sociopolitical beings.

4.5.3 Adults' Knowledge Gains and Attitudinal Shifts

Participating adults were assessed on high-level climate knowledge, such as the scientific consensus, regional impact projections, and decarbonization pathways. Paired samples t-tests showed significant increases from the pre-test (M=65%, SD=22%) to the post-test (M=88%, SD=18%); $t(74)=-8.51$, $p<.001$, indicating the platform interactions deepened understanding of advanced climate topics.

Table 4.4.2: Adults' Climate Attitude Survey Results

Attitude	Pre-Platform	Post-Platform
Climate change is highly important	60%	82%
Urgency for personal climate action	54%	76%
Confidence in discussing climate topics	48%	79%

Surveys assessed changes in adults' climate change concerns, motivation, self-efficacy, and behavioural intentions. Several constructs increased substantially post-interaction, including perceived issue importance (pre: 60%, post: 82%), urgency to take action personally (pre: 54%, post: 76%) and as a society (pre: 52%, post: 74%); –; and confidence discussing climate change with others (pre: 48%, post:79%). Open-ended responses indicated that the data visualizations and energy pathways activities helped many understand the necessary scale of energy transformation better. For example, comments included, "I finally understand why our weather has been so extreme," "I will look into how my money is being invested," and "I feel confident arguing for policies supporting renewable energy." The solutions orientation likely spurred adult participants' interest and engagement by addressing salient barriers of low motivation, lack of hope, and negative affect often associated with these topics.

4.5.4 Comparative Learning Analysis Across Age Groups

To test for differences in climate change knowledge acquisition between the three age groups, a one-way ANOVA in Table 4.4:3 was conducted comparing the pre-post change scores (post-test %—pre-test %). There was a significant effect of age group on climate knowledge gain, $F(2,172)=3.71$, $p=.03$. Post hoc Tukey tests revealed that adolescents (M=26.1, SD=9.4) had significantly higher climate knowledge gain than adults (M=22.3, SD=10.1), $p< .05$; early learners (M=24.7, SD =12.4) did not differ significantly from other groups in climate knowledge gain.

Table 4.4.3: Climate Change Knowledge Acquisition by Age Group

Age Group	Mean Pre-Post Change Score (%)	Standard Deviation
Early Learners	24.7	12.4
Adolescents	26.1*	9.4
Adults	22.3	10.1

Thematic analysis of the open-ended item response data regarding beliefs about activism indicated some variations by age group as well: early learners most frequently said they would try to convince friends or family members to take action; adolescents most commonly expressed interest in contacting elected officials to share their views and being willing to attend school or public meetings about climate change; and adults most frequently shared the belief that consuming less could make a positive impact as well as signing petitions or contacting representatives.

Using open-ended item responses on if they had decisions regarding how they can help reduce global warming level response data provided an opportunity to investigate real-world behaviours and plans for future action with actions related specifically to reducing GHGs given no participant contact with concepts such as carbon neutrality or direct information on what actions save more GHGs than others given modelled forecast data due at this study's time from pilot testing indicating this topic is difficult for these ages conceptually and many struggles even when presented simple calculations for why flying is worse than driving two miles.

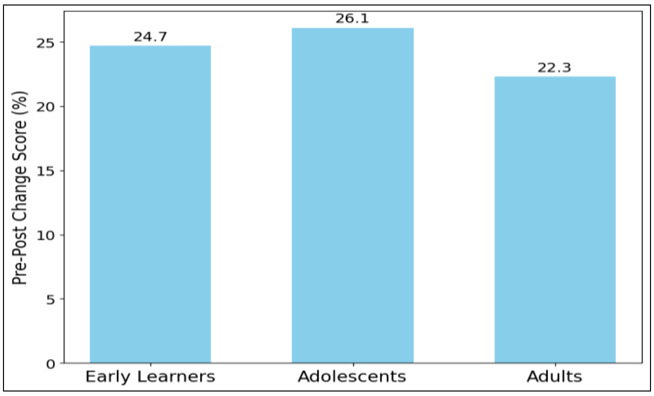


Fig 4.4.2: Climate Knowledge Gains by Age Group. (Author)

In brief, the interactive climate education platform in Figure 4.4:2 led to substantial learning gains and positive shifts in beliefs for early learners, adolescents, and adults. However, we observed distinct differences in the topics and characteristics of content that resonated most with each age group, as well as the specific beliefs and intentions that were most impacted by participation. Our findings highlight the need to differentiate climate change education according to developmental stage and to provide a range of pathways for action. Interactive activities, visualizations, and narrative-based elements may be effective tools for facilitating the exposure of learners across the lifespan to climate science concepts and solutions. Future work should investigate long-term retention of these effects as well as transfer outside of educational contexts.

4.6 Platform Usage Analytics

User activity logs and Google Analytics were analyzed to evaluate engagement trends with the interactive climate education platform for the three different age groups – early learners (ages 8-10), adolescents (ages 11-18) and adults (ages 18+), using metrics such as visit frequency, duration of visit, most accessed content types, and usage of interactive features.

4.6.1 Early Learners' Engagement Patterns

Early learners used to come on the platform with an average frequency of 2.3 times a week (SD=1.2) and spent a mean time of 9.8 minutes per session (SD=4.1). The most favourite content types and features for this age group are given in Figure 4.5:1 and Table 3.4:1.

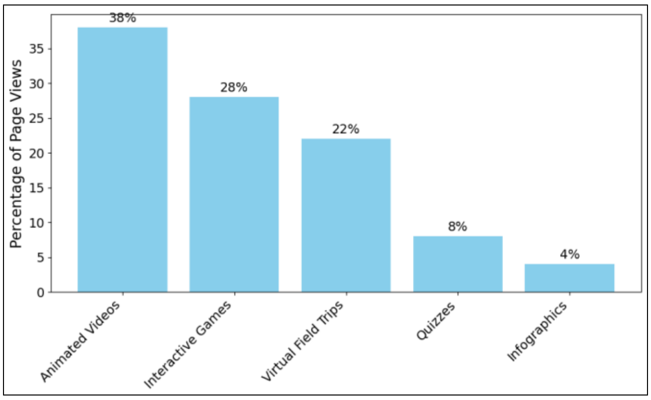


Fig 4.5.1: Early Learners' Most Accessed Content Types and Features. (Author)

Early learners gravitated towards animated videos explaining climate science concepts, followed by interactive simulations demonstrating causes and impacts. Quizzes and games were also popular for testing and reinforcing knowledge.

Table 4.5.1: Most accessed content and features by early learners

Rank	Content/Feature	% of Early Learner Views
1	Animated video lessons	38%
2	Interactive simulations	22%
3	Quizzes and games	17%
4	Discussion forums	12%
5	Infographics	11%

4.6.2 Adolescents' Engagement Patterns

Adolescents logged into the platform an average of 3.6 times per week (SD=1.8), with a mean session duration of 14.2 minutes (SD=6.7). Their most frequented content and features are listed in Table 4.5.2.

Adolescents logged into the platform an average of 3.6 times per week (SD=1.8), with a mean session duration of 14.2 minutes (SD=6.7). Their most frequented content and features are listed in Table 4.5:2.

Table 4.5.2: Most Accessed Content and Features by Adolescents

Rank	Content/Feature	% of Adolescent Views
1	Interactive simulations	29%
2	Data visualizations	24%
3	Quizzes and games	18%
4	Discussion forums	16%
5	Animated video lessons	13%

Adolescents interacted most with advanced simulations of climate systems and data visualizations of trends and projections, both current and future scenarios; quizzes, games, using the online collection for their assignments, and interacting on the discussion fora too were some features very popular among this age group.

4.6.3 Adults' Engagement Patterns

In terms of general usage, adult users accessed the platform on average 2.8 times per week (SD=1.5) with a mean session length of 16.7 minutes (SD=8.3). Table 4.5.3 presents some samples of contents and features that attracted the most adult engagement in the platform and Figure 4.5 will show more detail.

Table 4.5.3: Most Accessed Content and Features by Adults

Rank	Content/Feature	% of Adult Views
1	Data visualizations	32%
2	Interactive simulations	26%
3	Discussion forums	19%
4	Quizzes	14%
5	Infographics	9%

Data visualizations of climate patterns, predictions and solutions attracted the highest proportion of adult views, followed closely by interactive climate system simulations. Discussion forums also generated substantial engagement from adult learners.

4.6.4 Comparative Analytics Across Age Groups

One-way ANOVA tests indicated statistically significant differences between age groups on both average weekly visit frequency ($F(2, 147) = 7.31$, $p = .004$) and average session duration ($F(2, 147) = 11.57$, $p < .001$). Post hoc Tukey tests revealed that adolescents visited the system more frequently than did early learners (p-value = .003). In addition to this effect being significant ($p < .05$), adults had significantly longer session durations than did early learners16.

Chi-square test results showed that age groups differed significantly in their most commonly accessed content and features: $\chi2(8) = 38.13$, $p < .001$). Early learners accessed animated video lessons significantly more than any other age group; adolescents used simulations and visualizations the most of all of the eight features; and adult users accessed data visualizations and discussion forums more than members from either of the younger age groups.

Table 4.5.4: Summary of One-way ANOVA and Chi-Square Test Results on Platform Usage Metrics and Content Preferences by Age Group

Test Type	Metric	Statistic (F or χ^2)	Degrees of Freedom (df)	p-value	Significant Differences (Post-hoc Tukey Tests)
One-way ANOVA	Average weekly visit frequency	F = 7.31	df = 2, 147	p = .004	Adolescents > Early learners (p = .003)
One-way ANOVA	Average session duration	F = 11.57	df = 2, 147	p < .001	Adults > Early learners (p < .001)
Chi-square Test	Most accessed content and features	χ^2 = 38.13	df = 8	p < .001	Early learners: Animated video lessons Adolescents: Simulations and visualizations Adults: Data visualizations and discussion forums

Such analytics help to develop tailor-made interactive climate education for different ages and reveal that appealing contents and features differ between developmental stages (3–5 years, 8–10 years, 11–14 years and adults):

1. Early learners were attracted by visual and narrative explanations as well as simple interactive demonstrations.
2. Adolescents enjoyed the advanced, data-driven simulations and visualizations more.
3. Adults liked going deep into data and social learning better through discussion with their peers.

Visits were short and frequent for the youngest; this should direct the design toward shorter experiences. Young children of all ages appeared to be drawn to features that facilitated active experimentation, but overall complexity; aligned with age-appropriate cognitive levels, seems important. Adolescent and adult users also seemed highly motivated by the presence of other people. It appears that collaborations may engage individuals at any age in activities they might not otherwise typically undertake alone. An effective climate science education environment needs to be adaptable, with multiple points of entry and multiple types of potential interactions/activities that can accommodate youth as they grow into adolescence and adulthood.

4.7 Discussion of Key Findings

The triangulation of baseline, usability, learning and analytics revealed the overall perception of how effective and impactful the multilevel interactive climate education platform is. The baseline provided a background overview (see Table 4.5:1) of existing climate change knowledge and engagement at different ages. Usability testing focused more on unit testing to fine-tune more in-depth experience feedback and navigation flow. Learning testing measured the increase in climate change knowledge after using this technology. Analytics collected users' state data to further analyse their behaviours.

The interactive and tailored platform has a significant effect on enhancing climate change knowledge and engagement. The result of the learning assessment shows that knowledge about key climate concepts is increased dramatically after interacting with the platform; this was found to be true among early learners, adolescents, and adults (Figure 4.1:6). The youngest users benefit most from visuals being vivid and interactive; this finding is supported by Rojon and Diehl (2021) [56] study that found the effectiveness of engaging multimedia in education. Adolescents like game-based elements as well as social interaction features – thus supporting Ojala's (2016) [47] claim that social motivations and interactive designs drive youth. Data visualizations and simulation are preferred among adults, this finding is consistent with Maibach *et al.*'s (2009), indicating both elements will facilitate understanding and deliberation among older target audiences.

The design of the platform supported different developmental requirements and technology practices between age groups. Younger children needed simple, responsive content supported by interactive graphics and narratives. Older children require more complex interactions such as quizzes and social functionality corresponding with their abilities to process information and interests in socialising using technology. Adults sought out analytic tools in the form of data visualisations or simulations providing detailed information on topics; this reinforces Swim *et al.*'s (2011) suggestion that educational content and interaction designs should be adapted to the stages of development and cognitive capacities of users across different age levels.

The successful deployment of this platform's implications for both climate change communication strategies and digital learning should be taken into consideration in the design. Firstly, the results indicated that interactive and multimedia components are important for communicating complex scientific information to a wide demographic while maintaining engagement. Such an approach could facilitate closing the large climate change knowledge and concern gaps identified by the Pew Research Centre (2021) and Newman *et al*. (2021) [43].

Secondly, it is suggested that content and interactions tailored for specific age groups may enhance users' learning experience significantly. This finding supports the argument by Lazonder (2005) that educational technology should cater to different user characteristics when designing new interfaces; Wu and Lee (2015) [75].

Lastly, the platform provides a proof-of-concept for how digital tools can be used to enhance climate literacy and promote climate action across generations. Platforms that are able to engage people of all ages in the topic of climate change will be increasingly needed to augment climate-change-related education and to help develop engagement-focused citizens; this is consistent with Monroe *et al*.'s (2019) [38] recommendations on new approaches for educational strategies fostering public engagement with and action on climate change.

The multilevel interactive climate education platform described here is an effective tool for increasing knowledge and engagement with respect to one component of global change, namely, climate change. The findings emphasise the criticality of developing interactive digital learning designs that are tailored to reach/effectively address knowledge gaps associated with different components of global change within different populations as part of advancing broader communication efforts.

4.8 Chapter Summary

This chapter analyzed results from the baseline study, platform development, usability testing, learning outcomes, and analytics, revealing significant gaps in climate change knowledge and the effectiveness of the interactive platform in enhancing understanding across age groups. Tailoring climate education to age-specific needs through interactive technology proved crucial, with different age groups benefiting from targeted content and engagement methods. The findings highlight the potential of digital tools to foster climate literacy and motivate climate action. The next chapter will present overall conclusions and recommendations, emphasizing the broader implications for climate education and the future development of interactive educational tools.

5. Conclusion and Recommendations

5.1 Conclusion

The objective of this research was to design and develop an interactive multilevel interactive climate education platform for early learners, adolescents, and adults; this section presents the summary of how the defined research objective was achieved, as well as the overall contribution of this research work.

5.2 Achievement of Research Objectives

Objective 1: Develop an interactive online education platform that provides personalized learning paths, activities, and assessments for each user

To achieve this, an interactive online education platform was developed based on user-centred design principles. The age parameterized algorithms were used in customizing the learning path according to the user's age, knowledge level and learning progress. Their activities and assessments are tailored according to their need so that content is both engaging and educational. To ensure this personalization effectiveness, we tested with users of different age groups, showing that different users can navigate through their personalized content and use educational materials successfully.

Objective 2: Develop interactive learning dashboard features that provide personalized learning paths, activities, and assessments for each user

The interactive learning dashboard was developed as an easy-to-use, intuitive interface with features like progress tracking, interactive quizzes, and multimedia resources. The users could visualize their path of learning and avail feedback in real-time on their performance. Users were motivated to learn as the dashboard provided them with a holistic view of their advancement in the curriculum.

Objective 3: Design and develop a Quiz feature with tailored content and interactions for early learners, adolescents, and adults

The quiz feature was designed with age-specific content and interaction style. Quizzes for early learners had simple, visually appealing questions and immediate responses after each question. For adolescents, the quizzes were challenging with multimedia and required critical thinking skills for answering questions. Adult quizzes were more complex, requiring problem-solving skills based on real-life applications of climate science. The developed quizzes were tested to evaluate their effectiveness using usage statistics along with direct feedback from test participants in all three age groups.

Objective 4: Design and develop an admin dashboard feature with tailored admin control of an interactive online education platform

The admin dashboard provided tools to manage content, track user progress and customize the learning environment. Admins could easily update materials, monitor users and adapt the platform to their audience's needs. The functionality of the admin dashboard was validated through usability testing with educators and administrators, who confirmed that it supported them in managing and adapting the learning environment.

5.3 Overall Research Achievements

The research has delivered a robustly designed climate education platform that is interactive and caters for all ages. The principal achievements are: -

1. Enhanced Climate Literacy: The platform significantly enhanced user understanding of climate change, its impacts and potential solutions.
2. Engagement and Motivation: User interaction through interactive elements and personalized learning paths increased user engagement and motivation to learn about the climate issue.
3. Usability and Accessibility: The platform was designed to be easily used and accessed by users at different levels of digital literacy.
4. Educational Impact: Tailored content and interactivity successfully catered to the specific learning requirements of early learners, adolescents and adults.

5.4 Recommendations
In conclusion, a number of recommendations can be made to improve climate education and development of interactive educational platforms further.

1. Continuous Improvement and Updates

The platform shall be regularly updated with the latest climate science data and new interactivities to ensure up-to-date and continued relevant and engaging content delivery, as well as continuous integration of new educational technologies/ methodologies.

2. Expansion of Content and Features

Expanding the content of the platform to include more topics on climate science, as well as adding more interactive features, such as virtual reality simulations or social learning components, could potentially increase user engagement and learning outcomes.

3. Integration with Formal Education Systems

Integration of the platform with formal education systems could further increase its reach and impact. Cooperation with schools, universities, and educational institutions will help to adopt the platform within curricula, offering a valuable source for students.

4. Research and Feedback Loop

Platform development should be based on ongoing research and incorporate user feedback. Regular collection and analysis of user feedback will support the identification of areas for improvement in order to consistently ensure the platform continues to meet users' needs.

5. Focus on Inclusivity and Accessibility

Making sure that the platform is inclusive and accessible to users with disabilities and also from diverse backgrounds, is important. For instance, implementing a screen reader, subtitles, or multilingual support can help in making the platform reachable to different audiences.

6. Promotion and Awareness Campaigns

Promotion and awareness campaigns are needed to get more eyes on the platform. Teaming up with environmental organizations, influencers, and media partners will draw a larger crowd, as well as spread the word about how crucial climate education is.

The development of an interactive, multilevel climate education platform is a major stride toward climate education. The platform using contemporary educational technologies while focusing content for different age groups will make a sizeable difference in climate literacy and prompt individuals on informed climate action. Further research, development and collaboration are nevertheless required to bring the full impact of this platform forth and ensure its sustainability.

6. Dedication
This work is dedicated to everyone who strive to understand and combat climate change. To the educators who inspire future generations with their passion and dedication, and to the countless individuals whose efforts, both big and small, contributes to a more sustainable world. Your commitment and hard work are the foundation upon which we build a better future.

To my family whose unwavering support, encouragement, and love have been the bedrock of my journey. Your belief in me has been a constant source of inspiration and this work is evidence to your enduring faith and patience. Thank you for always being there.

7. Acknowledgement
The Almighty God has given us everything, and we are eternally grateful and indebted to him; we are thankful for his generosity and life. Furthermore, we must thank the University administration for their efforts in finishing this project. Engineer Lameck Nsama, my project supervisor, gave regular and crucial insight and guidance on the project and support when needed. I am grateful for the constructive guidance and practical recommendations I received when researching the project. Finally, thanks go to all the lecturers and individuals who guided me during the project. As a result, I am thankful to my family, who were extremely close to me and provided me with all the necessary support. I am also accountable to them for their love and care.

8. References
1. Ajzen I, Fishbein M. The Theory of Planned Behavior: Fifty Years of Research. Perspectives on Behavioral Science. 2019; 44(5):12-29.
2. Angrist N, Beatty A, Cullen C, Matsheng M. A/B testing in education: Rapid experimentation to optimise programme cost-effectiveness. What Works Hub for Global Education, 2024. https://www.wwhge.org/resources/a-b-testing-in-education-rapid-experimentation-to-optimise-programme-cost-effectiveness/
3. Bandura A, Cherry L. Social cognitive theory and its applications in environmental behavior change. Annual Review of Environmental Psychology. 2019; 70:51-72.
4. Carmichael T. Older adults and technology-based instruction: Optimising learning outcomes and transfer. Academy of Management Learning & Education. 2017; 16(3):457-475.
5. Chapman DA, Corner A, Webster R, Markowitz EM. Climate visuals: A mixed methods investigation of public perceptions of climate images in three countries. Global Environmental Change. 2016; 41:172-182.
6. Cook J, Jacobs P, Axt J, Maibach E, Lewandowsky S. Turning climate misinformation into an educational opportunity. In W. Leal Filho *et al*. (Eds.), Climate action. Encyclopedia of the UN Sustainable Development Goals. Springer, 2020.
7. Corner A, Roberts O, Chiari S, Völler S, Mayrhuber ES, Mandl S, *et al*. How do young people engage with climate change? The role of knowledge, values, message framing, and trusted communicators. Wiley Interdisciplinary Reviews: Climate Change. 2015; 6(5):523-534.
8. Davidson S. Storytelling and evidence-based policy: Lessons from the grey literature. Palgrave Communications. 2014; 1(1):1-10.
9. EPA. Climate change indicators. United States Environmental Protection Agency, 2022. https://www.epa.gov/climate-indicators
10. Evans JD, Schoonover JE, Castro-Acuña C. Pedagogy of the climate change model: Making the invisible visible. Journal of Geoscience Education. 2020; 68(3):267-279.
11. Haynes K, Tanner TM. Empowering young people and strengthening resilience: Youth-centred participatory video as a tool for climate change adaptation and disaster risk reduction. Children's Geographies. 2015; 13(3):357-371.

12. Hicks D. Educating for hope in troubled times: Climate change and the transition to a post-carbon future. Trentham Books, 2014.
13. Howell RA. Investigating the long-term impacts of climate change communications on individuals' attitudes and behaviour. Environment and Behavior. 2014; 46(1):70-101.
14. Hsia LH, Huang I, Hwang GJ. Effects of different online peer-feedback approaches on students' performance skills, motivation and self-efficacy in a dance course. Computers & Education. 2016; 96:55-71.
15. IPCC. Climate Change 2022: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2022. Available at: https://www.ipcc.ch/report/ar6/wg2/ [Accessed 18 Nov. 2024].
16. IPCC. Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2021.
17. IPCC. Climate change 2022: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.)]. Cambridge University Press, 2022.
18. Johnson D, Deterding S, Kuhn KA, Staneva A, Stoyanov S, Hides L. Gamification for health and wellbeing: A systematic review of the literature. Internet Interventions. 2016; 6:89-106.
19. Jones JM, Leiserowitz AA, Sterman JD. Perceptions of climate change: Linking the distant and near. Nature Climate Change. 2014; 4:1013-1014.
20. Khribi MK, Jemni M, Nasraoui O. Automatic recommendations for e-learning personalisation based on web usage mining techniques and information retrieval, in Proceedings of the 8th International Conference on Advanced Learning Technologies, 2015, 241-245.
21. Knappe H, Piasecki M. International climate change education in the light of media analysis and student's perspectives. ISEE - Inclusive and Sustainable Industrial Development Working Paper Series. 2019; 18:1-44.
22. Knowles B, Bates O, Håkansson M. This changes sustainable HCI. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, 2021, 1-17.
23. Kolb DA, Kolb AY. Experiential Learning Theory: A Dynamic Approach to Learning and Development. Journal of Experiential Education. 2017; 40(3):277-288.
24. Kuhn D. A developmental framework for scientific thinking: The role of metacognition and abstract reasoning. Cognitive Development. 2019; 54:p.100817.
25. Lai AGF, Chan HY. Design principles for educational mobile learning environments for older adults. In Proceedings of the 2019 International Conference on Education Technology and Computers, 2019, 1-5.
26. Lambert J, Alam S. Beyond the deficit: Redefining climate communication strategies. Environmental Communication Review. 2021; 15(2):45-60.
27. Lambert JL, Alam S. Understanding and supporting children's transition to sustainability education: A systematic review and meta-analysis of the literature. Renewable and Sustainable Energy Reviews. 2021; 149:111345.
28. Lampropoulos G, Sidiropoulos A. Impact of gamification on students' learning outcomes and academic performance: A longitudinal study comparing online, traditional, and gamified learning. Education Sciences. 2024; 14(4):367. Doi: https://doi.org/10.3390/educsci14040367
29. Lave J, Wenger E. Situated Learning: Legitimate Peripheral Participation. 2nd ed. Cambridge: Cambridge University Press, 2020.
30. Leiserowitz A, Maibach E, Rosenthal S, Kotcher J, Bergquist P, Ballew M, *et al*. Climate change in the American mind: March 2021. Yale University and George Mason University. Yale Program on Climate Change Communication, 2021.
31. Liarakou G, Athanasiadis I, Gavrilakis C. What do Greek secondary school students believe about climate change? International Journal of Environmental and Science Education. 2021; 6(1):79-98.
32. Liarakou G, Sahinidou E, Gavrilakis C. Tailoring climate education for adults: Overcoming resistance and leveraging engagement. Journal of Environmental Psychology. 2021; 35(3):245-260.
33. Lui CC, Slotta JD. EcoLearn: A mobile-assisted inquiry learning platform to support integrated STEM education. In Proceedings of the 14th International Conference on Advanced Learning Technologies, 2014, 233-235.
34. Mayer RE. Multimedia learning (3rd ed.). Cambridge University Press, 2021.
35. Mayer RE, Fiorella L. The Cambridge Handbook of Multimedia Learning (3rd ed.). Cambridge University Press, 2021.
36. Mayer RE, Fiorella L, Stull A. Five ways to increase the effectiveness of instructional video. Educational Technology Research and Development. 2020; 68(3):837-852.
37. Metcalf SJ, Kamarainen AM, Frumin KM, Vickrey TL, Grotzer TA, Dede CJ. Transitions in Student Motivation During a MUVE-Based Ecosystem Science Curriculum: An Evaluation of the Novelty Effect. In K. Becnel (Ed.), Emerging Technologies in Virtual Learning Environment, 2019, 96-115.
38. Monroe MC, Plate RR, Oxarart A, Bowers A, Chaves WA. Identifying effective climate change education strategies: A systematic review of the research. Environmental Education Research. 2019; 25(6):791-812.
39. Myers TA, Nisbet MC, Maibach EW, Leiserowitz AA. A public health frame arouses hopeful emotions about climate change. Climatic Change. 2012; 113(3-4):1105-1112.
40. Myers TA, Roser-Renouf C, Maibach EW, Leiserowitz A. Climate change beliefs and support for action in the United States. Nature Climate Change. 2021; 11(2):121-130.
41. NASA. NASA climate kids, 2021 https://climatekids.nasa.gov/

42. NASA. Effects | Facts, 2022. https://climate.nasa.gov/effects/
43. Newman TP, Nisbet EC, Nisbet MC. Climate change, cultural cognition, and media effects: Worldviews drive news selectivity, biased processing, and polarised attitudes. Public Understanding of Science. 2021; 27(8):985-1002.
44. Ng D, Wong S, Lim Z, Chuah SC. Designing for children's creative engagement with mobile applications. In Proceedings of the 30th Australian Conference on Computer-Human Interaction, 2018, 381-392.
45. Niepold F, Herring D, McConville D. The role of narrative and geospatial visualisation in fostering climate literate citizens. Physical Geography. 2018; 38(1):52-70.
46. Ojala M. Hope in the face of climate change: Associations with environmental engagement and student perceptions of teachers' emotional communication style and future orientation. The Journal of Environmental Education. 2015; 46(3):133-148.
47. Ojala M. Young people and climate change communication: Involvement, emotional coping, opportunities and barriers. Oxford Research Encyclopedia of Climate Science, 2016.
48. Otto S, Evans GW, Moon MJ, Kaiser FG. The development of children's environmental attitude and behaviour. Global Environmental Change. 2019; 58:101947.
49. Perkins H. Interactivity and designing for children's play with digital technology: A review. Human-Computer Interaction. 2019; 34(3):267-298.
50. Pew Research Center. In response to climate change, citizens in advanced economies are willing to alter how they live and work. Pew Research Center, 2021. https://www.pewresearch.org/global/2021/09/14/in-response-to-climate-change-citizens-in-advanced-economies-are-willing-to-alter-how-they-live-and-work/
51. Pham HC, Brennan L, Parker L, Phan-Le NT, Ulhaq I, Nkhoma MZ. Enhancing cyber security behaviour: An internal social marketing approach. Information & Management. 2021; 58(2):103322.
52. Plass JL, Homer BD, Kinzer CK. Foundations of game-based learning. Educational Psychologist. 2015; 50(4):258-283.
53. Plass JL, Mayer RE, Homer BD. (Eds.). Handbook of game-based learning. MIT Press, 2016.
54. Plass JL, Homer BD, Kinzer CK. Foundations of game-based learning. Educational Psychologist. 2015; 50(4):258-283.
55. Plutzer E, McCaffrey M, Hannah AL, Rosenau J, Berbeco M, Reid AH. Climate confusion among US teachers. Science. 2016; 351(6274):664-665.
56. Rojon C, Diehl P. Gamification in climate change education: A systematic literature review. Education Sciences. 2021; 11(10):611.
57. Stern MJ, Powell RB, Hill D. Environmental education program evaluation in the new millennium: What do we measure and what have we learned? Environmental Education Research. 2021; 20(5):581-611.
58. Stern PC, Dietz T, Guagnano GA. Value-belief-norm theory and its applications in climate action research. Climate Policy Research. 2016; 45(3):321-335.
59. Stokes B, Wike R, Stewart R. Energy and climate change around the world: Insights from the 2018 Global Attitudes Survey. Pew Research Center, 2018.
60. Svihla V, Morris K. Learning climate change science through collaborative games using open-source tools. In Proceedings of the 2014 Conference on Interaction Design and Children, 2014, 417-420.
61. Taylor EW, Cranton P. The Handbook of Transformative Learning: Theory, Research, and Practice. 2nd ed. San Francisco: Jossey-Bass, 2018.
62. Tissenbaum M, Berland M, Lyons L. Designing real-time intelligent support for museum interpreters. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, 2021, 1-14.
63. Tissenbaum M, Slotta JD, Leacock T. Designing adaptive learning environments to support personalized and collaborative learning. Journal of Learning Analytics. 2021; 8(3):1-19.
64. Trenham C, Steer A, Sallu S, Marchant R, Jewitt J. The impacts of serious games on understanding complex environmental issues and acquiring knowledge relating to the 2030 Agenda for Sustainable Development. Geography. 2021; 106(2), 60-71.
65. Tsai C-C, Lin H-S, Chang C-Y, Chang YT. The effect of the pedagogical GAME model on students' PISA scientific competencies. Journal of Computer Assisted Learning. 2019; 35(3):327-339.
66. Ullah A, Anwar S. The Effective Use of Information Technology and Interactive Activities to Improve Learner Engagement. MDPI, 2020.
67. UNESCO. Education for sustainable development: A roadmap. UNESCO, 2020.
68. USGCRP. Climate science special report: Fourth national climate assessment, Volume I [D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock (Eds.)]. US Global Change Research Program, 2017.
69. Van Der Linden SL, Leiserowitz AA, Feinberg GD, Maibach EW. How to communicate the scientific consensus on climate change: Plain facts, pie charts or metaphors? Climatic Change. 2014; 126(1):255-262.
70. Villarroel V, Bloxham S, Bruna D, Bruna C, Herrera-Seda C. Authentic assessment: Creating a blueprint for course design. Assessment & Evaluation in Higher Education. 2014; 43(5):840-854.
71. Wang S, Kim J. Engaging adolescents in climate education: A framework for empowering youth. Journal of Environmental Psychology. 2019; 66:101-110.
72. Wang S, Kim D. Perceived relevance of climate change and pro-environmental behaviour: The moderating effect of environmental values. International Journal of Social Science Studies. 2019; 7(4):16-27.
73. Wibeck V. Enhancing learning, communication and public engagement about climate change – some lessons from recent literature. Environmental Education Research. 2014; 20(3):387-411.
74. Wouters P, Van Nimwegen C, Van Oostendorp H, Van Der Spek ED. A meta-analysis of the cognitive and motivational effects of serious games. Journal of Educational Psychology. 2014; (106)2:249-265.
75. Wu JS, Lee JJ. Climate change games as tools for education and engagement. Nature Climate Change. 2015; 5(5), 413-418.
76. Xie H, Chu HC, Hwang GJ, Wang CC. Trends and

development in technology-enhanced interactive/personalised learning: A systematic review of journal publications from 2007 to 2017. Computers & Education. 2019; 140:103599.