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TRINITY COLLEGE

Serious games for teaching issues to do with sustainability and climate change

Carbon Footprints at the Geopolitical Level

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Abstract

This thesis aims to delineate the development and evaluation of the "serious game" CarbonQuest, designed to promote engagement with climate change education in the classroom of adolescents and to impart users with the seed to stay booking at climate change from a geopolitical perspective. Grounded in current pedagogical literature and human-computer interaction principles, the game seeks to foster empathy for the inequality of climate change impact for countries in the poor global south and provoke relevant discourse about carbon footprints at the geopolitical level. To evaluate the effectiveness of the game a cohort of 5 Transition Year students from Irish secondary schools were engaged in a comprehensive testing process. This process involved playing games through to the end, participating in group discussions about completing questionnaires to assess engagement and learning outcomes.

The results show that the majority of participants found the game helpful in understanding the concepts of sustainability and climate change as well as in developing their appreciation for the geopolitical factors that affect climate change. However some participants felt the game's representation of sustainability and climate change issues could be more impartial and equitable.

In conclusion, CarbonQuest has demonstrated its potential to facilitate learning and engagement in climate change education specifically, the intricate interplay between geopolitical factors and environmental repercussions. Due to its small sample size more testing is required to conclusively establish its efficacy as a learning tool.

Introduction

Motivation

Climate change has emerged as one of the most important global concerns of our day, with convincing data indicating its widespread effects on the environment, economics, and civilizations *(IPCC, 2021)*. This urgency necessitates increasing knowledge and education on the subject, particularly among adolescents who will bear the burden of mitigating the effects of climate change *(Fisher et al., 2015)*. However, the current status of climate change education is poor, with considerable gaps in content, delivery, and knowledge of climate change's intricate interconnection with geopolitical causes *(Boon, 2020).*

Addressing climate change at the geopolitical level can aid in identifying and mitigating its underlying causes, particularly given the interconnected nature of global politics, economic disparities, and environmental degradation *(Hulme, 2016)*. Developing a thorough grasp of these relationships is critical for supporting effective climate action and generating empathy for countries that are disproportionately affected by climate change and inequality.

Adolescents are particularly positioned to lead the battle for a more sustainable future because they were born into a world where climate change pervades their daily lives *(Fisher et al., 2015).* As a result, it is critical to increase their understanding of climate change and its interactions with global political, social, and economic factors. Serious games—educational tools meant to impart complicated topics while engaging players in a joyful and interactive environment—are one successful approach to accomplish this *(Michael & Chen, 2006).*

Serious games, which combine the entertainment value of traditional games with pedagogical approaches that enable deeper understanding and engagement, hold enormous promise for fostering learning and driving action on climate change *(Connolly et al., 2012)*. This participatory method has the potential to stimulate social action, elicit empathy for disadvantaged populations, and empower teenagers to make educated decisions for a more sustainable and equitable society *(Annetta, 2008)*.

In summary, this thesis seeks to increase teenagers' understanding of climate change and its complicated links with geopolitical considerations through the use of serious games. The goal is to drive social action, enhance awareness of the complex linkages between climate change and global politics, and inspire the next generation of climate leaders by fostering involvement and empathy in a fun and engaging way.

Goal

The goal of this project is to build a serious game suitable for adolescents (15-17 years of age) that sheds light on the the disparities in carbon emissions between the wealthy, industrialised countries of the west and the poor countries of the global south, effectively illustrating the where the burden of responsibility falls when it comes to climate change impacts. The game should be designed in such a way that it evokes strong feelings of empathy for countries in the global south with the intent of raising awareness and solidarity.

The result should be a cooperative game that promotes relevant discourse on carbon footprints at the geopolitical level during and after the game and by extension foster a deeper understanding of the intricate connections between geopolitical factors and environmental consequences.

Additionally the game must be effective at promoting active engagement with climate change and sustainability education materials in classroom settings, thus the game will have to be grounded in current pedagogical literature and informed by Human-computer Interaction principles.

Finally the goal of this project is to rigorously test the effectiveness of the resultant game as a teaching tool, measuring its impacts on the users' learning objectives and engagement with education on climate change and the geopolitical factors that shape it.

Background

Geopolitics and Climate Change

Climate Change

Climate change and geopolitics are intricately intertwined, with the effects of climate change affecting global politics, economics, and societal structures far beyond environmental concerns. To comprehend the urgency of tackling climate change, critical measures that assist gauge the severity of the problem must be considered *(IPCC, 2014)*.

Climate change, which is mostly caused by human activities like the use of fossil fuels and deforestation, has far-reaching consequences for the Earth's ecosystems and communities. Three essential metrics are among the most alarming climate change measurements. First, a temperature increase of 2 degrees Celsius is widely accepted as the maximum limit to avoid serious and permanent implications for the planet's ecosystems, climatic patterns, and human cultures *(IPCC, 2014)*. This restriction is intended to keep the Earth's climate system stable, as it has for the previous 10,000 years *(Steffen et al., 2018)*.

The second metric is the total quantity of CO_2 emissions that can be safely released into the atmosphere, which is estimated to be 656 gigatonnes. Exceeding this limit will cause significant climate changes and intensify the effects of global warming *(IPCC, 2014)*.

The third, and perhaps most alarming number, refers to the estimated 2795 gigatonnes of fossil fuel reserves already in the inventory of energy production corporations (McGlade & Ekins, 2015). If all of these stores are depleted, the Earth will surpass the 656-gigatonne limit, resulting in significant and irreversible climate change *(McGlade & Ekins, 2015)*. These measurements highlight the critical need for global cooperation to address climate change and its geopolitical consequences.

Living in the Anthropocene Epoch

Living in the Anthropocene period, defined by human activities that have had a profound impact on the Earth's ecosystems and geology, has reshaped our perception of the interaction between humans and nature. Geopolitics, which has traditionally concentrated on state boundaries and power dynamics, has now become inseparably entangled with climate change, as the wealthier, industrial, carbon-fueled population of mankind sets the planet's future course *(Dalby, 2013)*.

In the Anthropocene, the antiquated concept of nature as separate from humanity is no longer valid. Climate change must inevitably be included as a high-profile concern for global governance in geopolitics in the twenty-first century, particularly because climate change influences volumetric geopolitics, such as resource availability and territory boundaries *(Dalby, 2013)*.

As new geoengineering technologies emerge, challenging long-held notions about state boundaries and sovereignty, new political frameworks are required to confront these transformations *(Royal Society, 2009)*. Climate change is now recognised as a geopolitical concern, with implications for geopolitical security. Climate change's implications, such as increased natural catastrophes, limited food supplies, and heightened political tensions, have spurred researchers to investigate geoengineering solutions on both regional and global scales *(Royal Society, 2009)*.

Weather modification techniques, such as cloud seeding, are being tested in this context to manage small-scale meteorological manipulations. The bigger issue of modifying the climate system on a greater scale, on the other hand, is being explored with increasing urgency. Living in the Anthropocene period necessitates acknowledging and resolving the complex relationship between geopolitics, climate change, and the growing need for creative methods of global governance *(Dalby, 2013)*.

Inequality and climate change

Inequality contributes significantly to the perpetuation and exacerbation of climate change, with direct and indirect implications for global sustainability. The mechanisms by which inequality fuels climate change are complex. One important point to remember is that wealthier, high-emission countries are predominantly responsible for past carbon emissions, whereas poorer, low-emission countries face the brunt of climate change repercussions *(Boyce, 2018)*. The unequal consumption patterns of the world's rich contribute greatly to greenhouse gas emissions, while the world's poor, who bear the least responsibility for these emissions, are the most vulnerable to the repercussions of climate change *(Jakob & Steckel, 2018)*.

Furthermore, as global warming accelerates, the unequal distribution of climate change effects becomes increasingly obvious. According to research, when global warming increases from 1.5°C to 2°C, the repercussions on human lives, ecosystems, and economies disproportionately affect the world's most vulnerable populations *(Jakob & Steckel, 2018).* Climate change exacerbates current inequalities and develops new kinds of inequality, thereby threatening global security and stability.

Addressing climate change and inequality at the same time necessitates the implementation of comprehensive policy solutions, such as the Green New Deal, which attempts to address both climate change and economic and social imbalances *(Boyce, 2018)*. Recognising and acting on the link between inequality and climate change allows for the development of more fair and effective mitigation and adaptation policies to promote global sustainability and social justice.

Inequality and climate change are inextricably linked issues that influence and intensify one another. Understanding the connection between these two global concerns is critical for designing comprehensive plans that address both climate change and inequality concurrently.

The disproportionate contribution of wealthy nations and individuals to greenhouse gas emissions is one mechanism by which inequality causes climate change. Wealthier nations, as outlined in the report "How Inequality Fuels Climate Change: The Climate Case for a Green New Deal," have traditionally been responsible for the bulk of global greenhouse gas emissions due to higher levels of consumption and production *(Roberts, 2019)*. This pattern of inequality is also visible at the individual level, with the world's wealthiest 10% accounting for roughly half of global carbon emissions *(Oxfam, 2015)*.

Aside from unequal contributions to climate change, the repercussions of climate change disproportionately affect people who are already socioeconomically disadvantaged. The research "The Inequality of Climate Change From 1.5 to 2°C of Global Warming" demonstrates how climate change consequences, such as sea-level rise, extreme weather events, and reduced agricultural production, are unequally distributed among regions and populations *(King et al., 2018).* Vulnerable and marginalised populations face the brunt of these impacts, which frequently have fewer adaptation capacities, resulting in a vicious cycle of rising inequality and vulnerability.

Furthermore, the uneven distribution of climate change effects is a reflection of social, economic, and political imbalances within and between countries. Climate change impacts low-income communities, racial and ethnic minorities, women, and other marginalised groups disproportionately, who are frequently underrepresented in decision-making processes and face challenges to accessing resources and support *(United Nations, 2019).*

Addressing these imbalances is both a question of climate justice and a strategic requirement for effective climate action. According to research, reducing inequality can help to reduce emissions because wealth redistribution and increased access to resources and opportunities can lead to more sustainable consumption patterns, increased public support for climate policies, and increased community capacity to adapt to climate impacts *(Oxfam, 2015)*.

To summarise, addressing inequality and climate change is both a question of justice and fairness, as well as a strategic imperative for effective climate action. Recognising and resolving the complex relationship between these two global crises is critical for establishing comprehensive solutions to secure a sustainable, equitable, and resilient future for all.

The current state of climate change education

Pedagogical and Serious Games Theories

Serious games are digital games that are utilised for purposes other than entertainment *(Susi, Johannesson, & Backlund, 2007)*. E-learning, edutainment, game-based learning, and digital game-based learning are all related and overlapping topics. A more formal description is provided by *Zyda (2005)*: "serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives." Zyda emphasises the value of pedagogy while emphasising the relevance of enjoyment.

Michael and Chen (2006) define serious games in their book "Serious Games: Games that Educate, Train, and Inform." They claim that serious games can help players improve a variety of abilities, while noting that not all games are appropriate for all learning outcomes *(van Eck, 2006)*. Serious games provide learners with opportunities to experience circumstances that would otherwise be difficult due to safety, cost, or time limits.

Ritterfeld and Weber (2006) distinguish three techniques to incorporating enjoyment and learning into digital games:

1. Reinforcement paradigm: As a reward for successful learning, entertaining aspects are provided.
2. Entertaining features elicit interest and attention, preparing the learner for the learning process.
3. Blending paradigm: The learning technique is interesting in and of itself, with the satisfaction of game mastery being equivalent to the enjoyment of information and skill acquisition.

These paradigms concentrate on various aspects of inner and extrinsic motivation. *Ritterfeld and Weber (2006)* also propose three potential connections between entertainment and learning:

1. More entertainment leads to more effective learning (facilitator hypothesis).
2. Linear negative (distraction hypothesis): Because entertainment distracts from learning, greater entertainment leads to lower learning performance.
3. Inverse U-shaped (moderate entertainment hypothesis): Up to a point, entertainment is advantageous to learning; after that, greater entertainment value is detrimental to learning results.

The third relationship is seen to be the most likely, because the efficiency of games for learning is dependent on how much fun players have *(Prensky, 2007)*. The distinctions between commercial entertainment games and carefully designed learning games show that there is a trade-off between fun and learning.

Human-Computer Interactions

Human-Computer Interaction (HCI) is critical in developing successful and engaging serious games for teaching sustainability and climate change topics, such as Carbon Quest. HCI is concerned with the development of interactive computing systems that prioritise human use, with the goal of improving usability, accessibility, and overall user experience *(Rogers et al., 2015/2019)*. Because HCI is interdisciplinary, it allows for the integration of diverse domains such as computer science, psychology, and design, all of which contribute to the development of more successful and user-centric programmes *(Dix et al., 2004).*

The information processing model is a basic concept in HCI that gives an understanding of how people perceive, process, and interact with information given by a computing system *(Wickens et al., 2013)*. Gestalt psychology principles also have an impact on HCI, with the laws of grouping and perception being critical in building coherent and visually appealing interfaces *(Benyon, 2019)*. Proximity, resemblance, and continuity are examples of Gestalt concepts that improve intuitive user experiences by grouping relevant interface elements *(Benyon, 2019).*

Tactile feedback is another important part of HCI because it allows users to obtain sensory information from interactive aspects in the programme, which improves immersion and engagement *(Dix et al., 2004).* Attention design implications include leveraging grouping principles and lowering memory burden, which can be accomplished through consistency, avoiding overloading short-term memory, and minimising cognitive load through the use of mental models *(Wickens et al., 2013).*

Similar applications

This section provides a brief review of some of the existing serious games and related applications that aim to educate players on climate change, sustainability and geopolitics through serious games or similar media. Through the review of these applications we aim to gain insights to inform design decisions and gain inspiration for the development of our own serious game.

The Fate of the World (2011) by Red Redemption

URL: http://www.fateoftheworld.net/

Overview: The Fate of the world is a global strategy game that has its players role play as the head of the Global Environmental Organisation. The players must make geo-political decisions and tackle a dramatic set of scenarios "based on the latest science covering the next two centuries"(steam) whilst balancing the earth resources and climate with the demands of a growing population. The game uses a scientific model developed by Dr Myles Allen of Oxford University.

Interface: The Fate of the world is a card based strategy game that allows players to enact policies on many topics from geoengineering, technological research and international aid to "resource wars, drought, famine, extinction" (steam) over several rounds. The users will be given many scenarios to consider and the users actions will determine the outcome of the game.

Evaluation: Commercially the game has been a success, Fate of the World was nominated for the 2011 Index: Design Awards and as a Top 10 Social Impact Games of 2010-11 by Games for Change and has a metacritic score of 70. As a learning tool it also performs well, a review from Jenny Bristol for Common Sense Education gives an overall review of 4 out of 5 stars to The Fate of the World as a learning tool. She praises the depth and breadth of content of the game as well and its engagement and pedagogy. The depth of the game belies a steep learning curve, however the game provides a tutorial and easy mode for new players.

Enercities (2010) by Paladin Studios

Enercities (2010) by Paladin Studios: In this game, players build and manage a virtual city while considering energy, sustainability, and environmental issues.

URL: http://www.enercities.eu/

Overview: Enercities is an educational game funded by the European Commission which tasks users with developing and micro-managing a virtual city while considering energy, sustainability and other environmental issues. As players develop their virtual cities they will require more energy and must keep a close eye on their natural resources.

Gameplay: The game has four levels, each level bringing new buildings and higher energy requirements. New buildings will require higher and higher amounts of resources to build. The gameplay duration is 100 years starting from the year 2032, to expand the city several objects types can be built, residential, industrial, environmental, “objects to boost citizens well-being” and various types of renewable/non renewable energy sources, (EnerCities, a Serious Game to Stimulate Sustainability and Energy Conservation: Preliminary Results). During the gameplay the environmental impact of energy efficiency can be adjusted through different mechanisms such as CO_2 taxes, insulation, energy efficient light bulbs etc.

Evaluation: In the paper (EnerCities, a Serious Game to Stimulate Sustainability and Energy Conservation: Preliminary Results), shows the results of quantitative and qualitative analysis on the engagement of students with Enercities, EnerCities’ impact on environmental and energy awareness on students and EnerCities’ impact on students’ energy saving attitudes. The paper shows overwhelmingly positive results across all metrics however some students were critical of the game stating that the game didn't offer new insights on energy-saving techniques in their daily lives or was too generic.

Eco (2018) by Strange Loop Games

URL: https://www.strangeloopgames.com/eco/

Overview: Eco is a sandbox simulation game where players collaborate to build a civilization in a world where resources are limited and must be managed sustainably to avoid ecological collapse. The Eco sandbox is rich in activities from constructing buildings and towns, farming and hunting to crafting and trading. Players are tasked with establishing and maintaining their own set of laws and governance, as players develop their civilisations they will need to analyse data from the game to help enact policies to prevent ecological collapse. in proposed laws such as restricting harmful activities.

Interface: The game is a 3D open-world game. Players are able to traverse across different ecosystems as they engage in the many activities in the game. The game is built on an ecological simulation that presents the data generated from user activities as evidence to support policies they may enact in the game.

Evaluation: Eco has garnered much praise and recognition from players, educators and environmental enthusiasts along with many awards since its inception. In June 2016, Eco won the Grand prize at the Climate Game Challenge at the Games for change festival in New York and in September Eco was invited to participate in the UN Climate Summit as an intervention to address the climate crisis.

Again, the game's depth and breath contribute to the learning experience. The addition of a collaborative multiplayer mode helps to increase engagement and is necessary to adequately simulate how climate policies are deliberated on and enacted in the real world. The game is a comprehensive exploration of the interconnectedness of climate change and geopolitics.

Game Design

Overview

- Carbon Quest is a serious game targeted at adolescents 15-17 year olds.
- Serious game that puts players on the global stage. They are in control of a country's resources, finances and global trade and energy production infrastructure

- The game is round based, with 3 rounds lasting 15 minutes each. Each round represents one year of passing time.
- It is a collaborative multiplayer game which tasks users with meeting energy targets each year or risk getting fined
- To hit these energy targets players must engage in trading natural resources and building and fueling power plants.
- Players will need to keep an eye on key metrics to succeed which include their non renewable energy reserves, non renewable energy capacity, carbon emissions, wealth and energy production.

Carbon Quest is a real-time multiplayer game designed to educate adolescents aged 15 to 17 about climate change, sustainability, and geopolitics. The game immerses players in a global scenario in which they control fictional countries and are responsible for managing the country's resources, finances, and energy production infrastructure.

Carbon Quest is a round based game. It consists of three rounds, each lasting 15 minutes and representing one year of time passing. Each player must reach their annual energy targets or face penalties in the form of fines. To hit these energy targets, players engage in the trading of their natural resources and wealth as well as managing the construction and operation of their power plants. Players must make strategic decisions about how to allocate their resources and invest in energy sources in order to meet their goals and achieve success in the game.

Carbon Quest requires players to closely monitor key metrics such as non-renewable energy reserves, renewable energy capacity, carbon emissions, wealth, and energy production. However even with careful balance of these metrics, players will find that success is far from guaranteed.

The game ends when the time limit is reached, and players are evaluated on their success in producing energy. The country with the highest energy production is declared the winner, and players can review their performance to learn more about the factors that contributed to their success or failure.

Inspirations

Design Decisions:

Country profiles

5 country profiles were drawn from a cartesian product of the following factors:

- Financially wealthy (FW)
- Financially poor (FP)
- Resource rich (RR)
- Resource poor (RP)
- High capacity for green energy (HGE)
- Low capacity for green energy (LGE)

The resulting country profiles were then categorised based on their combinations of factors and named CAT1 through to CAT5 respectively.

- **CAT 1:** Rich in non-renewable and renewable resources, CAT 1 is expected to dominate the game. This country can quickly achieve its energy target and then trade with resource-poor countries to acquire more wealth and build additional power plants. High carbon emissions from this country may provoke interesting conversations.
- **CAT 2:** Financially rich but resource-poor, CAT 2 is expected to construct a few power plants before exhausting its resource supply. This country may trade aggressively with less wealthy countries or establish a close trading partnership with CAT 1, employing shrewd trading strategies to reach its energy targets.
- **CAT 3 and CAT 5:** Both economically disadvantaged and lacking non-renewable resources, CAT 3 has high green energy potential, while CAT 5 has low green energy potential. These

countries may struggle to reach their energy targets, finance power plants, and find suitable trading deals.

- **CAT 5:** Financially challenged yet rich in resources and limited in green energy capacity, CAT 5 is expected to collaborate with other countries to acquire the finances needed for building power plants and producing energy. This country will be of particular interest to countries with limited natural resources.

The categorisation of countries in CarbonQuest mirrors the real-world diversity of countries in the real-world in respect to their financial wealth, resource availability and green energy potential (Karekezi et al., 2012). The decision to keep count of the country profiles to five rather than the eight that were produced from the cartesian product factors was a prudent one as the extra three countries profiles discarded were too similar to the existing profiles and would not have added any new dynamics to the game.

The inclusion of the potential of green energy or green energy capacity as factors acknowledges the global push towards sustainable development and the energy transition from fossil fuels to renewable energy (Bazilian et al., 2013). Players can explore the potential of renewable energy investments and witness the benefits and challenges associated with them.

Finally, the different categorisations represent the unequal distribution of resources and wealth in the world today. This emphasises the need for equality to be at the centre of policies surrounding climate change and climate justice *(Roberts & Parks, 2007)*. This should encourage players to think about the ethical dimensions of climate change and climate policy.

Resources

To keep things simple, resource amounts are expressed as number values without units. The number associated with non-renewable resources represents the remaining quantity of that resource, whereas the number reflecting green energy capacity represents a country's capacity to produce energy from renewable sources *(Bazilian et al., 2013)*.

Non-renewable resources cannot be regenerated in CarbonQuest, emphasising their finite nature and the significance of sustainable resource management *(Böhringer & Rosendahl, 2010).* The game omits resource extraction mechanics on purpose in order to keep the focus on the key themes and objectives, such as fulfilling energy targets, trading resources, and investing in sustainable energy infrastructure.

Power-plants

Oil-fired plants, coal-fired plants, gas-fired plants, wind turbines, solar panels, hydroelectric dams, geothermal turbines, and nuclear plants are all featured in the game. The power plants chosen represent a varied spectrum of both non-renewable and renewable energy sources that are commonly employed in the actual world, providing a thorough overview of energy production technologies *(Chou et al., 2014)*.

When a power plant is purchased, it is immediately added to the player's inventory, without the requirement for construction materials or time. This design choice streamlines gameplay and allows players to focus on strategic energy production and resource management decisions.

Although the power plants' costs, carbon emissions, and fuel amounts are not accurate representations of real-world data, an effort has been made to keep some semblance of realism, such as the relative carbon emissions of each plant type. However, game balance and educational objectives take precedence above overall realism.

The game also adds the concept of limited green energy capacity to reflect the fact that some countries may have geographical or environmental limits in harnessing specific renewable energy sources *(Karekezi et al., 2012)*.

Power plant fuel consumption consumes resources, and in order to balance, green energy plants will draw from the equivalent green energy capacity. The energy production process immediately generates energy and, if applicable, emits carbon emissions. The game only enables one fueling instance at a time before returning the player to the home page, restricting the rate of energy production and encouraging strategic decision-making.

By purchasing numerous plants of the same type, players can boost their country's energy production rate. Owning 'n' solar panels, for example, provides for the generation of 'n' times the energy produced by a single panel at the cost of utilising 'n' times the green energy capacity. This approach encourages investment in power plants later in the game, as energy demands increase, influencing the game economy.

Trading

The CarbonQuest application relies heavily on trading and negotiating with other players. Players can trade non-renewable resources between each other or buy resources from other players for cash, encouraging collaboration as well as competitiveness and strategic decision-making.

Players in CarbonQuest can accept or reject incoming trade proposals. Communication and negotiation take place in real time, requiring either in-person interactions or the use of telecommunication tools. Due to technical constraints and to encourage active interaction among players, verbal communication was chosen as the channel of communication, strengthening the social aspect of the game. It also simulates real-world resource negotiations and diplomacy dynamics.

Trading as the only way to obtain extra resources and money adds a dimension of complexity to the game, compelling players to engage in strategic interactions with one another. This design decision emphasises the importance of effective communication and cooperation in addressing global concerns linked to energy, sustainability, and climate change (Chou et al., 2014).

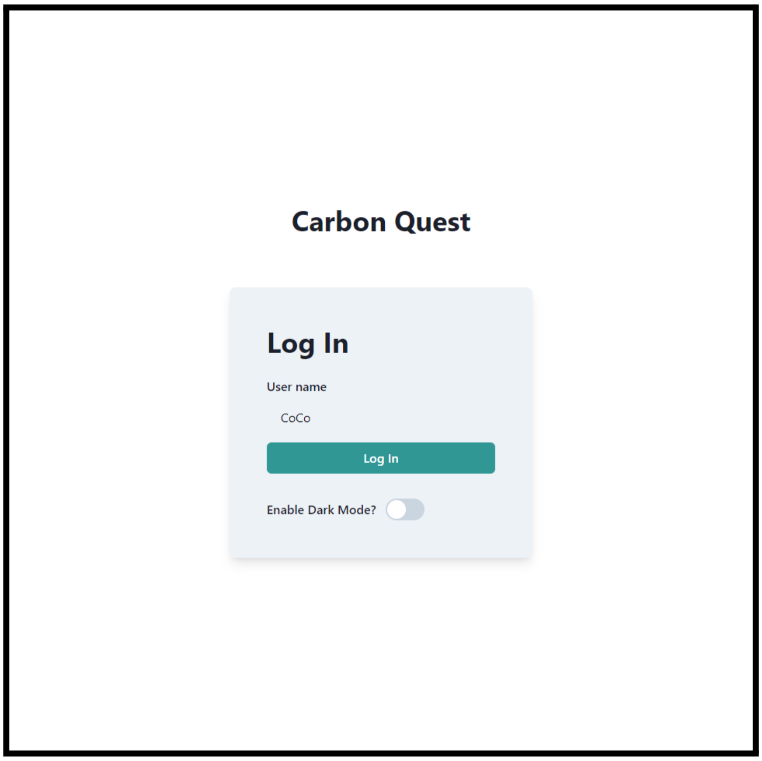
Rounds and fines

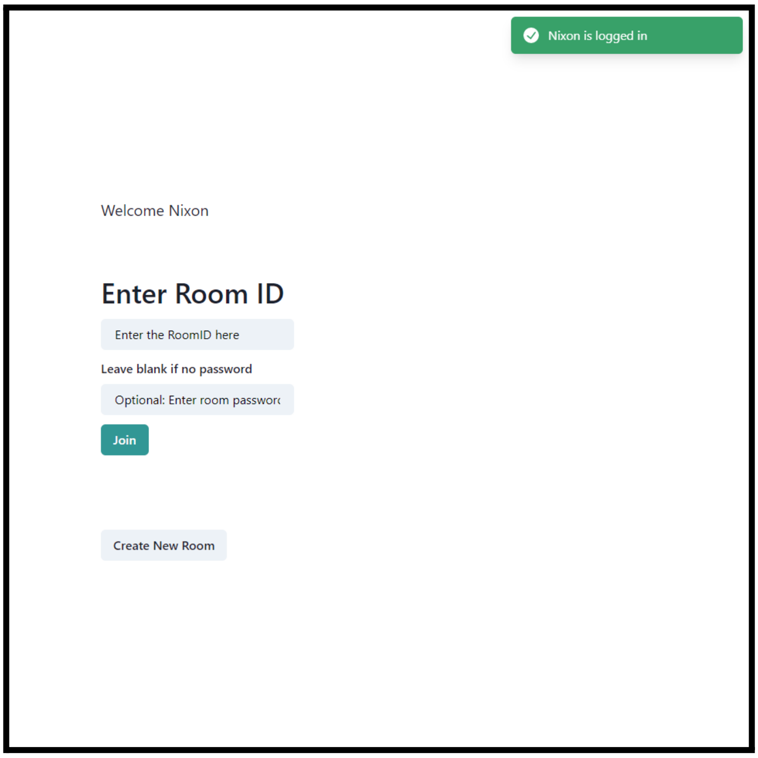
Each round lasts 15 minutes and represents a year, giving participants enough time to plot, negotiate, and execute trades. If a player fails to meet their energy target, they are fined 500 euros, which represents the necessity to borrow money to cover the remaining energy expenditures. Despite the lack of interest in the game, this punishment mechanism emphasises the financial consequences of insufficient energy production and motivates players to carefully manage their resources and develop efficient strategies.

Rigging the game

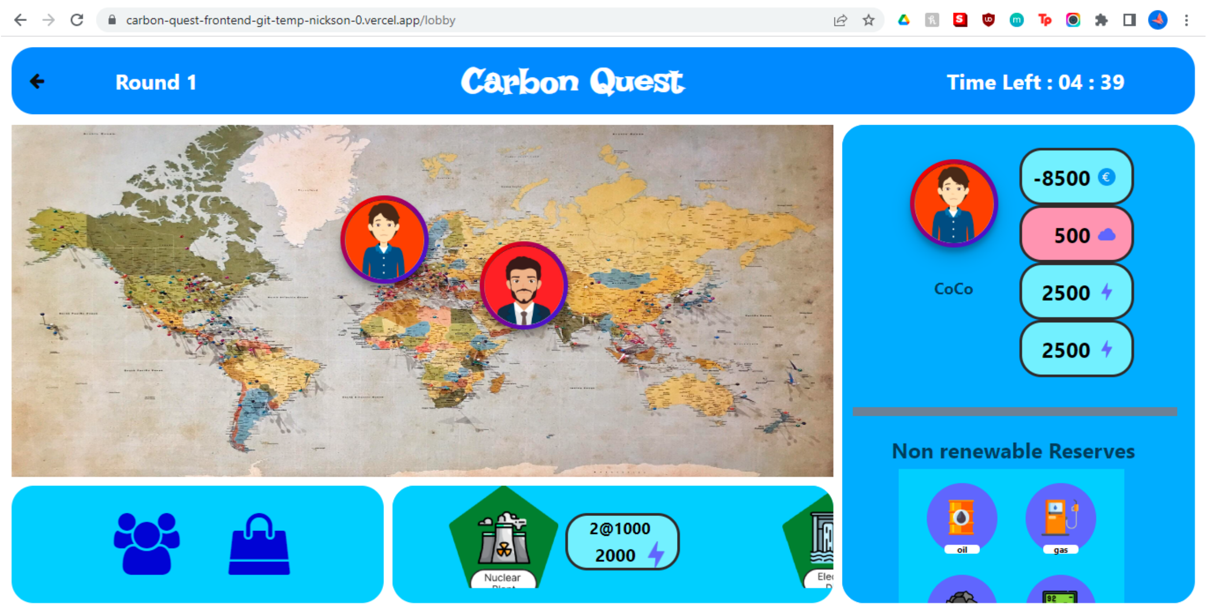
CarbonQuest is designed in a way that ensures that countries will fail to meet their energy targets, reflecting the issues experienced by countries in the Global South. This design choice is intended to elicit strong feelings of empathy among participants while also raising awareness of the unequal distribution of resources and opportunities in the global energy landscape.

Screen Design

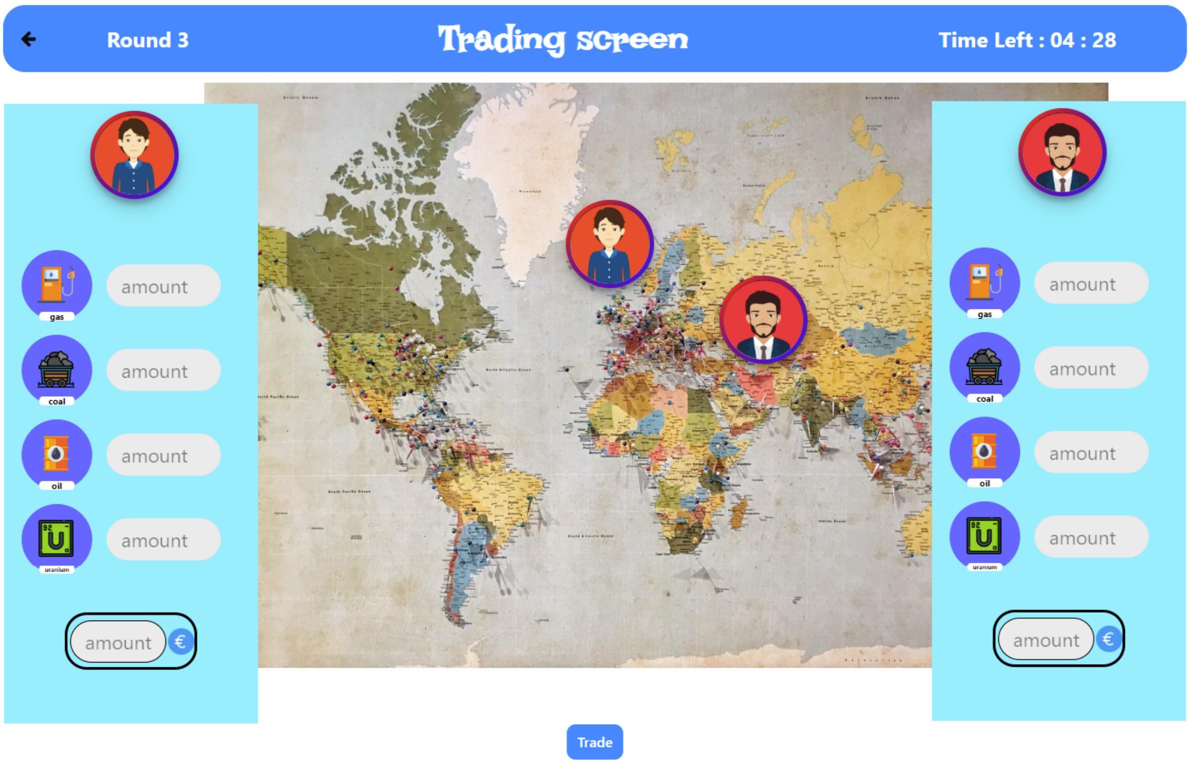


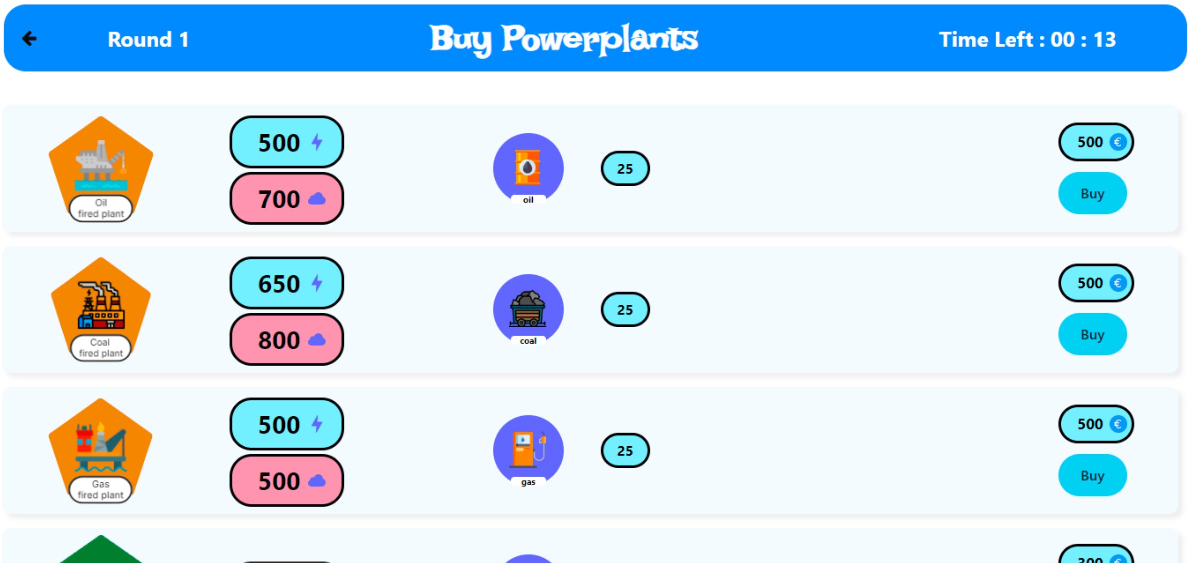

Nixon is logged in
Welcome Nixon
Enter Room ID
Enter the RoomID here
Leave blank if no password
Optional: Enter room passwor
Join
Create New Room

These three screens show how a users logs into to the CarbonQuest application. The current application has new users created through and API call or direct update to the database. For evaluation purposes the database was filled with pre-configured profiles.



This is the main page of the application. We use gestalts theory to inform the design of this and subsequent screens, this includes but is not limited to proximity (metrics, resources, activities), continuation and consistency.





Project Specification

Project Considerations

Project Scope

The game is a loose simulation of countries on the global stage trading amongst each other to acquire the resources needed to invest in and fuel various power plants with the objective of reaching their energy requirements within some time constraint. It is by no means a high-fidelity simulation of the global trade of resources and materials. The game is designed to portray the elements of global trade that are relevant to the themes and objectives of the application and to encapsulate some core albeit simplified principles of economics such as scarcity, supply and demand, costs and benefits and incentives.

Given the intended audience of this application, the complexity and near-infinite ceiling of granularity that a simulation of global trade may have, several constraints were imposed on the game.

- **Simplified economic model:** The game has its own simplified economic model to increase accessibility and to avoid distracting users from the main objective of the game. The amount of resources available has been limited to ensure that the principle of supply and demand is illustrated faithfully in the game; however, users are free to implement their own trade strategies and policies. Trading has been heavily simplified and will take the form of quick-fire verbal negotiations and agreements between users. Apart from trading, there are no other economic actions available to users and concepts like resource extraction and supply chains have been abstracted or implied but not implemented.

- **Limited resources and power plant options:** To keep the game focused and manageable, the number of resources and power plant options available to players have been limited. The game includes a specific set of resources and power plant types that are relevant to the game's objectives and theme.

- **Reduced realism:** Game balance and educational objectives take precedence above overall realism.

Functional requirements

1. **Resource trading:** Users should be able to initiate and accept trade offers with other players for resources and money.
2. **Resource management:** Users should be able to manage their resource inventory, including viewing the resources they have collected and traded, and the current balance of the money.
3. **Real-time communication:** The game should allow real-time communication between players, i.e changes in the game state should be visible to all connected clients
4. **Game state:** The game should maintain a current state, including the positions and resources of all players, and game variables such as time elapsed.
5. **Multiplayer support:** The game should support multiplayer, including the ability to create or join game sessions, and the ability to view other players' game state.
6. **Cross-platform support:** The game should be able to run on popular web browsers such chrome, firefox and edge

Non-functional requirements

1. The game should be built using principles drawn from human-computer interaction design principles.
2. The game should be able to grounded in pedagogical and serious games literature
3. The game should be dependable and free from faults preventing players from enjoying themselves while playing.
4. The game should be simple to operate, with easy-to-understand controls and detailed instructions.

Initial technology choices

A web application was decided as the most prudent medium to deliver this serious application for a number of reasons:

- The researchers own experience with building web applications
- **Maintainability:** Hosting services such as Heroku and Vercel and many others allow web applications to be maintained and updated with relative ease. This allows for fast bug fixing and content updates with little to no downtime. These tools are also very beginner friendly.
- **Accessibility:** To be effective for as many users as possible this application needs to be accessible. A web application is a medium that is accessible on many modern devices and does not require the download of additional software.
- **Time constraints:** Compared to other media, web applications can be developed relatively fast. This is ideal given the time constraints of several academic months for this project

The following are technologies that were considered for building the application:

Frontend

Language: Javascript, CSS, HTML

Framework: React

React is a popular frontend framework for javascript that allows developers to quickly build user interfaces. React is all about reusing UI components which can be composed to create large and more complex UI components. React components can then be defined as a Javascript function or class that returns JSX (this is a syntax extension to JavaScript that allows you to write HTML-style code). This allows one to leverage their skills in CSS and HTML. React adds interactivity through stateful components and has many tools to handle complex state management.

React was used for this project specifically because of its robust state management tools that ease the process of managing and updating the application data. The application requires a dynamic UI, capable of synchronising real-time updates between five different users. React combines this robust state management with a virtual DOM (Document Object Model). The virtual dom allows for fast and responsive rendering of dynamic content.

State management: Redux

Redux toolkit is a library commonly used in React applications to manage complex application states. Redux works by creating a central "store" that can be accessed by different parts of the application. It is particularly useful in larger complex apps

Redux was selected over other alternatives such as MobX and Apollo Client, primarily because of the researcher's experience, compatibility with React and its fit for the requirements of the application. Redux is used to manage CarbonQuests state and handle real time updates to the user interface.

Hosting: Vercel

Vercel is a cloud-based platform used for hosting and deploying web applications. Vercel offers performance and scalability to a web application and is remarkably easy to use. With some configuration Vercel also works with popular tools for real time communication such as Socket.IO.

Vercel was chosen to host the frontend of the application but not the back end. Issues with configuring Vercel for websockets made heroku more suitable hosting for the backend. Vercel was chosen over the likes of AWS and Firebase primarily because of its ease of use and the experience of the researcher

Language: Node.js

Framework: Express

Node.js and Express allow for robust web applications to be written in javascript. They are both remarkably easy to use and learn, thus making the development process faster. Express provides utilities that handle routing, middleware and much more.

Node.js and Express are the backbone of this application. They are used to implement the game logic and handle HTTP requests as well as requests from websockets. Node.js was chosen over the likes of Ruby on Rails, Django etc because of its ease of use, the researchers experience and its compatibility with preceding technologies.

Database: MongoDB

MongoDB is a NoSQL database perfect for handling data that are better represented as objects rather than records. MongoDB uses a document-oriented data model that is very flexible and allows the development process to be dynamic. MongoDB was a great choice to use as it better represented the data in CarbonQuest and significantly sped up the development process.

MongoDB Atlas was used to deploy and host the MongoDB backend. MongoDB Atlas provides a reliable way to handle large volumes of unstructured data. Node.js was used to interact with MongoDB atlas.

Hosting: Heroku

Heroku is a similar application to Vercel. It is another cloud-based hosting service that allows developers to quickly deploy and manage web applications. Heroku was used in conjunction with Vercel to host the Carbon Quest application. Heroku was better suited for configuring web sockets used to handle trading within the game.

Real-time communication: SocketIO

Socket.IO is a javascript library used to handle the real-time communication in this web application, this included updates to the game state and for trade offers. Socket.IO integrated seamlessly with the other technologies listed and was the obvious choice over options like SignalR and Pusher. Socket.io shines in its ability to handle bidirectional communication and it also reconnects players that disconnect automatically which is crucial.

These choices of technologies make up the MERN Technology stack and offer scalability, cross scalability, cross-platform compatibility, and seamless real-time communication.

Tech stack Comparison

Building a real-time multiplayer resource management game requires a technology stack that offers scalability, cross-platform compatibility, and seamless real-time communication. This evaluation will demonstrate why the MERN stack, comprising MongoDB, Express, React, Node.js, and Socket.IO, is the most prudent choice for this project, based on the application requirements. We will do this by comparing the different technologies within the MERN stack to corresponding technologies in alternative technology stacks and compare their merits.

Comparison with Alternative Technology Stacks

- MEAN Stack (MongoDB, Express, Angular, Node.js): The MEAN stack shares many similarities with the MERN stack but uses Angular instead of React. Although Angular is a powerful framework, it has a steeper learning curve and a more complex architecture. React's performance optimization, simplicity, and wider adoption make MERN a more prudent choice for this application.
- LAMP Stack (Linux, Apache, MySQL, PHP): The LAMP stack, a traditional web development stack, lacks the real-time communication capabilities required for this project. Additionally, the synchronous nature of PHP may hinder the application's ability to handle multiple concurrent connections efficiently. MERN's asynchronous nature and Socket.IO integration provide a more suitable foundation for a real-time multiplayer game.
- ASP.NET Core + SignalR: Although ASP.NET Core and SignalR offer a strong alternative for real-time communication and scalability, they require knowledge of the .NET ecosystem and

may limit cross-platform compatibility. The MERN stack's JavaScript-based nature ensures compatibility across various platforms.

The MERN stack, with its powerful combination of MongoDB, Express, React, Node.js, and Socket.IO, offers a scalable, cross-platform, and efficient solution for building a real-time multiplayer resource management game. Its advantages over alternative technology stacks, such as MEAN, LAMP, and ASP.NET Core + SignalR, make it the most prudent choice for this application.

System architecture

This section analyses different possible architecture approaches for rendering the web application.

Client-Side Rendering (CSR):

- The server sends an HTML file and uses JavaScript to fetch data and populate the UI.
- Content is rendered in the browser by JavaScript after the initial page load.
- The application makes API calls to the server to fetch data and updates the DOM using JavaScript.
- CSR can be used to create responsive applications. The applications are generally fast after the initial load.

Server-Side Rendering (SSR):

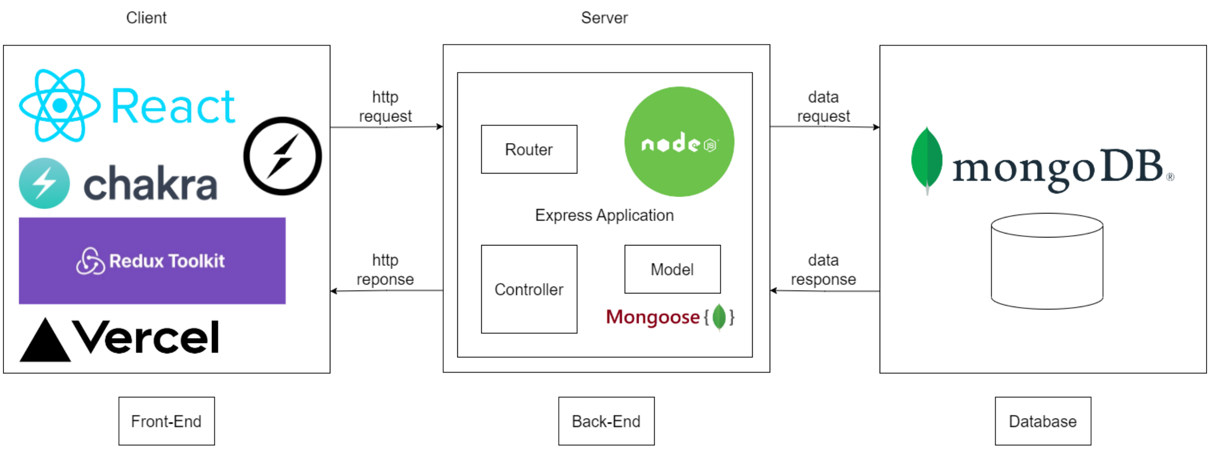
- The server renders the HTML file based on a request from the application before sending it to the client.
- The application browser receives a fully populated HTML file and displays the contents without waiting for JavaScript to fetch any more data.
- SSR, can be slow and is better suited for static websites. SSR is not the best choice for dynamic applications

Hybrid Rendering (also known as Universal or Isomorphic Rendering):

- Combines CSR and SSR, rendering the initial view on the server and then updating the view using JavaScript.

- However, although the server sends a fully populated HTML file, the application still relies on JavaScript for interactivity and further updates.
- Can be a technical challenge to set up

Given the requirements of the application a structure that enabled the application to be reponsive with fast load times was crucial. The application has many dynamic and slow load times would hurt the application thus Client-Side Rendering using React was chosen.



Implementation

The Implementation section of this thesis is dedicated to elucidating the process of bringing the Carbon Quest application to life. First, we will explore the development and integration of the game's core logic, outlining how each function contributes to the themes and objectives of the application, and ultimately, the overall functionality of Carbon Quest. This discussion will offer a comprehensive understanding of the mechanics underpinning the educational experience.

API implementation

Modelling users

The user model, as with all models discussed in this section, was created using Mongoose within our Node.js based backend. The user model has the following fields: username, resources, energy production, power plants, and three additional fields used to handle game session segmentation.

In addition to the user model, a corresponding user controller was created to manage the game's logic and user interactions effectively. The user's controller serves as an intermediary between the user models and the game environment, ensuring smooth and accurate communication of information.

The user's controller incorporates the following functions:

1. Create a new user
2. Retrieve all users
3. Retrieve users by room ID
4. Retrieve a single user by ID
5. Update a user by ID
6. Delete a user by ID
7. Calculate the energy production
8. Calculate the carbon emissions
9. Update a user's money

While not all of these functions were utilised in the current version of the Carbon Quest Application, this robust set of functions provides a solid foundation for future development and allows for scalability as the project grows. The decision to build out the controllers of the application thoroughly was a demonstration of the commitment to extensibility and the principles of good software engineering.

In conclusion, the user modelling and corresponding user controller play a pivotal role in Carbon Quest's implementation. The Mongoose-based user model accurately captures the various country profiles and the themes of resource inequality and trading leverage from the real world. The user controller ensures the game's logic and player interactions are managed seamlessly, enabling fluid gameplay and an engaging user experience.

In order to approximate the real-world scenario, promote critical thinking, and develop meaningful dialogues among players, significant thought was given to the resource allocation and trading dynamics throughout the implementation process. Carbon Quest's complexity, while difficult to implement, substantially adds to its instructional value by giving users an enhanced understanding of the difficulties of global resource management and climate change.

Modelling the resources

- What resources are there
- The value and scarcity of resources
- Green energy capacity
- The fact that you cannot trade green energy resources

Trading and negotiating

Trading and negotiating with other players is a key activity in the CarbonQuest application. In the Carbon Quest application, players can trade non-renewable resources with each other. Each player also has the option to accept and reject incoming trades. In this current version of the Carbon Quest application negotiation takes place verbally in real-time so players must be able to communicate in person or via telecommunication software.

This section concerns itself with implementing the trade logic through the trade model and controller and supporting library socket.io to handle bi-directional communication between the server and the connected clients as they send and receive trade offers.

The trade model has the following fields and attributes:

- **Seller:** Reference to User model
- **Recipient:** Reference to User model

- **ResourcesOfferedPlayer1:** An array of objects containing the non-renewable resources and its amount offered by player1
- **ResourcesOfferedPlayer2:** An array of objects containing the non-renewable resources and its amount offered by player2
- **SenderMoney:** Integer value representing the money offered by player1
- **RecipientMoney:** Integer value representing the money offered by player2
- **Status:** The current status of the trade (e.g. pending, accepted, rejected)

The following figure is an example of the trade document in mongoDB atlas.

```
  _id: ObjectId('6426a5e186ec269d4cbb24dc')
  senderId: ObjectId('6421a7cce3687deca6619703')
  recipientId: ObjectId('6421b369e3687deca6625a27')
▸ senderResources: Array
▸ recipientResources: Array
  senderMoney: 0
  recipientMoney: 250
  status: "accepted"
  __v: 0
```

This model was implemented with Mongoose

The corresponding trade controller implements the trade logic with the following functions:

1. Create trade: this function is responsible for creating the trade offer that will be sent between players. This function validates if the sender and recipient exist and are different users, validates that the sender has enough resources and money, sets the trade status to “pending” and creates and saves a new trade document to the database.
2. Accept a trade: upon a player accepting a trade offer, this function finds the trade documents by ID and updates the recipient’s and the sender’s resources and money amount to reflect the trade.
3. Reject a trade: this function finds the rejected trade document and updates the status to rejected.

The client side and the server side of the application communicate with each other through web sockets. On the client various event functions are used for the game logic behind making a new trade, accepting a trade offer and rejecting a trade offer. When these events are triggered these websockets emit these events to the server. In the server these events and the server side updates the application accordingly.

1. Requesting a new trade using socker.emit('requestTrade', { data: resource }).
2. Accepting a trade using socker.emit('acceptTrade', { data: localStorage.getItem('tradeId') }).
3. Rejecting a trade using socker.emit('rejectTrade', { data: localStorage.getItem('tradeId') }).

Purchasing power plants

The power plant model provided is defined using Mongoose, a MongoDB object modelling tool designed to work in an asynchronous environment. Mongoose provides a simple schema-based solution to model application data.

- The powerPlantSchema is created using the mongoose.Schema constructor. The schema has the following fields:
- type: The type of power plant. The valid power plant types are defined in the enum array and must be one of the following: 'Oil-fired Plant', 'Coal-fired Plant', 'Gas-fired Plant', 'Geo-Turbine', 'Nuclear Plant', 'Solar Panel', 'Wind Turbine', or 'Electric Dam'. This field is required.
- fuelType: The type of fuel used by the power plant. The valid fuel types are defined in the enum array and must be one of the following: 'uranium', 'solar', 'geoThermal', 'hydro', 'wind', 'gas', 'coal', or 'oil'. This field is required.
- energyProduction: A number representing the energy production of the power plant. This field is required.
- CO2 Production: A number representing the carbon dioxide (CO2) production of the power plant. This field is required.

- fuelAmount: A number representing the amount of fuel required for the power plant. This field is required.
- price: A number representing the price of the power plant. This field is required.

The power plant controller provided imports with the PowerPlant model and User model to interact with the respective data in the database. It contains the following functions to handle various CRUD operations and game logic related to power plants:

1. createPowerPlant: This function creates a new power plant document in the database using the information provided in the request body.
2. getAllPowerPlants: This function retrieves all power plant documents from the database.
3. getPowerPlantById: This function retrieves a single power plant document by its ID
4. updatePowerPlantById: This function updates a power plant document by its ID
5. deletePowerPlantById: This function deletes a power plant document by its ID
6. buyPowerPlant: This function handles the logic for a user to purchase a power plant.
7. updatePowerPlant: This function updates a user's power plant based on the countValue and the power plant's fuel type, energy production, and CO_2 production. It updates the user's energy production and resources (non-renewable or renewable) accordingly.

The frontend implementation for buying power plants in the game is done using React.

MarketPlace Component:

The MarketPlace component is responsible for fetching and rendering all power plant items in the market. It utilises the Redux library for state management and dispatches the fetchAllMarket action to fetch the power plants from the backend API. Once the power plants are fetched, the component updates its local state allMarket with the fetched data.

Fueling Power Plants

A single function found in the powerplant controller handles the logic for fueling power plant:

- This function handles the fueling of power plants in the game. It is an asynchronous function that takes a request object and a response object as arguments. The request object contains the user ID, power plant ID, and the count value which represents the amount of fuel the user wants to purchase.
- It starts by finding the power plant in the database using the power plant ID provided in the request.
- If the power plant is not found, it returns a 404 status code with an error message.
- If the power plant is found, it finds the user in the database using the user ID provided in the request.
- It then checks if the power plant has a non-zero CO2 production, indicating that it uses non-renewable resources.
- If the power plant uses non-renewable resources, it calculates the user's new CO2 production and updates the non-renewable resource's amount accordingly.
- If the power plant uses renewable resources, it checks if the fuel type is 'uranium', updating the non-renewable resource's amount in that case. Otherwise, it updates the renewable resource's amount.
- The user's energy production is increased based on the power plant's energy production multiplied by the count value.

The frontend then handles error checking before sending a request to the API.

Testing and Evaluation

Planned workshop and evaluation session

Participants in the application's testing phase were chosen from Transition Year students in Irish secondary schools participating in the Bridge21 programme. Permission for this study project was acquired from the school administration and the board of management. Permission for this study was also granted by the ethical committee at Trinity College Dublin.

During the testing phase a cohort of were introduced to CarbonQuest and instructed on how to play the game. Every student had their own computer.

Students then had the opportunity to play the game together to completion. Communication with the researcher was purposefully kept to a minimum in order to allow students to organically achieve the learning objectives included within the serious game. Upon completion of the game, the students gathered as a group to discuss their experiences.

Following the group conversations, students were asked to complete a questionnaire meant to assess user engagement with the learning material, as well as to identify potential barriers and limitations in using the serious game as a teaching tool. The data acquired gave insights into the application's efficacy in facilitating learning and engaging pupils in the subject matter.

A supervising educator was also present during the assessment process, in addition to the student testing. They offered vital insights into the educational features of the microworld by providing their pedagogical viewpoint on the application. Their knowledge enabled a more thorough evaluation of the application's effectiveness as a teaching tool, as well as the identification of areas where changes could be made to better fit with educational aims and teaching practices.

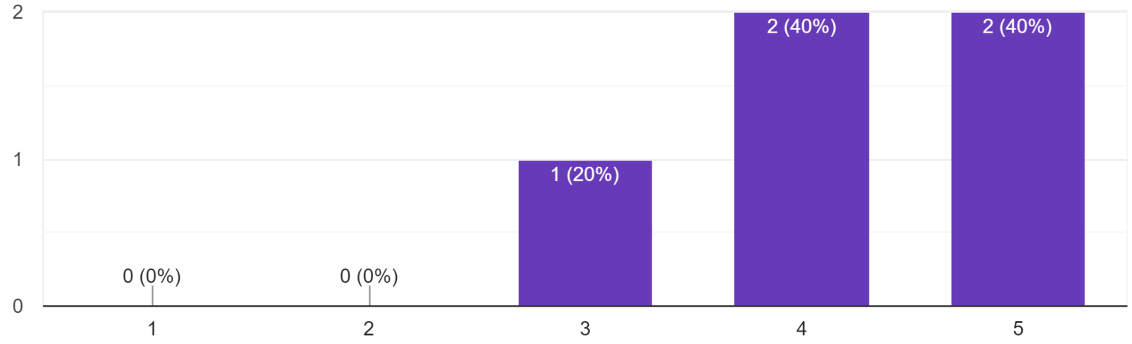
Results

The Questionnaire was divided into two sections: a usability section and a learning objectives section.

The results from the usability section are as follows:

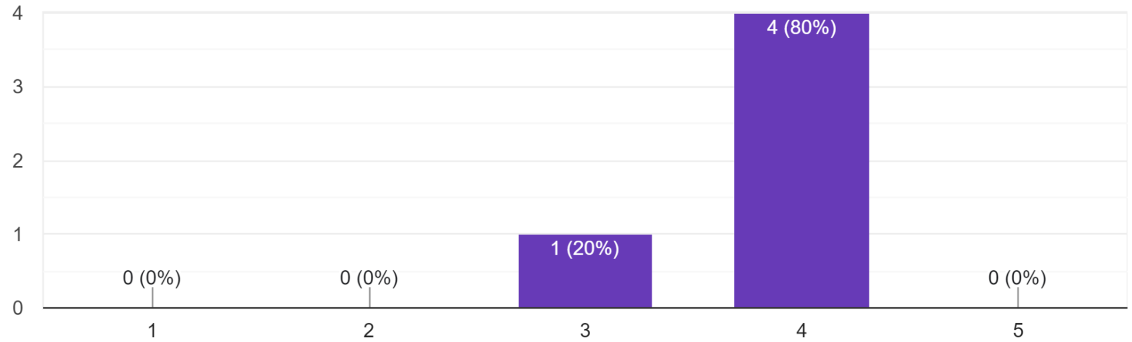
How well did the microworld help you understand the concepts of sustainability and climate change?

5 responses



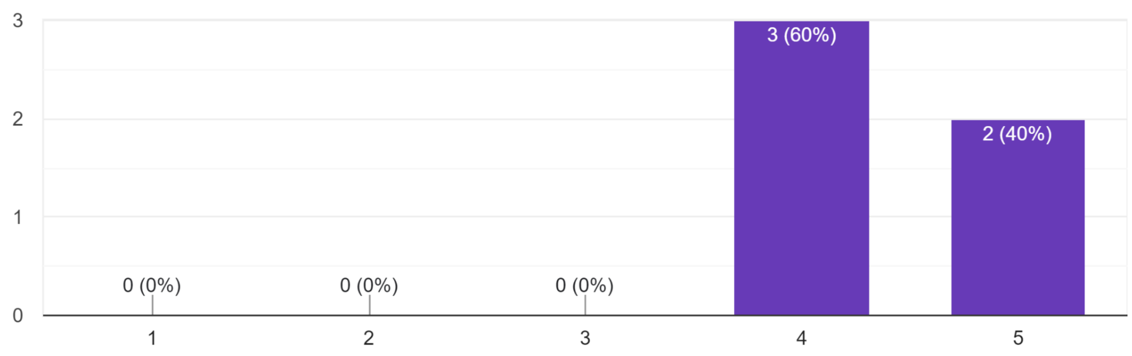
To what extent did the microworld help you develop your problem solving skills?

5 responses



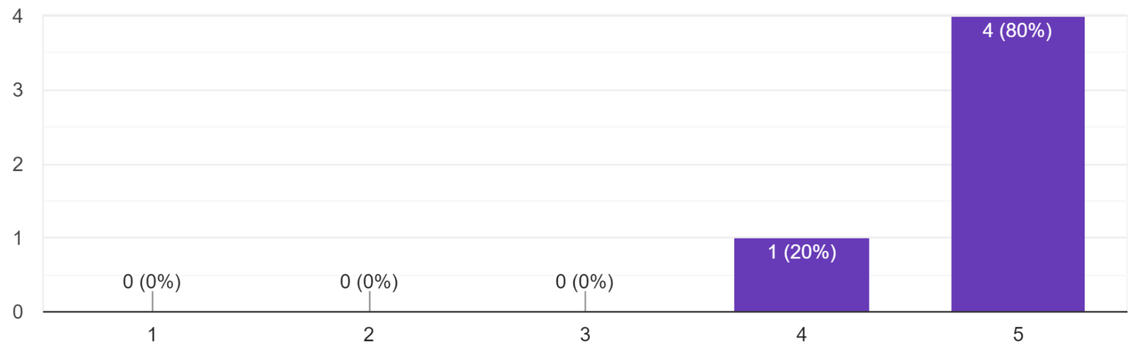
To what extent did the microworld help you develop your critical thinking skills?

5 responses



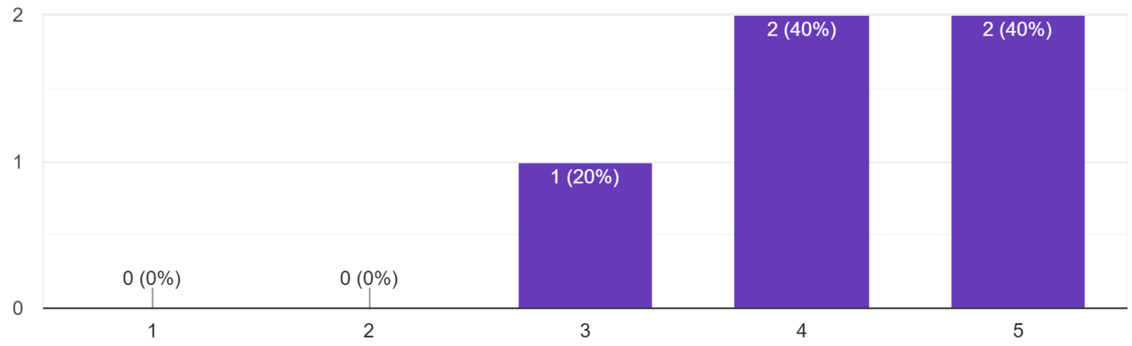
How engaging did you find the microworld?

5 responses



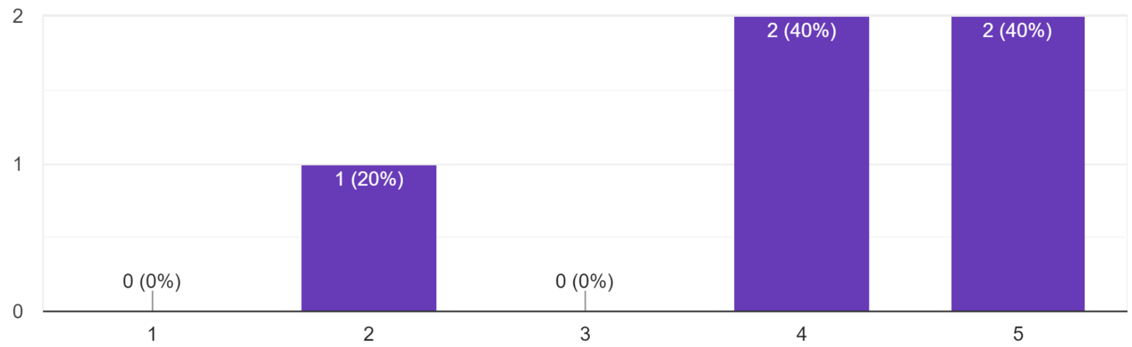
To what extent did the microworld help you understand the interconnected nature of the global economy and the role that governments and large or...ions play in driving or mitigating climate change?

5 responses



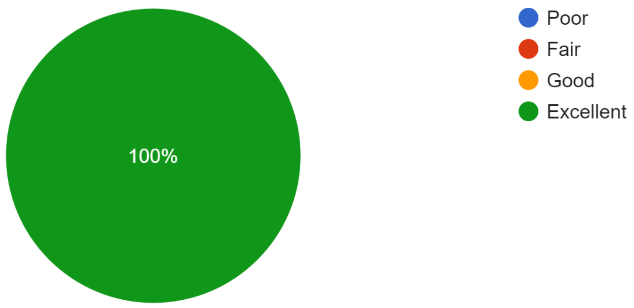
How accessible and user-friendly did you find the microworld?

5 responses



Overall, how would you rate your experience with the microworld?

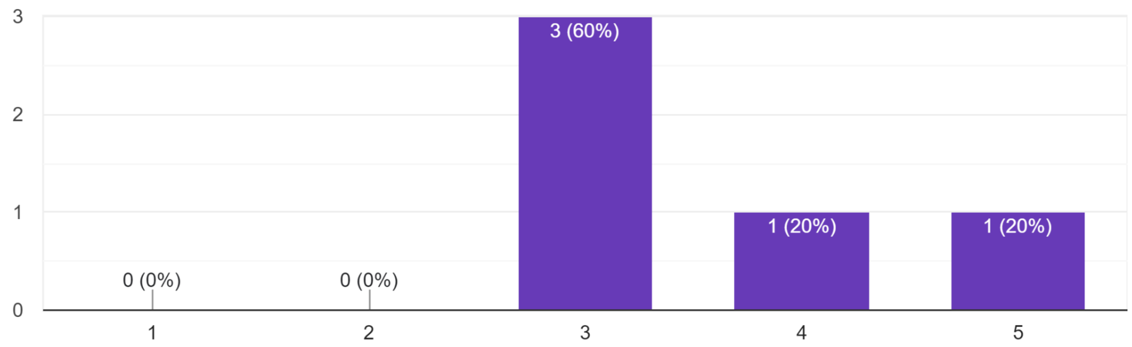
5 responses



The following sections covering the learning objectives:

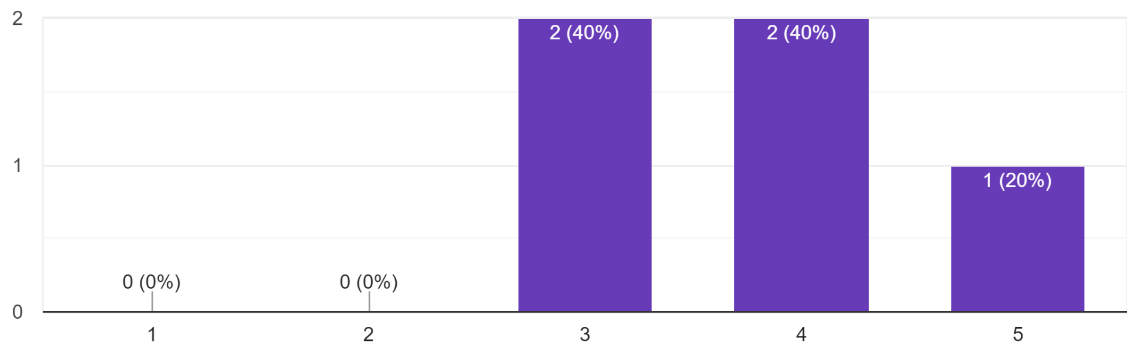
How fair did you perceive the microworld to be in its representation of sustainability and climate change issues?

5 responses

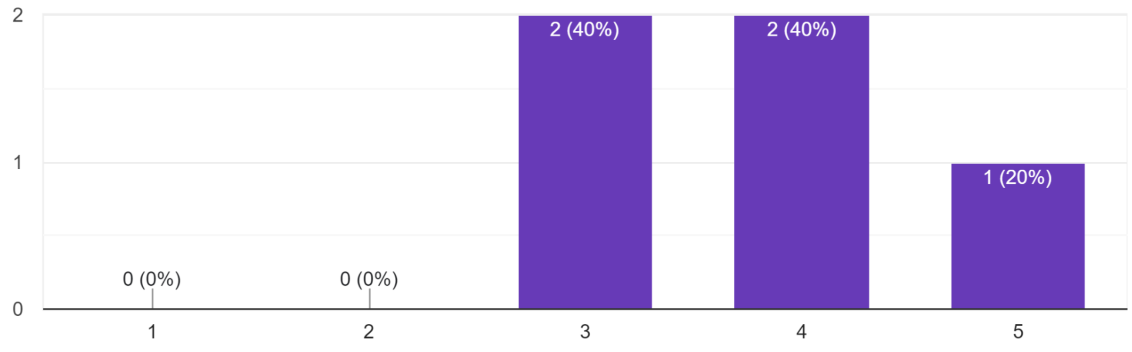


How impartial did you perceive the microworld to be in its representation of the role that governments play in driving or mitigating climate change?

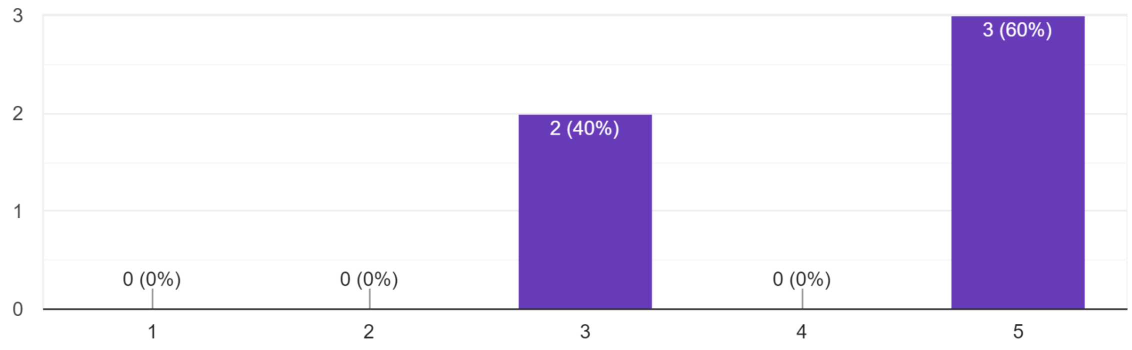
5 responses



How equitable did you perceive the microworld to be in its representation of the impacts of climate change on different populations and regions?
5 responses



How balanced did you perceive the microworld to be in its representation of the trade-offs and challenges associated with achieving sustainability and mitigating climate change?
5 responses



Do you believe that the microworld represented a fair and accurate depiction of the issues related to sustainability and climate change, or did you feel that it was biased or incomplete in any way? If so, please explain.

"yes"

"yes, because it showed how it's easier for countries to trade in non renewable resources because its cheaper than renewable energy"

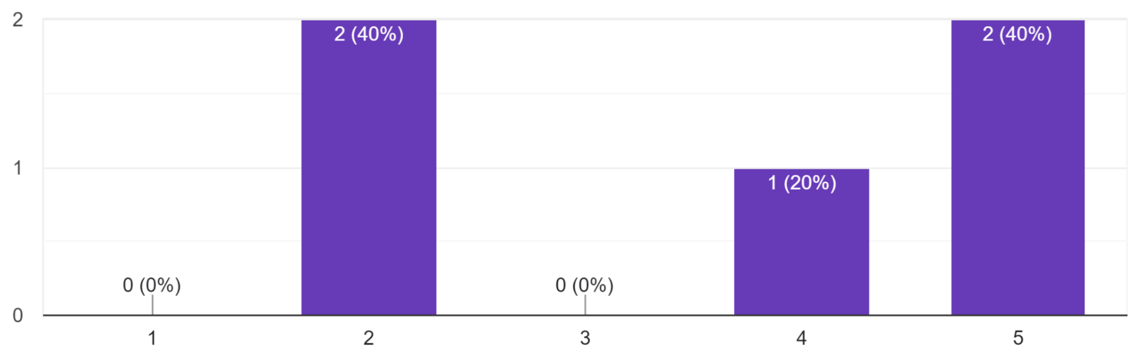
"yes because the rich countries are in control and the poor countries have nothing"

"I think the microworld represented an accurate depiction of the issues related sustainability and climate change."

"Pretty fair, the limited reasources and insistence on trading made sense in the endh my country starved our rivers dried and the sun dissapeared, even then my fate never changed, as god was real and he hates us."

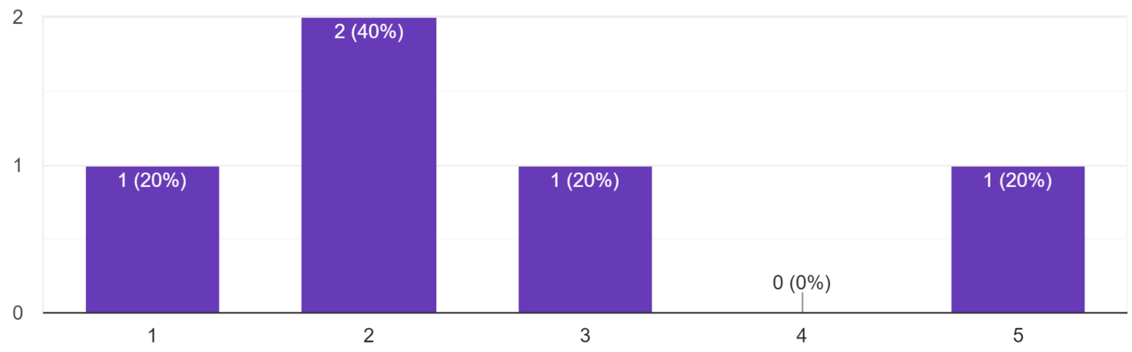
How challenging did you find the negotiation and resource allocation elements of the microworld?

5 responses

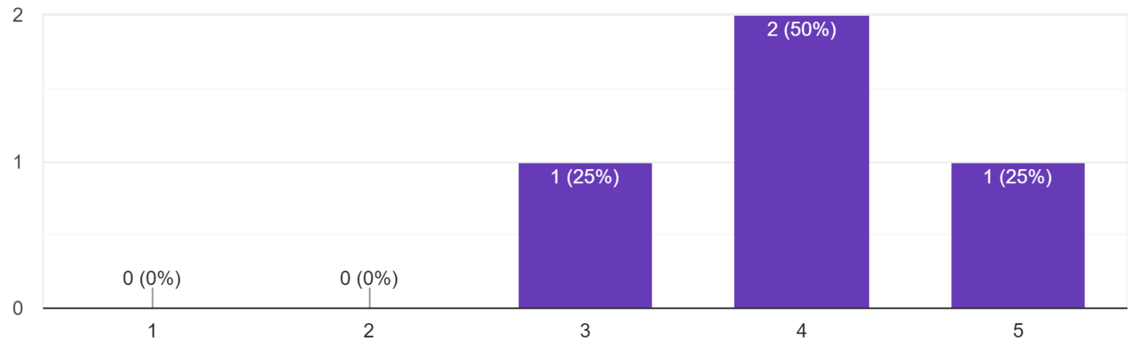


How frustrating did you find the negotiation and resource allocation elements of the microworld?

5 responses



How did the negotiation and resource allocation elements of the microworld impact your trust in the other players?
4 responses



Were there any strategies that you employed while negotiating and allocating resources in the microworld? If so, please describe them. ("Please do not name third parties in any open text field of the questionnaire. Any such replies will be anonymised.")

"i sold off my non renewable resourses at a high price"

"trading more money that the resources were worth as i was a wealthy country"

"ask for more than needed"

"Trading resources I didn't need as much, in return for things I needed more, eg. money."

"The richer countries had nothing to gain from me therefore they left me die like a dig in the street a waste of space and sinking ship left to rot."

How did the negotiation and resource allocation elements of the microworld impact your understanding of the issues related to sustainability and climate change? ("Please do not name third parties in any open text field of the questionnaire. Any such replies will be anonymised.")

“it helpes me understand that some pepe value different resourses differently”

“i learned more about why countries tend to shy away from renewabke energy”

“It all helped me understand the issues related to sustainability and climate change, and in fact made me realize that the richer countries will trade more strategically rather than out of good will.”

“if you have nothing to give you will get nothing, good will dosent exist”

Evaluation summary

The CarbonQuest serious game was evaluated with a cohort of n=5 students who completed a questionnaire. Overall, the results demonstrated that the game was beneficial to the majority of participants in grasping the ideas of sustainability and climate change. The majority of respondents rated the game highly for its ability to help them improve problem-solving and critical thinking skills.

In terms of engagement, the majority of participants found the game to be entertaining. However, there were some mixed feelings about the game's usability and accessibility. Despite this, all participants evaluated their overall microworld experience as great.

The results of an assessment of the game's representation of sustainability, climate change challenges, and the role of governments were mixed. Some players thought the game was fair and accurate, whilst others thought it was biassed or incomplete. A few students went on to explain further, stressing both positive and negative parts of the game's depiction of these topics.

The students found the negotiation and resource allocation elements to be tough and sometimes irritating, but they appeared to contribute to a deeper grasp of the concerns surrounding sustainability and climate change. Participants reported using a variety of bargaining methods, mirroring real-world situations in which wealthier countries might trade more strategically.

The sample size of five participants may be insufficient to produce statistically meaningful results. As a result, additional testing with a bigger sample size is needed to ensure a more comprehensive evaluation of the game's effectiveness and to uncover any other potential flaws or adjustments that are required.

Conclusions

To conclude, this thesis has demonstrated the potential of CarbonQuest as a serious game designed to facilitate the understanding of how climate change and geopolitics are intertwined and how understanding their link is imperative to addressing climate change. Through various mechanisms in the game, CarbonQuest engages players in a fun but educational experience that impart valuable feelings of empathy for the global south and a better understanding of inequality can worsen climate change and its impacts.

The testing and evaluation of CarbonQuest conducted with a cohort of 5 transition year students, indicated a generally positive response to the game's ability to facilitate learning and engagement. Unfortunately its limited sample size necessitates further testing to establish its efficacy more conclusively.

Summary

Future Work

More features

In future iterations of CarbonQuest, the inclusion of dynamic events could dramatically improve the learning experience and game depth. These events could provide participants with some more accurate portrayal of the real-world challenges and opportunities that countries confront when addressing issues of sustainability and climate change *(Connolly et al., 2012)*.

Positive occurrences, such as technological advances in green energy sources, could assist players to value the need of research and innovation in climate change mitigation and in the game may prove as an incentive to move away from fossil fuels as a source of energy. These events could also highlight the potential benefits of shifting to renewable energy sources and investing in technology developments.

Natural disasters could highlight a country's vulnerability to the effects of climate change and the need for resilience planning and disaster risk reduction policies. These events could develop empathy for impacted countries among players, promoting a feeling of global responsibility and solidarity.

Balanced events, such as the slow depletion of fossil fuels, could be used to replicate the challenges of energy transition and the need of changing to sustainable energy sources. Additionally, the establishment of a COP fund event can promote the concept of global cooperation and provoke conversations surrounding the burden of responsibility of climate change.

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Appendices

Frontend: https://github.com/Nickson-0/Carbon-Quest-Frontend

Backend: https://github.com/Nickson-0/Carbon-Quest-Backend