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The Climate Challenge Game: How Might Computer Games be Used to Communicate the Issues of Climate Change?

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Disclaimer

Except where otherwise stated and acknowledged, I certify that this dissertation is my sole and unaided work,

Hannah Rowlands
30th August 2006

Abstract

This study set out to examine the use of computer games for the communication of climate change issues, using the Climate Challenge Game as a case study. In particular, any changes in knowledge, understanding and attitudes towards climate change, as a result of playing the game, were assessed, as were the players' attitudes towards the use of games for communication. A survey was carried out, with participants asked to fill out an online questionnaire before and after playing the game. It was found that many participants did learn about climate change, and that some attitudes were changed as a result of the game, and the concept of using games as communication tools was well supported by the participants.

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Introduction

Aims

This study aimed to examine how computer games might be used in communicating the issues about climate change. It used the Climate Challenge Game as a case study. The specific research questions asked were:

1. In what ways did the game affect the player's knowledge, understanding and attitude towards climate change?
2. How did the players evaluate the game as a communication tool?
3. What kind of player did the game particularly appeal to

Hypotheses

In order to answer these questions, a set of hypotheses was drawn up. These were:

1. Playing the Climate Challenge Game affects the player's attitudes towards climate change;
2. Playing the Climate Challenge Game gives the player an understanding of the wide variety of policy options, from the international to the household level
3. Playing the Climate Challenge Game gives the player a greater knowledge of the science behind climate change
4. Players find the Climate Challenge Game an effective way of learning about climate change
5. A wide range of people enjoyed playing the game, regardless of their previous interest in gaming or climate change

Literature Review

The Climate Challenge game is interesting because it is designed to communicate a topical issue, namely climate change, to the general public and because it does this in an innovative and fun way, namely using an online computer game. This literature review will first look at how climate

change is communicated to the general public, and will then look at the development of serious computer games, which are computer games designed for more than just fun, and the use of games and the Internet in education and specifically in environment and climate change. Lastly, other research projects using similar research methods to those used in this project will be discussed.

Communication of Climate Change

How is the climate change message put across to the general public?

Climate change is a global problem that should be addressed at every level of society, from the household to business to government (Defra, 2006a). This means that explaining the issues surrounding climate change to the general public is of vital importance, if everyone is to take measures to reduce carbon dioxide emissions. Governments have a role to play in this, and have set up public awareness campaigns, such as the UK Department for Environment, Food and Rural Affairs (Defra) campaign Climate Challenge, which has the aim to "to educate, excite and inspire" people about climate change (Climate Challenge, 2006). Indeed, a future version of the Climate Challenge game aimed at school children at key stages 3 and 4 will be funded by the Climate Challenge fund, associated with the campaign.

How effective are these methods?

There have been several recent surveys assessing people's attitudes towards climate change. One such survey, carried out by the School of Environmental Sciences at the University of East Anglia entitled "Public Perceptions of Nuclear Power, Climate Change and Energy Options in Britain" (Poortinga et al, 2006), found that 91% of respondents believed that the world's climate is changing, and most wanted every possible action to be taken against climate change, although most placed the main responsibility at the global and nation level, not with the individual. However, misconceptions were found, such as 39% of respondents who believed that nuclear power causes climate change. Another survey of 600 high school students between the ages of 11 and 16 found broadly similar results (Boyes, 2004), with students recognising that a reduction of industrial and

vehicle emissions and the use of renewable energy could help reduce carbon dioxide emissions, but again fewer of the students believed that individual actions could help, and this might be caused by a sense of detachment. There was also the same confusion concerning the link between nuclear power and climate change.

These suggest that the role of climate change communications is less to convince people that climate change is happening, but rather to clarify the climate science, to explain the different mitigation and adaptation options, and to give people individual empowerment in tackling large, seemingly insurmountable problems. This last point is seen as crucial in engendering a sense of world community and responsibility with regard to climate change, especially amongst young people (Dahlburg, 2001).

Serious Computer Games

This section will look at the role of computer games in education and will then look at games which aim specifically to educate about climate change or the environment.

What is Digital Game-Based Learning?

A more effective way of learning than the traditional method – ingestion of facts without deeper involvement – is to engage the learner in a more meaningful learning experience, an example of which is play (Beard and Wilson, 2002). Play is an activity that one chooses to do, that is pleasurable, totally absorbing, promotes the formation of social groupings and increases ones involvement in a way that makes one receptive to learning (Prensky, 2001). A game, being a subset of play, is organised play with goals, rules and some aspect of competition (Fabricatore, 2000). Elgood identified four criteria that a game or gaming device should satisfy (Elgood, 1997):

1. A sufficiently clear framework to be recognisably the same each time is it used
2. It confronts the player with changing situations which are partly or wholly influenced by their actions
3. Identification beforehand of some winning or losing criteria
4. It requires for its operation some level of documentation, physical material, computation or administrative or behavioural skill

Computer games are a subset of games, but are characterised by the following six key elements which work together to engage the player (Prensky, 2001):

1. Rules
2. Goals and objectives
3. Outcomes and feedbacks
4. Conflict/competition/challenge/opposition
5. Interaction
6. Representation or story

Another aspect that makes games so compelling is the idea of flow, a mental state of intense concentration, not unique to computer games, in which challenges presented are perfectly matched with the ability to solve them (Csikszentmihalyi, 1990).

Digital Game-Based Learning (DGBL) is "any marriage of educational content and computer games" (Prensky, 2001). It includes any learning game which feels like a computer game but has content and context designed to put the player in a learning situation about a particular subject.

There are many categories of computer games, and specifically of learning games, including puzzles, adventures, experimental games, motivational games, modelling and simulations (Dempsey et al, 1996). A simulation game is one which contains skill, chance and strategy and simulates an aspect of reality (Wikipedia, 2006), which, in the case of Climate Challenge, is the national and international arena of climate change policy.

Can Computer Games be Valuable Learning Tools?

There is a dichotomy, it would seem, between those who believe that Digital Game-Based Learning can be a valuable tool in education, and those who believe that computer games are merely good for entertainment, and solitary, destructive entertainment at that. This means that much of the relevant literature should be checked for researcher bias from both sides.

For example, in his book *High Tech Heretic – reflections of a computer contrarian*, Stoll argues that

making learning fun denigrates the act of teaching and of learning, and that time spent in front of a computer is time that could be spent facing another person (Stoll, 1999). However, the very title of his book sets out his agenda, and so it is unlikely that an unbiased discussion of the value of computers in education will be found in it.

At the other extreme of the argument are those who are vocal advocates of computer games as the future of successful education, in which learners are motivated by and enjoy the learning experience (Prensky, 2003).

A more balanced stance would be to accept that some, but not all, games are good for some, but not all, learners (van Eck, 2006). It is also apparent that there has been relatively little disciplined study of gaming which might resolve the matter (Squire, 2002), (Mitchell and Savill-Smith, 2004).

Why are Computer Games good for learning?

Prensky gives three key reasons why Digital Game-Based learning works (Prensky, 2001):

1. the added engagement from a game environment for learning, especially for otherwise boring subjects;
2. the interactive learning process which provides responsive, instant feedback to the player;
3. the way these two are put together, keeping a clear focus in the specific context of the game in question.

In addition, games are often visually rich, which helps maintain the player's attention. They provide a complete, interactive virtual playing environment in which the player is immersed in an imaginary world, allowing them to take chances in a controlled way. Games can be designed with large amounts of content and different levels of challenge to suit each player. They can also be updated and customised, leading to a wide range of long-term uses.

Games are particularly suitable as learning environments for children and young adults, in fact anyone who has grown up with computer and games. The current average age of game players in the UK is 28, and 65% of the 24-35 age group are gamers (BBC, 2005). The younger generation of learners has grown up immersed in digital technology, which has changed their basic skill-set in

the following ways (Prensky, 2001):

1. Computer games train players to process information much faster and to make rapid decisions based on available information;
2. Game players are more comfortable processing many media inputs and outputs simultaneously;
3. They are used to hypertext information obtained from multiple sources and learning in a non-sequential way;
4. They have higher visual intelligence;
5. They are accustomed to worldwide connectedness through the Internet;
6. They prefer active, rather than passive, learning experiences, preferring to work things out for themselves through trial and error than be told how something works;
7. Computer games teach players problem-solving skills, which blurs the line between work and play;
8. Computer games give instant feedback and clear rewards for effort put in;
9. Game players' lives are pervaded by fantasy, and the sharing of fantasy worlds through websites and games;
10. Technology is seen as a positive thing, rather than a negative thing, which makes computers a comfortable learning tool for the younger generation, but can lead to resistance from teachers who did not grow up with computers.

Whether or not these new characteristics of today's learners are deemed desirable, they should be taken into account when designing educational materials that will engage the student.

Games Designed to Educate

There are many examples of computer games that are designed to educate the player. An example of a project that set out to design a series of such games is the Games to Teach programme at Massachusetts Institute of Technology (MIT, 2006). Its aim was to “move beyond

the current state of edutainment products which combine the entertainment value of a bad lecture with the educational value of a bad game" by developing conceptual prototypes for teaching a range of subjects at high school and college level. Games include the "Environmental Detective" in which players use hand-held computers with geolocation to determine the source of a water pollution event.

A whole catalogue of entertaining games with non-entertainment goals can be found at the Social Impact Games website (Social Impact Games, 2006). These games range from teaching algebra to disaster management. They also list the best off-the-shelf commercial games, which are designed primarily as entertainment games, but have educational themes, such as Sim City, which is a city simulation game.

How is climate change being communicated through the Internet and games?

There is a lot of material on the Internet about climate change, mostly in the form of educational websites aimed at children, such as Defra's Global Warming website (Defra, 2006b). Other websites provide useful explanations of the science behind climate change, such as climate*prediction*.net (climateprediciton.net, 2006) or Real Climate (Real Climate, 2006), both of which are edited by climate scientists, but avoid discussion of the politics of climate change.

There are a small number of computer games and board games which are designed to explain climate change. Most of the online games are relatively small and aim at getting across a simple message. Examples include Tearfund, a christian charity, which has a Climate Change Pentathlon game on its website (Tearfund, 2006), involving five simple games explaining five simple actions that individuals can do to reduce their carbon dioxide emissions, and Glasgow Science Centre, which has a Climate Change Challenge game (Glasgow Science Centre, 2006) which contains a cartoon picture of a landscape, and the player has to click on the images that they think are harmful to the environment in order to get points, plus an explanation of how that item affects climate change.

A more in-depth set of three climate change games has been created by the European Climate Forum (European Climate Forum, 2006). The first is a board game called "Keep Cool – gambling

with the climate" and focuses on the politics of climate change and the need for international cooperation. The second, also a board game, is called "Winds of Change" and focuses on technological options by challenging the players to turn their "grey" polluting cities into "green" climate-friendly cities, without ruining their economies or suffering disasters from climate change. The third, called Klimspiel, is a computer game which is downloadable from their website but is only available in German. It was developed to accompany an exhibition in the Deutches Museum in Munich in 2002 and involved each player taking on the role of either the government, a business leader or a householder. The rules are explained via a video of a (male) climate scientist, and players are shown the results of their choices in the form of graphs and diagrams at the end of each round. Occasionally, climate shocks are announced by a TV news presenter (also male). Since the game was designed for use in a museum, it is intentionally short, relatively simple and with limited interactivity.

Research Methods

This last part of the literature review will analyse the methods used by other research projects using similar techniques to those used in this study, namely research using computer games and simulations, and Internet experiments.

Research Using Computer Games and Simulations

There are two main international associations for the promotion and study of games and simulations in education, the International Simulation & Gaming Association (ISAGA) and The Society for the Advancement of Games and Simulations in Education and Training (SAGSET). For example, the published proceedings from the 34th Annual Conference of ISAGA (Shiratori et al, 2005) contain articles on "The Features and Roles of Simulation Software in the Classroom" and "The Quantity and Context of Video Game Violence in Japan: Toward Creating an Ethical Standard".

Of particular interest in the context of this study is "Environmental Commons Game: Is the Free Rider a 'Bad Apple'?" (Ohnuma, 2005), concerning a game designed to simulate "The Tragedy of

the Commons" situation. Players take on the roles of factory managers who are required to maximise their assets, whilst working with the other players to maintain the purity of the environment. The game is seen as a useful tool for analysing the behaviour and emotions of the players, in order to see if they choose the supposedly rational free rider option or not. The authors concluded that the game is an effective tool in environmental education because it allowed the participants to understand intuitively the importance of mutual cooperation within the game situation, and allowed them to translate that into real world situations.

The use of simulation models to elicit information about people's attitudes to issues relating to the environment forms the core of integrated assessment (IA), in particular participatory integrated assessment. For example, the Georgia Basin Futures Project, which made use of GB-QUEST, a complex, regional IA model (Carmichael et al, 2004) and (Tansey et al, 2002). The model was developed to be used via the Internet, but for the purposes of the study was used in focus groups, laboratory style studies and educational applications. This approach was different from traditional surveys about environmental issues because it placed those issues in a specific regional context.

Research Using the Internet

The Internet is increasingly being seen as a useful tool for carrying out experiments which require a relatively large number of people to participate, especially in the fields of economics and psychology. There are a number of advantages and disadvantages of Internet experimentation, which are summarised in Table 1.

	Arguments against Internet Experiments	**Arguments for Internet Experiments**
1	Not everyone has Internet access	More diverse populations can be reached relative to lab experiments
2	Selection-effect: Internet subjects are likely to be different from laboratory subjects	Demographics of Internet users approach those of the general population
3	Loss of control over the physical environment of the experiment	Lower administrative costs; Reduced experimenter effects
4	Subjects appear less attentive in Internet experiments	No discernible differences in levels of rationality
5	More noise and higher variance	

Table 1: Pros and Cons of Internet Experiments (Charness, 2003)

One obvious use of the Internet is online surveys, such as “Climate Control Survey” commissioned by Channel 4 (Channel 4, 2005) to investigate attitudes towards climate change and “Gamers in the UK”, a survey carried out by the BBC (BBC, 2005) to investigate the role of computer games in society. These surveys were useful in the questionnaire design process for this study.

Online surveys are part of a wider set of public consultation exercises, which use the Internet to reach their sample population. A more involved type of survey is the “Norms Evolving in Response to Dilemma”, or NERD, project (Ahmad et al, 2005) and (Danielson and Ahmad, 2004), which aims to develop a democratic ethic of biological technologies. Participants are still required to answer questions about biotechnology in the format of an online survey, but they are given information from advisors as they progress through the survey. They are also given certain facts about the subject, and the option to explain their answer in a comments box. The research emphasis, therefore, is less on the answers but on the information people use and what factors affect their choices. By analysing which advisors are consulted, the study is able to draw deeper conclusions about the decision-making process.

The Internet may be the ideal medium for conducting democratic processes (Fishkin, 2000), in particular “refined” public debate, which involves a scientifically random sample who take a baseline survey, followed by a weekend of face to face deliberation with the other members of the sample in small groups, finishing with the same survey at the end. In this way, rather than a simple snapshot of public opinion, changes in opinion over the weekend are found, based on considered judgements rather than top of the head attitudes. This method of before and after surveys, with an attitude-changing activity in the middle, forms the core of this study.

The field of experimental economics has been turning to the Internet to carry out experiments in recent years. One study, which carried out the same experiment in a laboratory and over the Internet (Anderhub et al, 2001), found that both media produced similar data when economic decision behaviour is concerned. Interestingly, the variance was generally higher and decision times shorted on the Internet experiment. Their conclusions were that the Internet provides a sounds environment for experimental economics, it is cheaper than a laboratory and allows a

larger number of participants, but that payment of participants was more difficult than in a laboratory setting.

The Climate Challenge Game

The following section describes the Climate Challenge Game, explaining its aims, the game play and how scientific information was put into the game. The author was fortunate enough to be involved in the design of the game, providing scientific advice to the development team.

Aims of the Game

The Climate Challenge game is a short, online computer game about climate change, funded by the BBC and developed by Red Redemption Ltd. It's three broad aims are:

1. Individual empowerment – the attitude that climate change is not only happening, but it is something we can all do something about
2. Understanding policy options – giving the player an understanding of the different mitigation options, from the individual to the international
3. Bringing it all together – clarifying contradictory information, putting across the scientific consensus and providing a means of comparison of options

The target audience for the game is professionals aged between twenty and forty. The game is written in Flash and will be available on the BBCi website at no cost, and should take around an hour to play through.

Game Play

The player takes on the role of the European Nations throughout the 21st century. The game consists of ten turns, each lasting a decade.

Local Policy Screen

The first screen that the player sees after the opening welcome page is the first Local Policy screen, as shown in Figure 1.

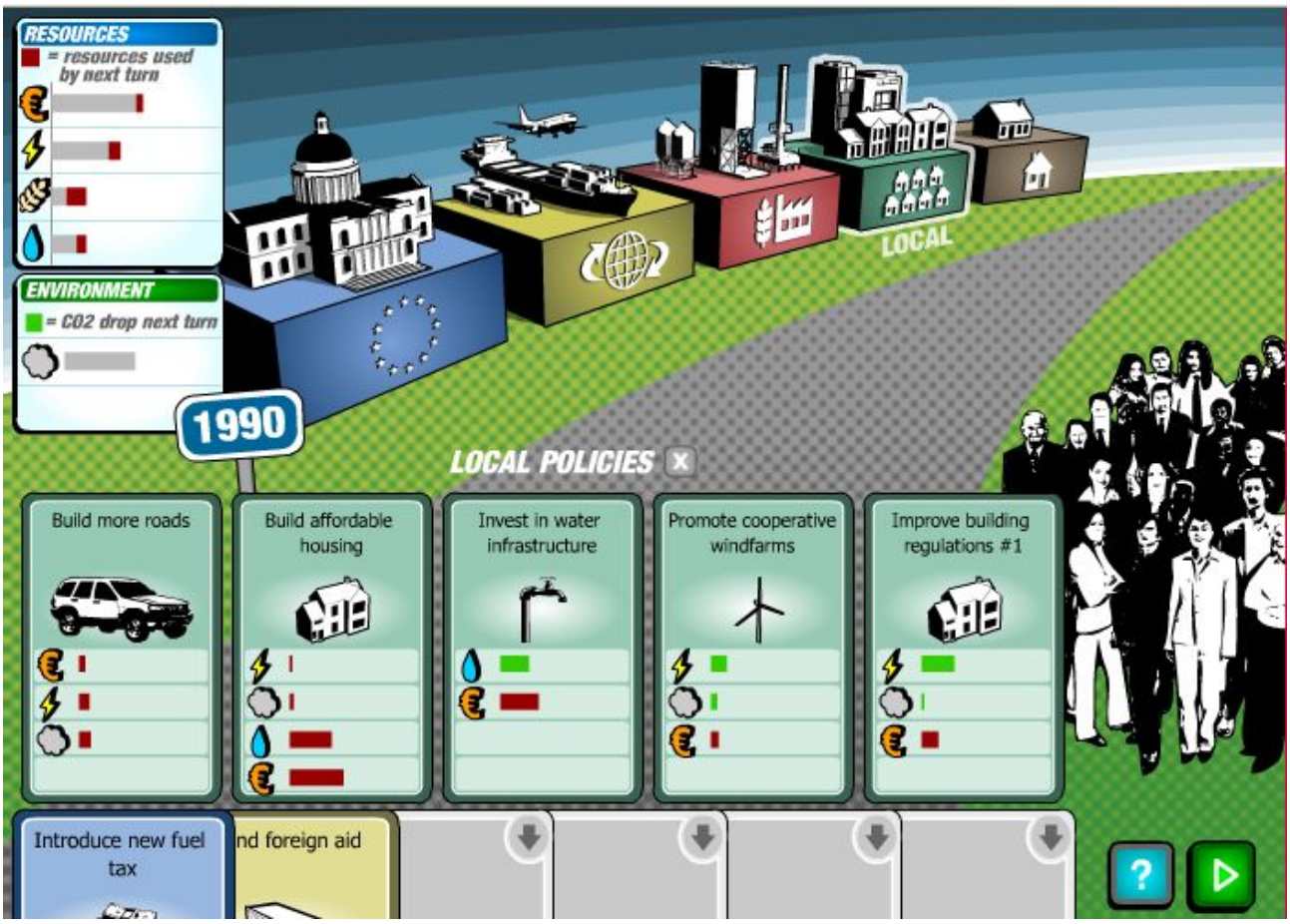

Figure 1: the Local Policy Screen in the Climate Challenge Game

The player sees their resources – money, power, food and water – and their environmental indicator – carbon dioxide – as grey bars indicating amount, and green or red tips to indicate whether they are increasing or decreasing.

In the background is an image of a road disappearing into the horizon, symbolising the future consequences of their actions.

The crowd of people represents the public, with opinion about each policy represented by an approval “swingometer”.

There are five policy categories – national, trade, industry, local and household – and a selection of policies in each, shown as policy cards. Hovering over a card shows a description of the policy, some pros and cons, and a public opinion “swingometer” showing the popularity of the policy (Figure 2). The player chooses up to six policies a turn by clicking on them, after which they sit in slots at the bottom of the screen.

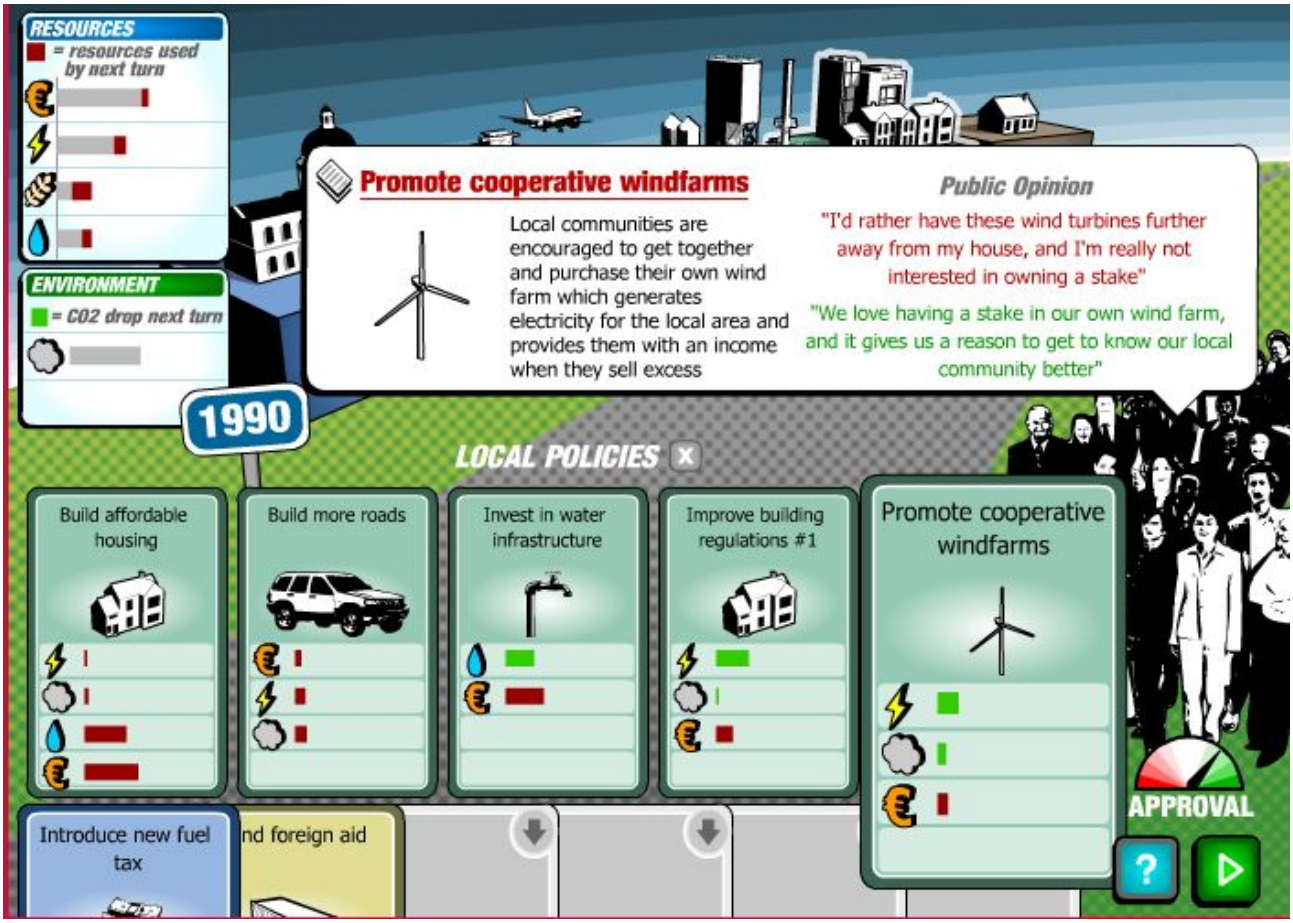

Figure 2: Local Policy Screen, showing Policy Information

Event Screen

When they have chosen their policies, the player sees grey carbon dioxide clouds emitted as a result of their policy decisions. A crisis roadblock rushes down the road towards them. Crises are sometimes totally random, but will usually be related to a lack of resources, or to the effects of climate change. Events may also occur, which are positive reactions to climate change, such as a charity concert.

The Climate Times

A newspaper then spins towards the player and reveals their popularity in the form of an election graph, and reactions to their policy decisions in the form of newspaper articles, (Figure 3).

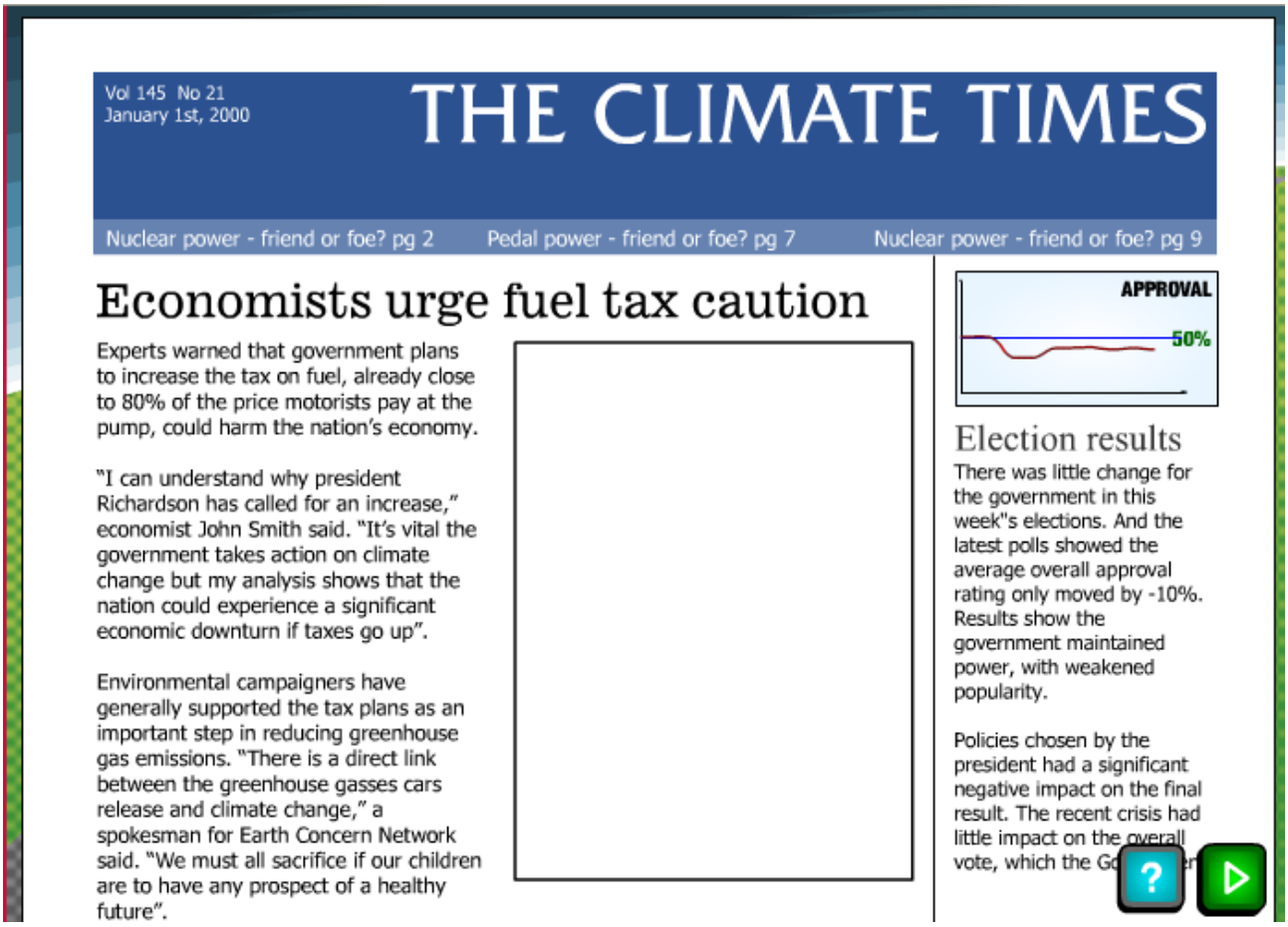

Figure 3: Newspaper Screen in the Climate Challenge Game

Global Policy

This last phase is where the player engages with other regional blocs to establish Kyoto-style targets (Figure 4). This phase occurs three times during the game. The player sees the six other negotiators, representing regional blocs around the world. They can subsidise or persuade the other negotiators in order to achieve a consensus on carbon dioxide targets. The other negotiators' behaviour is based on real-world data, on the player's previous game behaviour, and is partly random. If the player has been particularly successful at reducing their own emissions, then other regions are more likely to vote yes.

The game continues in a series of local policy, events, newspaper and international negotiation for ten turns, until 2100.

Figure 4: Global Negotiation Screen in the Climate Challenge Game

Scientific Input

The Climate Challenge Game sought to use the best scientific data available for the statistics in the game, however it was created to be a game which meant decisions had to be made to balance the accuracy of the data with the game's fun and educational merit.

Players do not see actual numbers in the game, only bar charts, although they can see more detailed graphs by clicking on a resource. This was to keep the game simple, but allow for detail if players want it.

Where at all possible, data within the game come from reliable scientific and governmental sources. The priority was on the accuracy of carbon dioxide emissions, with the other resources being as close as possible to “real” values, but at the very least maintaining internal consistency, so that comparisons between various policies can be made.

Carbon Dioxide Emissions

The baseline for carbon dioxide emissions, which increase over time regardless of the player's actions, is taken from the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios, using the A1B scenario (IPCC, 2000). This scenario follows the general A1 storyline, which describes a future world of “very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies”. The A1B scenario is distinguished by its direction of technological change in the energy system, which is balanced between fossil intensive and non-fossil energy sources. Carbon dioxide emissions in the A1B scenario lie approximately in the middle of the range on six main scenarios considered in the report (Figure 5). This scenario was used because it would be neither too difficult nor too easy for the player whose aim, therefore, is to reduce continually rising emissions.

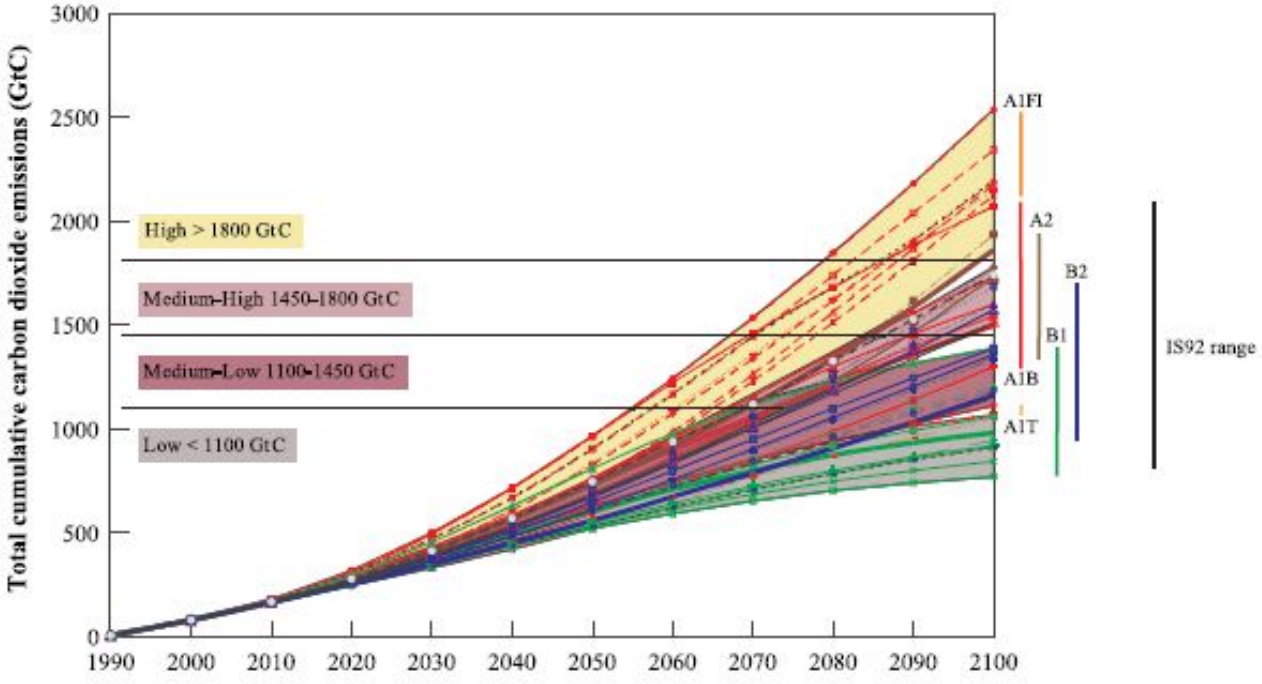

Figure 5: Total cumulative carbon dioxide emissions in GtC for the six SRES scenarios. (Source: IPCC, 2000)

The game made use of the United Nations Environment Programme Java Climate Model, available from their website (UNEP, 2006), which produces data for given scenarios on carbon dioxide emissions, world GDP, population and energy use.

Carbon Dioxide Emissions Reductions

All policies are taken from actual government policy documents, except ones near the end of the game, which are deliberately futuristic. The UK government's Climate Change Programme 2006 (Defra, 2006a) was a major source of policies, and the anticipated carbon dioxide reductions from each were transferred directly from the report into the game. The Potential for Microgeneration: Study and Analysis, carried out by the Energy Saving Trust for the Department for Trade and Industry (DTI) (EST, 2005), was also very useful in determining emissions reductions in many household-level policies.

Other Resources in the Game

Energy, food and water are the secondary resources that must be managed throughout the game. Data for these were taken from various sources, including the UNEP model mentioned above and the DTI website (DTI, 2005).

It was not possible to find sources for all the policies, so some are estimates derived from other policies, and this is noted on an accompanying website. Food and water statistics were particularly hard to quantify, as the values needed for the game are not those that are typically published by water or food industries.

For areas where information was unavailable, secondary sources such as Wikipedia were used. Wikipedia is an excellent source of information, but much of the data is unverified, so was used with caution.

Crises

The climate change crisis events are taken from the Impacts, Adaptation & Vulnerability Contribution of Working Group II to the Third Assessment Report of the IPCC (IPCC, 2001).

Other Considerations

The game was designed with accessibility issues in mind so, for example, all the colours are distinguishable by players who are colour blind.

The game is intentionally apolitical, hence the use of European Nations, rather than the European

Union. It was hoped that initial prejudices held by players would not put them off playing and enjoying the game.

Method

Outline

Participants were invited to take part in the study by email, which gave them a link to the study website. There were three parts to this study:

1. They were asked to fill in a pre-game questionnaire which aimed to elicit their existing knowledge, understanding and attitudes towards climate change;
2. They played the game, and data on how they played was stored;
3. They were asked to fill in a post-game questionnaire which aimed to elicit:
    - Any changes in knowledge, understanding or attitudes towards climate change as a consequence of playing the game;
    - Their evaluation of the game as a communication tool;
    - Personal information.

Sample

People were chosen to take part in this part of the study with the basic condition that they had not played the Climate Challenge game before. This was easy to ensure since invitations were sent out before the official launch of the game on the BBCi website. The only people who had played the game prior to this were development team, scientific advisors and a small number of play-testers.

The population was the target audience for the game, which is professionals aged between 20 and 40. This population was broken down into sub-populations relevant to the game, and invitation email distribution was targeted accordingly. These sub-populations included regular computer games players and climate experts.

Overview of Questionnaire Design

Guidance on survey design was taken from Dillman's Total Design Method, described by Bernard (Bernard, 2002). The advice is aimed at postal surveys, but was easily adapted for an online survey. The key points are:

1. Professionalism: survey software, PHPSurveyor, was used that is professional in both the functionality of survey design and the final look of the survey.
2. Front and back covers: for an online survey, these are the welcome and final pages, which were kept simple, with an explanation of the survey on the welcome page and a brief thank you on the final page.
3. Question order: the first question was interesting, easy to answer and non-threatening, to encourage participants to continue. Demographic questions were placed at the end of the survey, so that participants who might find them threatening were not discouraged, and would be more willing to complete it, having already invested time in the rest of the study.
4. Clear formatting: keeping the survey easily readable can be easier with an online survey since the page can be as long as is needed, rather than being constrained by actual paper size, although it was kept relatively short to avoid too much scrolling. Questions were grouped by subject, with each group on a single page.
5. Length: the questionnaires were kept relatively short, since the participants were also required to play a game which could take up to an hour to finish.
6. Cover Letter: an email was written that introduced the study, which could be forwarded on by whomever initially received is, so as to reach as large a population as possible.
7. Inducements: small monetary inducements were not practical for this online survey so each participant was given the chance to enter a prize draw. Three prizes were offered in order to give each participant a good chance of winning.
8. Contact and follow-ups: PHPSurveyor had the facility for participants to save their responses mid-way through the study and return later, optionally giving their email address

when they did this. These participants were sent a reminder email and were also contacted whenever a bug was found in the software that might have prevented them completing the study.

A range of question types was chosen, so that there would be a mixture of quantitative and qualitative data for analysis. It was also hoped that these different styles of question would help maintain the interest of the participant.

Care was taken with question wording to avoid offending participants, appearing to be condescending towards them, or boring them. Participants were, where possible, given an option to say “don't know” or to provide an alternative option. When attitudes towards a controversial topic were being assessed, the most controversial option was worded in a way that would allow participants to choose it, rather than feel they should say what they thought ought to be said.

Assessing Knowledge of Climate Change

The participants were asked to describe their knowledge of climate change, as an interesting benchmark for how they answered factual questions. Further factual questions were drawn from misconceptions found in other surveys. For example, it has been found (Boyes, 2004) and (Poortinga et al, 2006) that some people believe nuclear power causes climate change, so one question asked whether different energy sources, including nuclear, contributed to climate change.

Participants were asked what they thought the causes of climate change were as an open-ended question, so that no suggested answer was given. A small number of technical questions were asked about greenhouse gases, the impacts of climate change, the sectoral contributions to climate change, and countries that did not sign up to Kyoto. The questions about causes and impacts of climate change, and whether certain electricity generation methods contribute to climate change, were asked again in exactly the same way in the post-game survey.

Assessing Understanding of Climate Change

There were four understanding questions in the pre-game questionnaire, asking what the main challenges are for national governments introducing climate change policies, in which the

participant was given a range of answers plus an “other” option, and why they thought different countries did or did not sign up to the Kyoto Protocol, which were open-ended. In the post-game questionnaire, they were again asked about the challenges facing national governments, but the international question was re-phrased to ask what are the main challenges in getting international agreements signed by all parties. These questions were the most difficult to design because they relied on a certain amount of knowledge about the subject, and the willingness of the participant to take the time to answer them.

Assessing Attitudes towards Climate Change

It was decided not to ask if climate change was happening, since it has been shown (Channel 4, 2005) that a large majority of people do now believe that it is happening, so instead participants were asked how important climate change was in the context of other social problems. They were also asked who they thought was responsible for causing and tackling climate change, given a range of options based on the categories used in the game.

As well as the factual question about energy sources, they were asked whether they would be happy having these sources supply their electricity whether these could help reduce emissions in the future. Attitudes towards different policy options were found using a ranking question with eight different policies. The participants' personal feelings towards climate change were elicited by asking how they thought climate change would affect them personally, whether they thought they personally were part of the solution, and what personal actions they took on climate change.

Evaluation of the Game as a Communication Tool

The purpose of this set of questions was to assess the process itself, primarily by asking the participants what they thought of the game – whether they enjoyed it, whether they thought they learnt anything from it, and, if so, what they learnt. They were also asked if there were any things about the game that they did not like, and if they thought a game was an appropriate way to communicate climate change. This information is useful not only for this study, but to inform the design of similar future climate change games.

Demographic Questions

Certain anonymous information was requested from the participants, including age, gender, country of residence, level of education, educational subject, work status and job sector. Information that was relevant for this study included the number of cars owned by their household, how often they play computer games, which are their favourite games, how often they use the Internet, and if they had given money or time to any charity in the last year, and if so, what kind of charity it was. This last was designed to find the sub-population who were already involved in environmental campaigning, and so may have a higher awareness of climate change even though they are not professionally or educationally trained in the subject.

At the end of the survey, participants were asked to give their email address to be entered into a prize draw and to be kept informed about the study.

Pilot Testing

Once the questionnaires were drafted, and initial feedback had been received from the project's supervisor, ten people were sent the questionnaires to provide feedback. As recommended by Bell (Bell, 2001), these testers were requested to answer the following questions:

1. How long did it take you to complete?
2. Were the instructions clear?
3. Were any of the questions unclear or ambiguous?
4. Did you object to answering any of the questions?
5. In your opinion, were any major topics left out?
6. Was the layout clear and attractive?
7. Any other comments.

Pilot Test Sample

The people chosen to pilot the surveys were either those with experience designing questionnaires, whom it was hoped would be able to give insights based on this experience, or those who fell into the desired sample population for the study, but who had already played the

Climate Challenge Game as developers, advisors or play-testers.

Suggestions and Comments from Pilot Testers

Of the ten people asked to be pilot testers, six responded. Their main comments were:

- to clarify the wording of some questions;
- to suggest changes to answers for some multiple-choice questions;
- to turn some open-ended questions into multiple-choice questions and also to allow comments on some multiple-choice questions; it was decided to keep some open-ended questions, despite them being more time-consuming for the participant;
- to compliment the layout and look of the survey;
- to point out some minor technical problems, which were dealt with;
- to suggest asking how participants thought climate change would affect them personally;
- that the pre-game questionnaire took around ten minutes to complete.

Participant Experience

In order to maintain the interest and focus of the participant, the following user experience flow was devised:

1. They receive an email asking them to take part in the study, from a friend, a mailing list or an Internet forum;
2. They click on a link in the email, which takes them to the study website;
3. They begin the survey straight away, without any registration;
4. They are led smoothly through the pre-game questionnaire, the game, then the post-game questionnaire, without changing browser window. There is an option to save their answers, with a username and password, so they can return later;
5. Finally, they can give their email address to be entered into the prize draw, and to receive further information about the study.

Technical Aspects of the Survey

Software called PHPSurveyor was used to design and run the survey, and to store the data in a SQL database. Technical assistance was provided by Red Redemption Ltd, who developed the game, to embed the game into the survey website, and to ensure that data from the game were stored with that participant's questionnaire responses. The survey was tested using Mozilla Firefox and Internet Explorer web browsers.

Problems Encountered

One major bug encountered in the first day after the launch prevented those using Internet Explorer from starting the post-game survey once they had finished the game. This was overcome, but game data was not stored for participants using Internet Explorer, and completion of the game could not be ensured.

Statistical Analysis

This section will discuss a plan for analysis of data from the study.

Responses

The survey website was made available for two weeks in July/August 2006. In all, 142 people completed the study, and 62 left unfinished studies, which were not completed by the end date, even after reminder emails were sent out.

Response Bias

Since participation in the study was voluntary, it was expected that those who were already interested in climate change would be more likely to take part. Also, the distribution method meant that a larger number of informed people were likely to take part. Questions asking participants to describe their knowledge of climate change and what they do to reduce their personal emissions were intended to take these into account by allowing final data to be filtered.

Plan for Analysis of Data

The questions were designed to give a mixture of qualitative and quantitative data. The qualitative

data can be analysed using content analysis, “by hand” rather than using computer software, due to the relatively small number of responses. The quantitative data can be analysed using standard descriptive statistics, calculated using SPSS or simpler calculator software. PHPSurveyor had a basic facility for summary statistics and provided frequency tables for responses.

Questions with a range of answers can be analysed in tables and bar charts. Nominal data, which can not be ranked, can be analysed using frequency tables, and the mode. Ordinal data, such as participants' ages, can also provide a mean. Data from grid questions will be displayed using a compound bar chart.

Areas for analysis will be:

1. Descriptive analysis of pre-game climate change questions;
2. Comparison of pre-game and post-game climate change questions;
3. Examination of game evaluation questions;
4. Use of sub-populations, as defined by responses to demographic and pre-game questions.

Results

Summary of Sample

Demographic information was taken from each of the 142 participants who completed the study and is summarised in Table 2.

Characteristic	*Category*	*%*
Age	Under 18	6%
	19 – 24	14%
	25 – 34	47%
	35 – 44	20%
	45 – 54	6%
	55 – 64	4%
	65 – 74	2%
	75 and above	0%
Gender	Male	65%
	Female	34%
	Rather not say	1%
Country of Residence	Australia	6%
	Austria	1%
	Canada	2%
	China	1%
	France	1%
	Germany	6%
	Italy	1%
	Japan	1%
	Netherlands	1%
	United Kingdom	64%
	United States of America	17%
Level of Education	GCSEs or equivalent	3%
	A levels or equivalent	4%
	Undergraduate	28%
	Post-graduate degree	56%
	No qualifications	1%
	Rather not say	2%
	Other	6%
Work Status	Full-time	48%
	Part-time	13%
	Seeking Work	2%
	Not working	1%
	Retired	2%
	Student	30%
	Rather not say	1%
	Self Employed	2%
	Other	1%

Characteristic	*Category*	*%*
Number of Cars in Household	None	33%
	1	38%
	2	25%
	3 or more	4%
Frequency of Computer Game Play	Every day	9%
	5-6 times a week	5%
	3-4 times a week	8%
	1-2 times a week	11%
	2-3 times a month	4%
	1-2 times a month	6%
	Every couple of months	11%
	Less often	16%
	Never	28%
	Other	2%
Frequency of Internet Use	Every day	87%
	5-6 times a week	8%
	3-4 times a week	1%
	1-2 times a week	1%
	2-3 times a month	0%
	1-2 times a month	1%
	Every couple of months	0%
	Less often	1%
	Never	0%
	Other	1%
Charitable Donations	Yes	81%
	No	14%
	Rather not say	5%

Table 2: Summary of Demographic Data

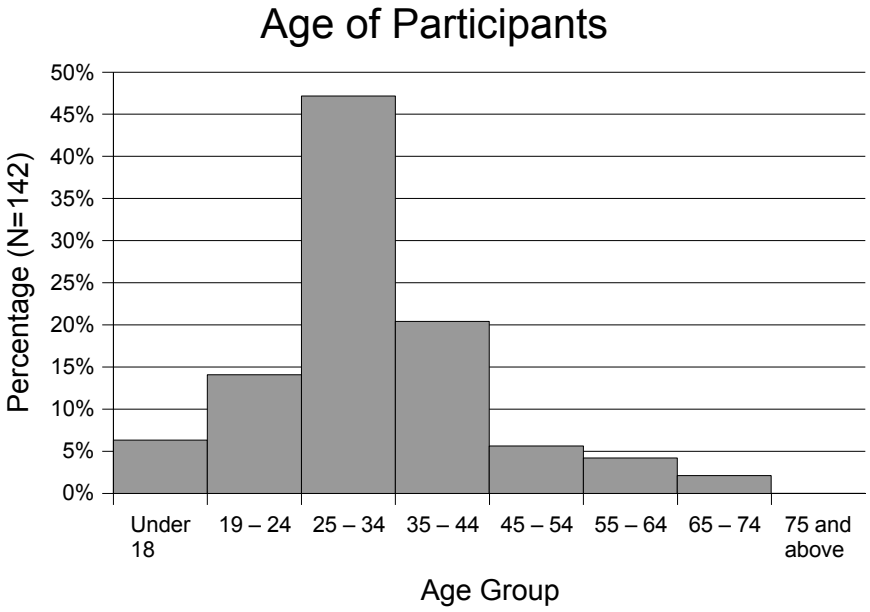

Figure 6: Histogram of Ages of Participants

The modal age of the participants was 25-34, which corresponds with the target age range of the game (Figure 6)

The sample was heavily biased towards Higher Education, with 56% having a post-graduate qualification. The most common educational subject group was Geography, Earth and Environmental Sciences (14%), with Engineering second (8%) and Bioscience third (7%).

The largest categories of employment sector were Higher Education (15%) and Other (14%), which included the voluntary sector, computer games, mining and consultancy.

When asked how often they played computer games, the modal answer was “Never” (28%), although the majority of participants did play games, and they were asked what games they played, as an open-ended question. The results were categorised into eight types of game, and are shown in Figure 7.

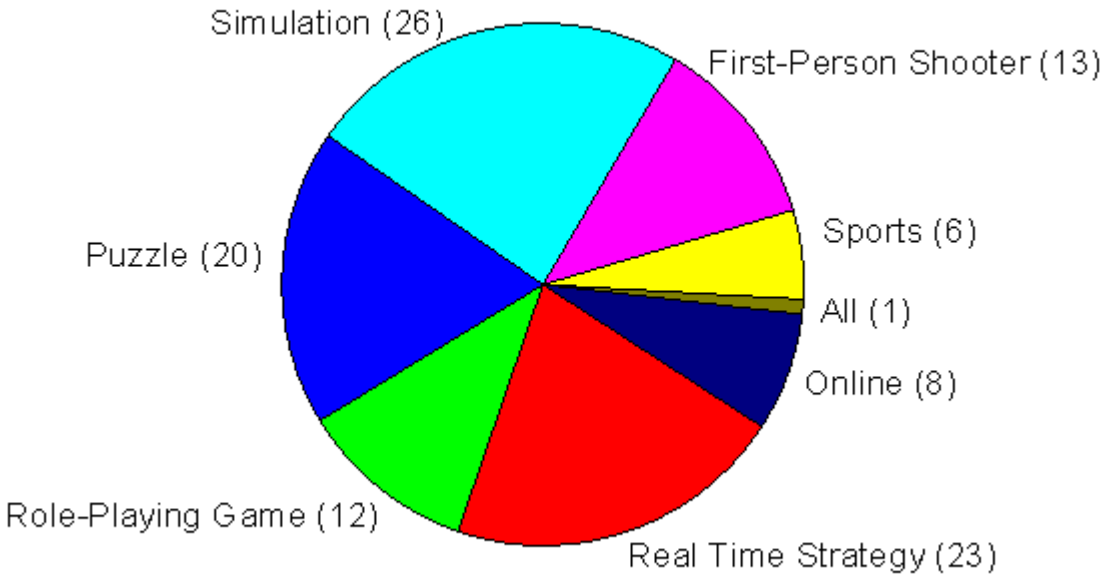

Figure 7: Pie Chart Showing Categories of Favourite Games

More than 80% of participants said they had given time or money to a charity in the part year, and the types of charities are shown in Table 3 of which the most common was environmental, with development second.

Type of Charity	***Frequency***
Environment	56
Development	48
Religious	15
Civil liberties	28
Health	32
Animal	4
Homeless	4
Youth	4
Other	6

Table 3: Types of Charities Donated To

Pre-Game Climate Change Questions

The most interesting of the pre-game results are discussed here, but a summary of all the results can be seen in Appendix 1.

Knowledge Questions

Self-Description of Knowledge

As can be seen from Figure 8, the distribution is skewed towards those who describe themselves as knowledgeable about climate change.

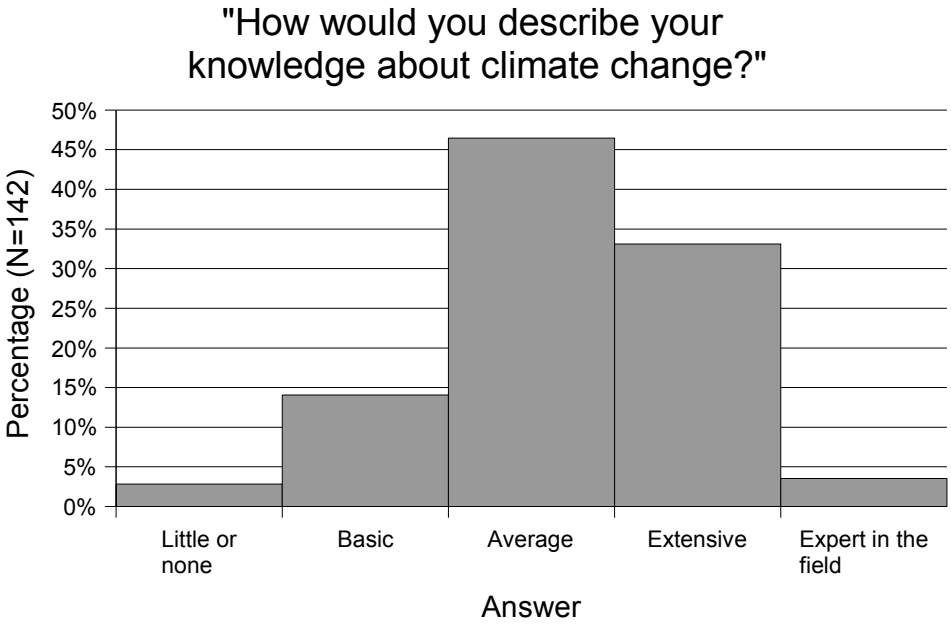

Figure 8: Self-Description of Knowledge about Climate Change

Causes of Climate Change

Some participants replied with a single word, others wrote up to twenty causes. The responses were coded into eight categories, as listed in Table 4.

Category	***Frequency***
Industry	98
GHGs	62
Land Use Change	56
Natural	53
Social	53
Incorrect Responses	21
Agriculture	16
Political	12
Total:	371

Table 4: Answers to Causes of Climate Change Question

Most stated that climate change was caused by the use of fossil fuels. Many also linked this with greenhouse gas emissions. Around one third mentioned deforestation, another third mentioned natural causes such as solar cycles, and a further third mentioned social causes such as

overpopulation and globalisation.

Several responses were incorrect. Many participants said that pollution caused climate change, and, although they possibly meant carbon dioxide emissions, it was felt that pollution was too general a term to allow, since they could have been referring to local air pollution which causes health problems. Only two participants stated that depletion of the ozone layer caused climate change, and only one thought nuclear waste caused climate change. Several participants seemed to confuse causes of climate change with effects of climate change, such as melting of the ice caps or loss of biodiversity. A few also said that global warming was a cause of climate change.

Participants were asked which of a list of atmospheric gases contributed to climate change (Figure 9).

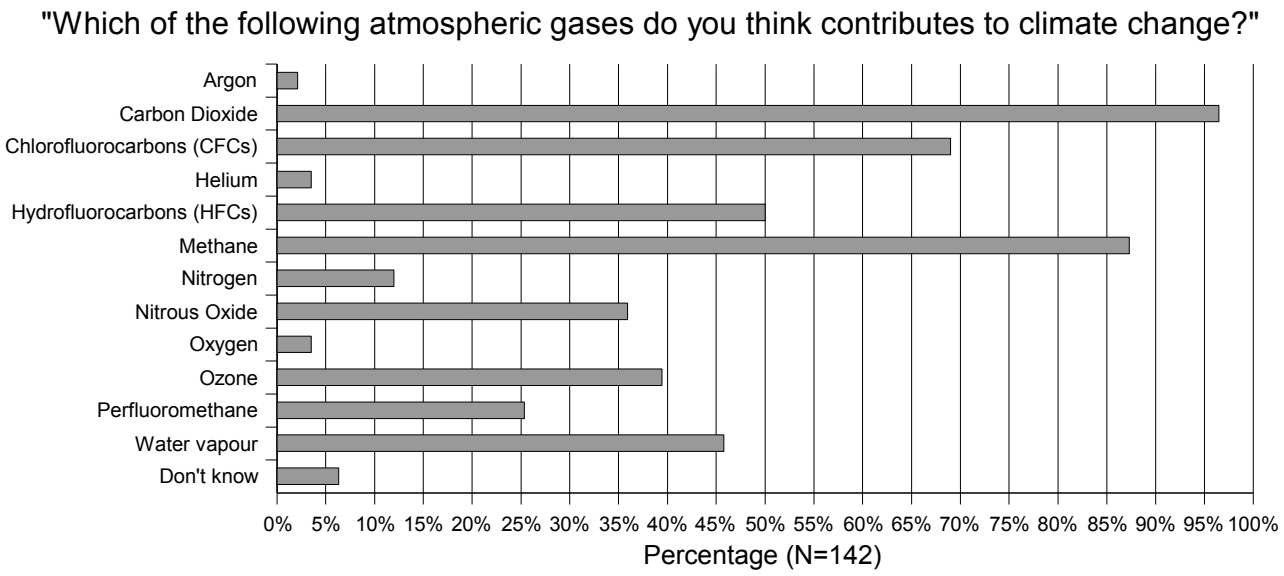

Figure 9: Answers to Greenhouse Gases Question

Nearly all the participants correctly identified carbon dioxide as a greenhouse gas, and 87% correctly identified methane as well. The least correctly identified greenhouse gas was perfluoromethane. 12% incorrectly thought that nitrogen was a greenhouse gas.

Impacts of Climate Change

Participants were asked to select three from a list of actual, possible and incorrect impacts of climate change (Figure 10)

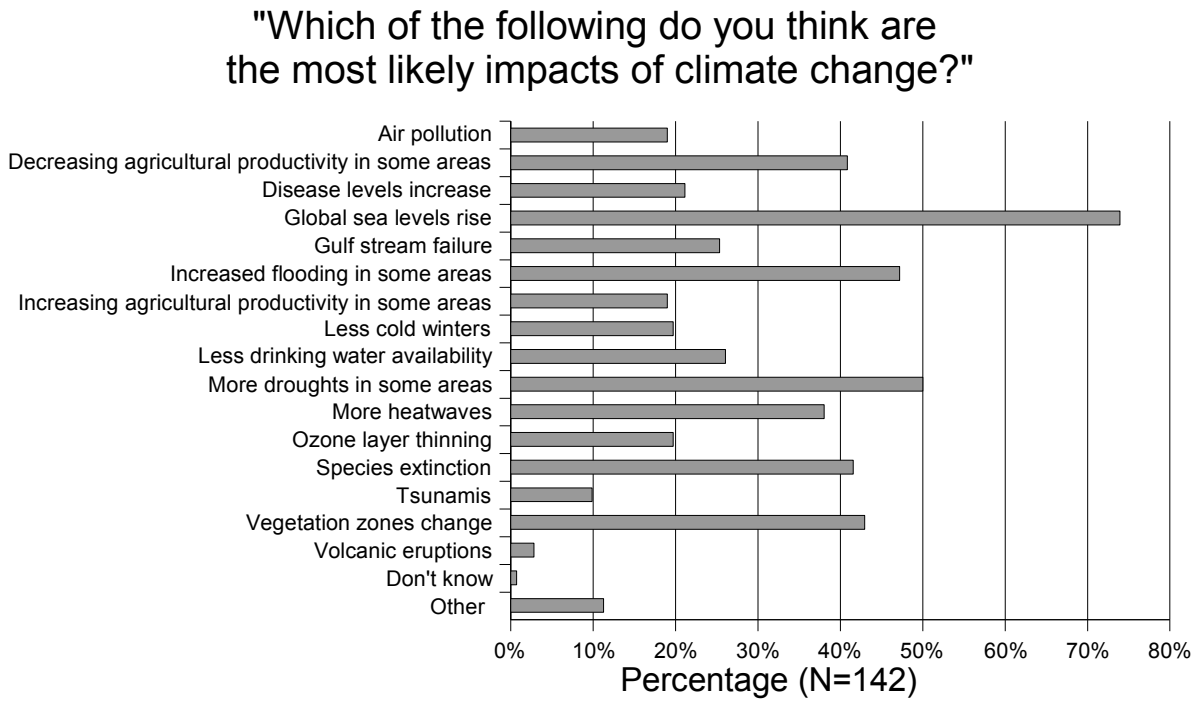

Figure 10: Answers to Impacts of Climate Change Question

Most correctly identified the main impacts of climate, such as sea level rise. 19% thought, incorrectly, that air pollution was an impact of climate change. Other incorrect impacts were thinning of the ozone layer (20%), tsunamis (10%) and volcanoes (3%). Further impacts given in the Other option mainly related to social impacts such as migration or war, and extreme weather events.

Contributions to Climate Change

When asked which sector in developed countries contributes most to climate change, most answered Energy Production (51%), and 23% answered Transport and 20% chose Industrial Processes. Very few participants chose the other options.

The first of a series of grid questions about energy generation was factual and asked whether they thought each method contributed to climate change (Figure 11)

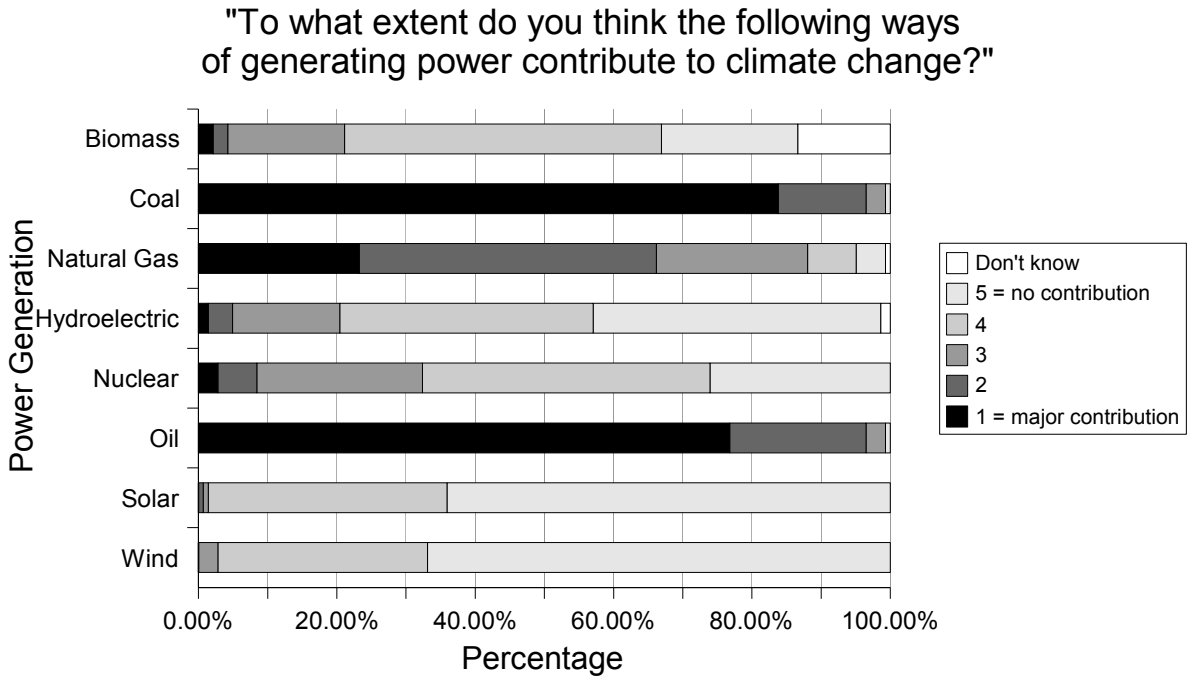

Figure 11: Answers to Power Generation Contribution to Climate Change Question

Most of the participants knew that coal and oil contribute to climate change, and that solar and wind do not. Biomass was the only answer that received a significant number of “Don't know”s.

Kyoto Protocol

This was a factual question assessing knowledge of the politics of climate change. The participants were presented with all 40 Annex I countries, with a brief explanation of what the term Annex I means, and asked which two had not ratified the Kyoto Protocol. The correct answer was Australia and the USA, reflected in the responses, with 97% choosing the USA and 47% choosing Australia. The third most selected answer was the Russian Federation (21%) and fourth was Japan (8%).

Attitude Questions

Climate Change in a Wider Context

This question asked participants to rank nine current social issues, including climate change, in order of importance. The first choices are shown in Figure 12.

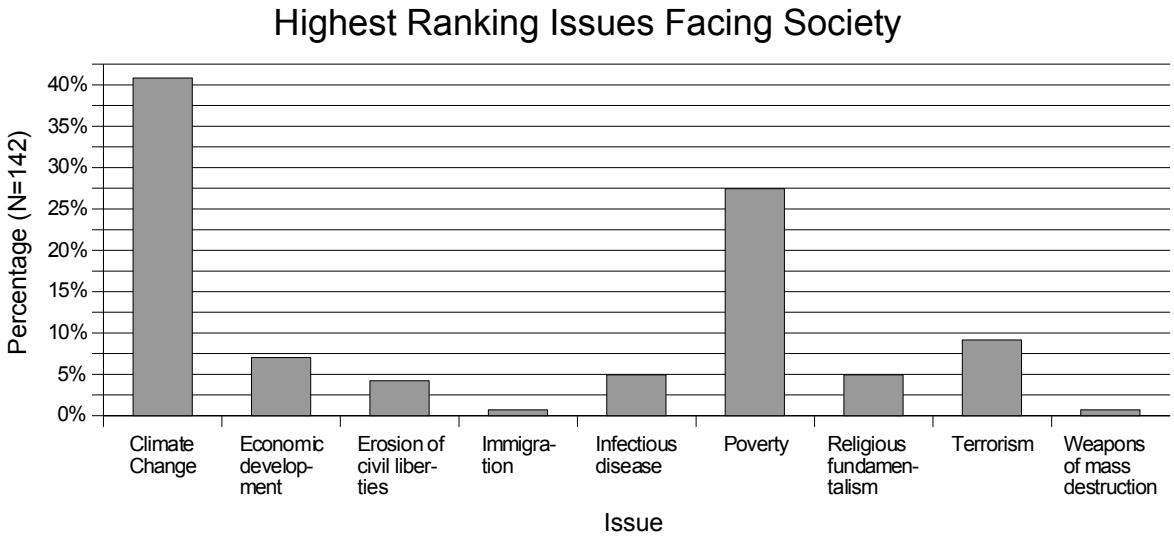

Figure 12: Histogram of Highest Ranked Issues Facing Society

As can be seen from the Figure 13, climate change is considered to be one of the most important issues facing society, with only 7 participants ranking it below 6th place.

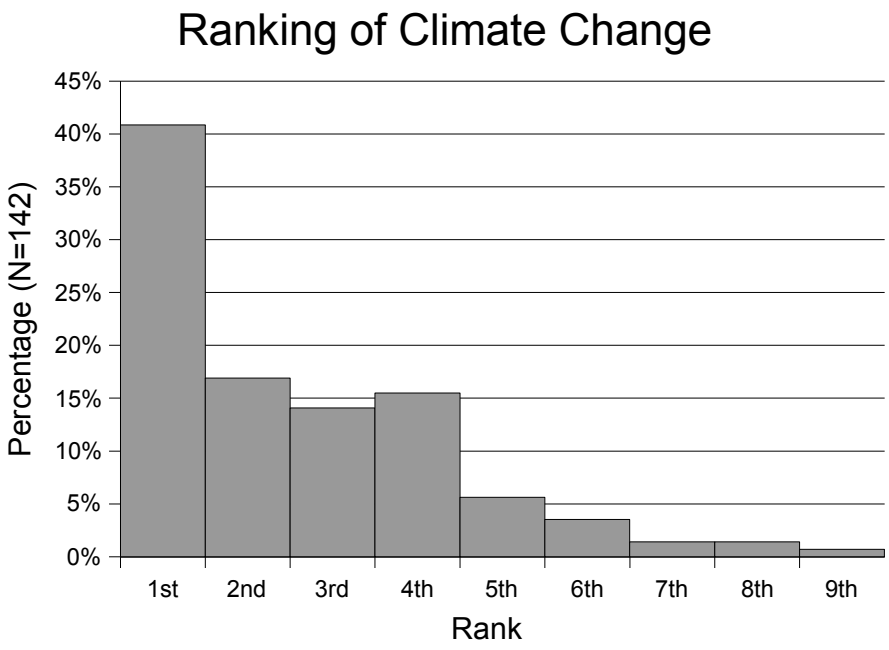

Figure 13: Ranking of Climate Change

Personal Effect of Climate Change

This was an open-ended question asking participants how they thought climate change would affect them personally. The responses were coded into categories, and are listed in Table 5.

Affect	*Frequency*
Climate or Weather	61
Lifestyle of Quality of Life Change	52
Resources or Prices	38
Society and the World	32
Concern, And Future Generations	23
Natural Habitat	21
No or Little Impact	19
Don't Know or Uncertainty	10
Very Negative	6
Total:	262

Table 5: Table Showing How Climate Change will Affect them Personally

The most common response was to mention changing weather or climate, including extreme weather events such as heatwaves, hurricanes, or floods.

Several thought that their quality of life would decrease, and that they would have to change their behaviour, such as gardening, holidays, or where to live in the future. There was also concern about personal health.

The third most common response was that resources would become more scarce and more expensive, especially energy, food and water, but also insurance.

Around one quarter of responses mentioned the wider impacts of climate change on society. There were concerns that climate change would increase the number of immigrants and social unrest, that there would be slower economic growth and that levels of disease would increase.

15% expressed worry about climate change, especially concern about their children and future generations. Many of those who thought that climate change would not affect them personally said that it would affect their children.

Some participants mentioned impacts on the natural environment, such as loss of biodiversity and sea level rise. This is where the influence of the earlier question is most clearly seen, since several participants thought that climate change would lead to air pollution, and that this would affect them personally.

A number of participants said that the personal effects of climate change would be minimal because they thought they were too old for the full impacts to be felt, or because they live in a rich country where the impacts would be less severe.

A small number of participants felt that the world was doomed by climate change.

Responsibility for Causing and Tackling Climate Change

As can be seen from Figure 14, the modal answer for causing climate change was Industry and Business, with National Governments and Individuals coming second and third. When it came to tackling climate change, nearly all chose National Governments.

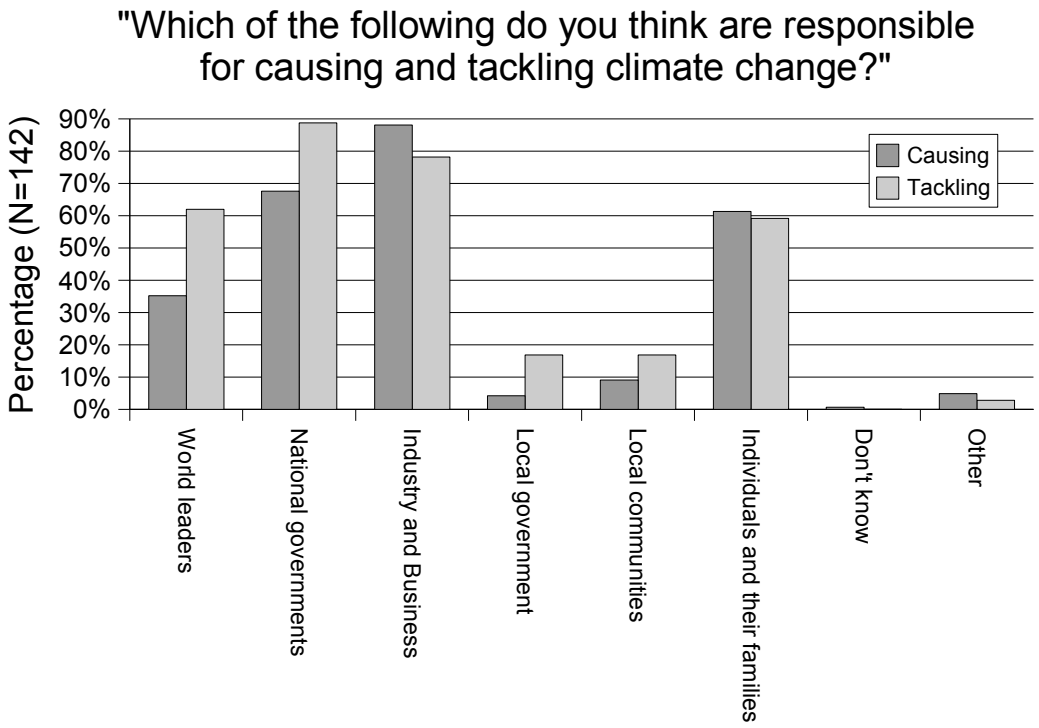

Figure 14: Answers to Responsibility for Causing and Tackling Climate Change Questions

Reducing Emissions

Participants were asked to rank a selection of eight potential ways of reducing carbon dioxide emissions. A histogram showing first choices is shown in Figure 15.

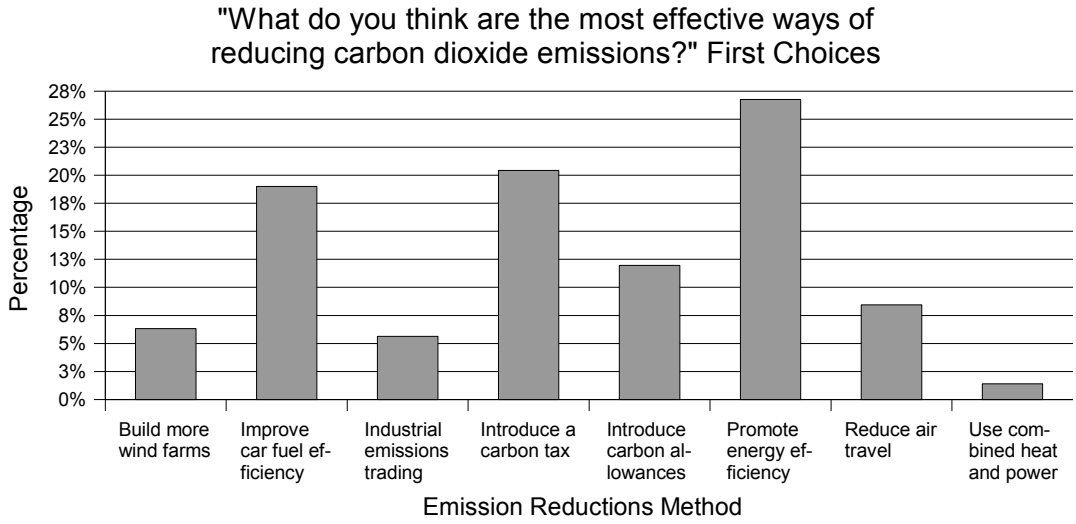

Figure 15: First Ranked Choices for Question about Emission Reductions

Electricity Generation in the Future

This was the third question in the series about electricity generation methods. As can be seen from Figure 16, coal and oil were very unpopular and solar and wind were very popular. Participants seemed less sure about hydroelectric. Nuclear was relatively well supported, with about half as many strongly disagreeing as strongly agreeing. As with the previous similar questions, Biomass received the most “Don't know” responses. Natural gas was more popular than coal or oil.

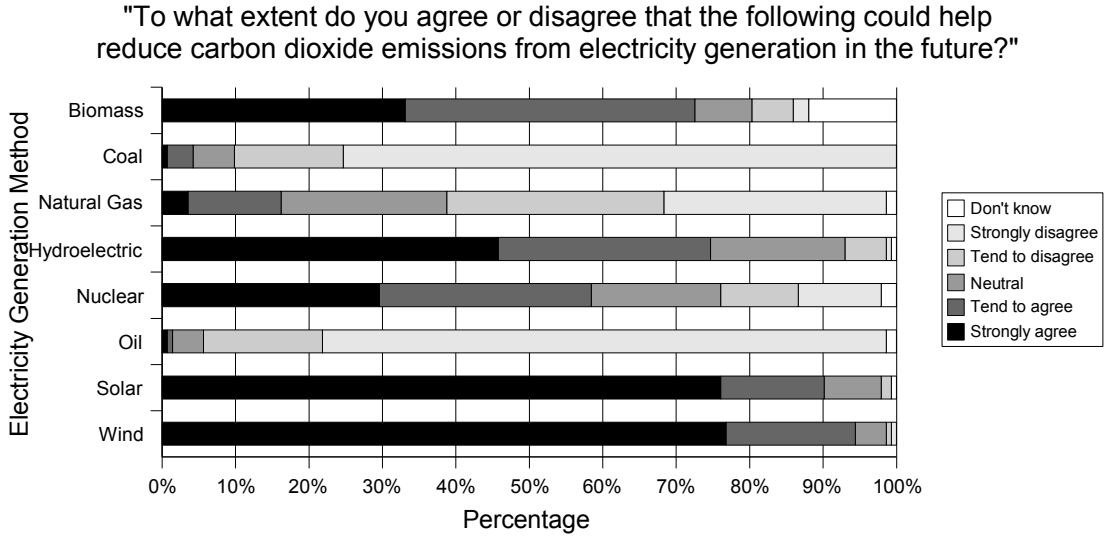

Figure 16: Answers to Future Electricity Generation Question

Personal Relation to Climate Change

As can be seen in Figure 17, just over half the participants said they strongly agree that they are part of the solution to climate change. Not a single participant felt that they were strongly not part

of the solution.

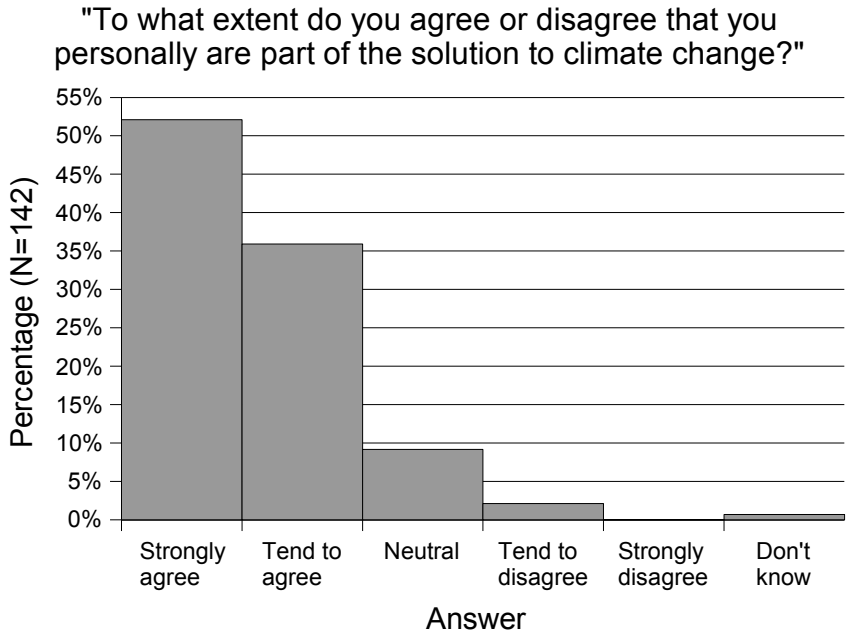

Figure 17: Answers to Question about Being Part of the Solution

Participants were also asked what personal actions, if any, they currently take to reduce their impact on climate change. The responses were coded and are listed in Table 6.

Answer	***Frequency***
Daily Life	131
Activism / Job / Politics	16
Communicate	14
Nothing	11
Aspiration	7
Run Climate*prediction*.net	2

Table 6: Answers to Personal Actions Question

Almost all the participants said that they take various actions in their daily lives to reduce their impact on climate change. A number also tackle climate change in their jobs, by their political decisions and through volunteering activities. Around a tenth of participants said they encourage those around them, either friends or pupils, to makes changes. A small number said they do nothing, and some said they were hoping to make changes in the future, such as installing renewable energy generation in their home. Two participants run the climate*prediction*.net climate modelling programme on their computers.

Those who do something in their daily lives mentioned:

- reducing car and air travel;
- walking or cycling more;
- reducing energy and water use in the home;
- recycling and reducing waste;
- buying local produce;
- generating or purchasing renewable electricity;
- offsetting carbon emissions.

Understanding Questions

Challenges Facing National Governments

This question gave the participants five suggested answers, but allowed comments and Other answers. The quantitative answers are shown in Figure 18, and the comments are discussed below.

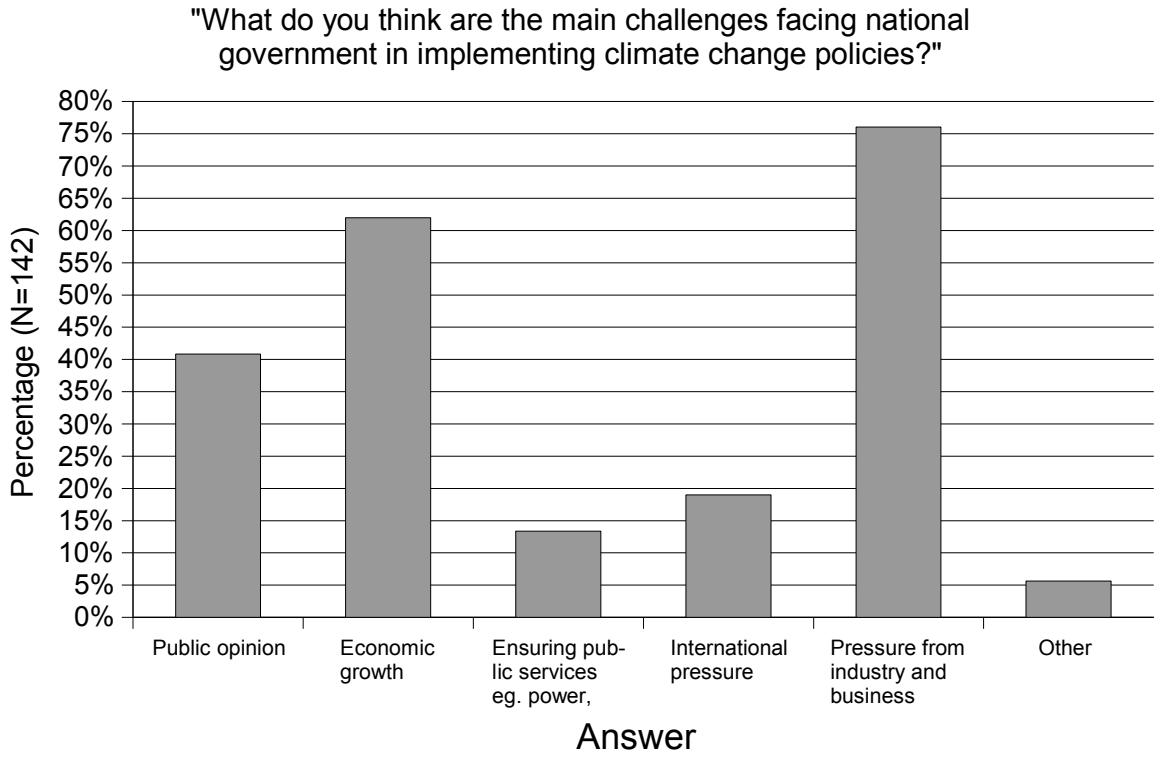

Figure 18: Answers to Challenges Facing Governments Question

The modal answer was Pressure from Industry and Business. Those who chose this option felt that companies prioritise profit over anything else, and that being good for the environment was uncompetitive. Also, it is not in a business's interest to encourage reduced consumption, and that they would need to be forced by legislation to change. It was felt that big businesses have a greater influence over government policy than public opinion or the needs of the environment.

Those that chose Economic Growth felt that a more sustainable model of economic growth, that could deal with climate change, was needed, and that governments needed to be willing to make long-term policies.

41% of participants chose Public Opinion, with comments that people were lazy, selfish and unwilling to change, but also that they did not know how to make the necessary changes. They blamed ignorance about climate change, especially in the USA, and a lack of understanding of risk.

Those that chose International Pressure pointed out that every country needs to sign up to agreements so as not lose out economically, and that internal pressure forces the government to deal with local issues before global ones.

There were a number of Other answers, which included public apathy, the USA, short-termism and capitalism.

Kyoto Protocol

Most participants had correctly chosen the USA from the previous question, and now they were asked why the two countries had not ratified the Protocol. They mostly gave answers for the USA, but since only half of the answers for the second country were correct, there were several answers giving explanations for incorrect countries. The categories are listed in Table 7, and include reasons for Australia separately.

Answer	*Frequency*
Economics	68
Industry	63
Self-Interest	20
Other	19
World	18
Kyoto	17
Public Opinion	14
Australia	13
Short-termism	7

Table 7: Answers to Why Countries Did Not Ratify the Kyoto Protocol

The most common response, accounting for nearly half the participants, was the argument used by the USA that the costs of Kyoto would damage their domestic economy. The second most common response was that the USA government was pressured not to ratify by its industry, and the oil lobby in particular.

There were a number of other responses mentioned by between ten and twenty participants. One was American selfishness and attachment to their culture. Another was the reason given by the USA that they wanted developing countries such as India and China to take on targets as well. Several participants said that the American government did not believe in climate change or that they believed there were better ways of tackling climate change than Kyoto. Lastly, a number of participants felt that public opinion was against ratifying Kyoto, or that politicians felt it would lost them votes.

Those that specifically gave a reason for Australia mentioned coal reserves, reliance on coal exports, and pressure from the USA.

The Other responses included the USA believing themselves to be too powerful to need to conform to international pressure and having a dislike of international commitments, or that the USA has bad leadership.

Participants were then asked why they thought the other Annex I countries had signed up to the Kyoto Protocol. The categories are shown in Table 8.

Answer	*Frequency*
Climate Change	74
Public	38
Responsibility	26
Easy / Spin	25
International	23
Collective Action	13
Gain	10
Total:	*209*

Table 8: Answers to Why the Other Annex I Countries did Ratify Kyoto

The most common answer, mentioned by just over half of the participants, was that these Annex I countries believed in the science of climate change and were willing to take action now to protect their longterm wellbeing. 25% thought that there was strong and informed public opinion supporting Kyoto in these countries. Nearly 20% said these countries thought it was the right thing to do and that they took responsibility for causing climate change in the first place. 17% thought that Annex I countries signed up either because they thought their targets would be easy to achieve, due to existing energy efficiencies or the 1990 baseline, or simply for good publicity. Quite a number thought that countries had signed up due to international pressure or the desire to look good in the eyes of other nations. Lastly, a small number of participants thought that Annex I countries were willing to cooperate to tackle climate change, and that they might actually gain economically through energy efficiency and flexible mechanisms.

The last of the questions about the Kyoto Protocol asked why developing countries might have signed up. This question not only assessed understanding, but knowledge, since participants could show that they knew about the Clean Development Mechanism, for example. The answers, coded into seven categories, are listed in Table 9.

Answer	*Frequency*
Economic Gain	69
Environment / Future	35
Goodwill / Political Gain	28
Hit Hardest by Climate Change	25
International	15
Nothing to Lose	15
Don't Know	8
Total:	*195*

Table 9: Answers to Why Developing Countries Signed up to the Kyoto Protocol

These responses were the weakest of all the Kyoto questions. There was only one major

response, which was economic or technological gain from the Protocol. The other responses were mentioned by at most one quarter of participants. The more common of these were a genuine concern for the environment and the future, political goodwill from the richer countries, and knowledge that these poorer countries were likely to be worst hit by climate change. An even smaller number of participants thought that developing countries signed up due to international pressure or because they had nothing to lose. Nearly 6% of participants did not know why developing countries might have signed up.

6 participants specifically mentioned the Clean Development Mechanism, although more thought that developing countries would get aid money, benefit from technology transfer, or be able to take part in carbon trading.

Quite a number of participants thought that developing countries would want to develop along a more sustainable path, and thus signed up to Kyoto in order to benefit from more environmentally friendly technology and because they cared about the environment.

Comparison of Pre- and Post-Game Questions

This section looks at the ten questions that were asked before and after the game.

Causes of Climate Change

The differences in responses are summarised in Table 10.

Difference	***Frequency***
Different	64
Same	40
Clearer	21
Less Detailed	9
Incorrect Response	6
No Answer	2
Total:	*142*

Table 10: Differences in Responses to Causes of Climate Change Questions

45% of participants wrote responses that were different from pre-game response, but were neither more or less correct. Nearly a third of responses were the same as the pre-game ones, or said “same as before”.

15% of the post-game responses were noticeably clearer, more accurate or more specific than the pre-game responses. For example, whereas many participants had said "Greenhouse gases" or "carbon dioxide emissions" before, they said "Greenhouse gases caused by a wide range of home and industrial activities" or "human activity - vehicles, farming, industry" afterwards.

Some participants went from vague, incorrect responses before the game, to more accurate, clearer responses after the game. For example, one participant wrote beforehand,

Pollution; Loss of bio-diversity; Natural cycles in the Earth's climate

and afterwards wrote

Transport; Industry; Intensive farming; Energy production

Another participant wrote

Cars, cows, planes, experiments/products with badly tested chemical substances, industrial waste, refrigerators, spraycans, cleaning products, washing powder, perfumes?, pharmaceuticals, fertilizers

showing confusion as to the causes of climate change, whereas their post-game response was

Pollution, bad energy sources, travel, ineffective housing, bad industry, lack of research on alternative energy, reliance on coal, planes, cars

A very small number of participants appeared to reduce their understanding of climate change with their post-game responses. However, they had spent around an hour playing the game by this point and perhaps did not want to write as much as they had at the beginning. Even fewer maintained their incorrect response from the pre-game question.

Impacts of Climate Change

The two sets of results are broadly the same (Figure 19). Only two options gained after the game – increased flooding in some areas and less drinking water availability. All the other options reduced in frequency.

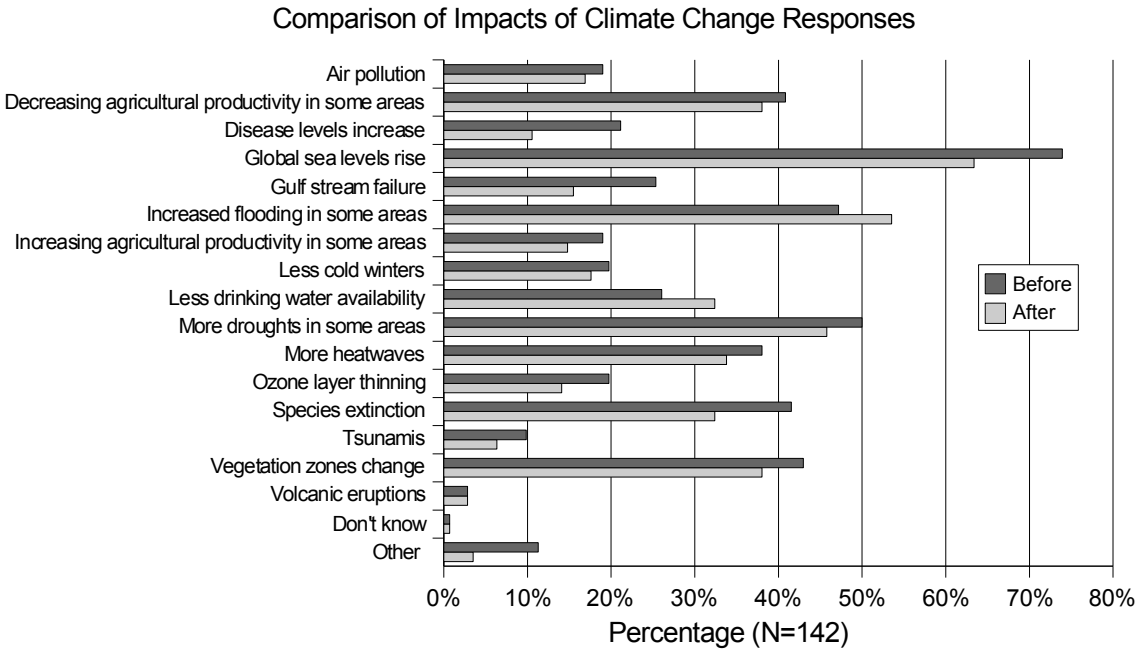

Figure 19: Comparison of pre-game and post-game Responses to Impacts of Climate Change Question

A t-test was carried out on the number of incorrect answers given before and after playing the game, to determine whether participants had increased the accuracy of their answers by playing the game. The average number of wrong answers before the game was 0.51, and afterwards was 0.40. From these data sets, t=1.14589, degrees of freedom n=282, and at the 0.05 level, the difference of the means was not significantly different from the test mean. This means that the mean number of incorrect answers did not decrease significantly after the game.

Personal Impact of Climate Change

One third of participants said the same thing as they had before. Most of the pre-game Don't Knows remained Don't Knows except one who wrote

Availability of fuel resources and building materials

as their post-game response. One participant who wrote

I'll avoid waste and unnecessary spending

before playing the game, wrote

I'll be more responsible on personal behaviour and maybe politically too

afterwards, which indicates a growing political awareness about climate change. Another wrote

Will not affect me but can affect next generations...

before the game, and then wrote

will affect next generations and I feel personally responsible

to do as much as I can to improve the situation

indicating they now take some responsibility for future generations. Again, some responses were shorter than their pre-game counterparts.

Contribution of Power Generation to Climate Change

The overall pattern of responses is similar to the pre-game responses (Figure 20), with most participants choosing coal and oil as major contributors, and solar and wind as the least contributors.

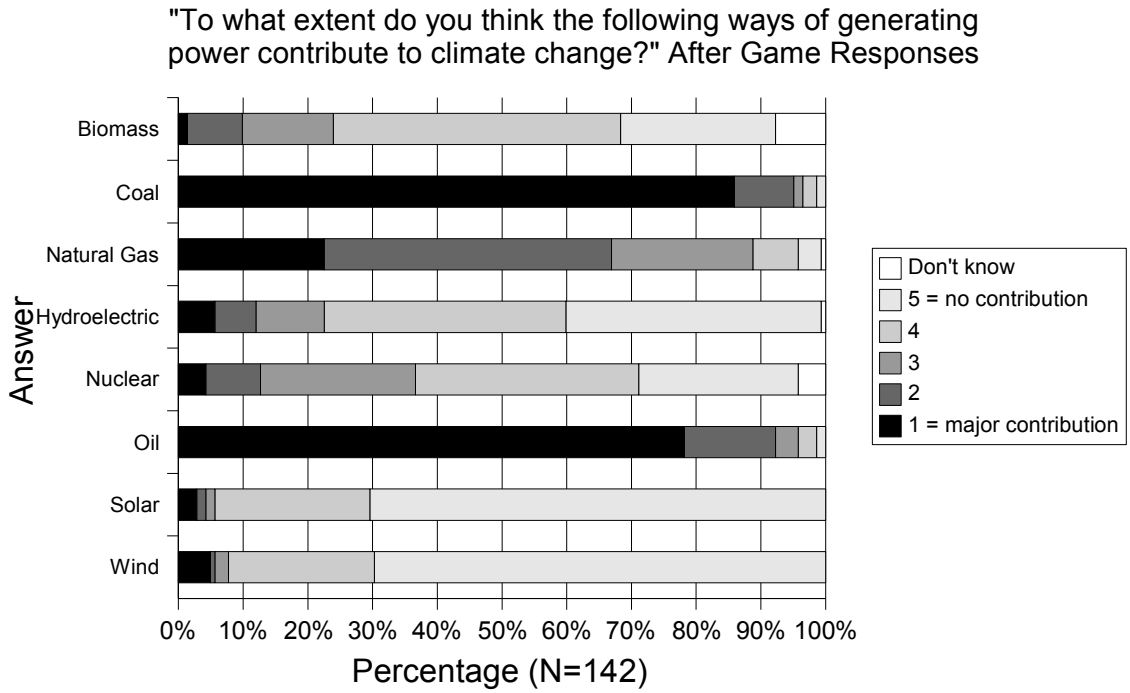

Figure 20: post-game Responses to Contributions to Climate Change Question

Several participants thought that wind and solar had a major contribution to climate change after playing the game, and more participants thought solar and wind had no contribution after the game

than before.

Looking at the “Don't Know” responses (Figure 21), there are nearly half the number of Biomass responses, and there are more Nuclear responses.

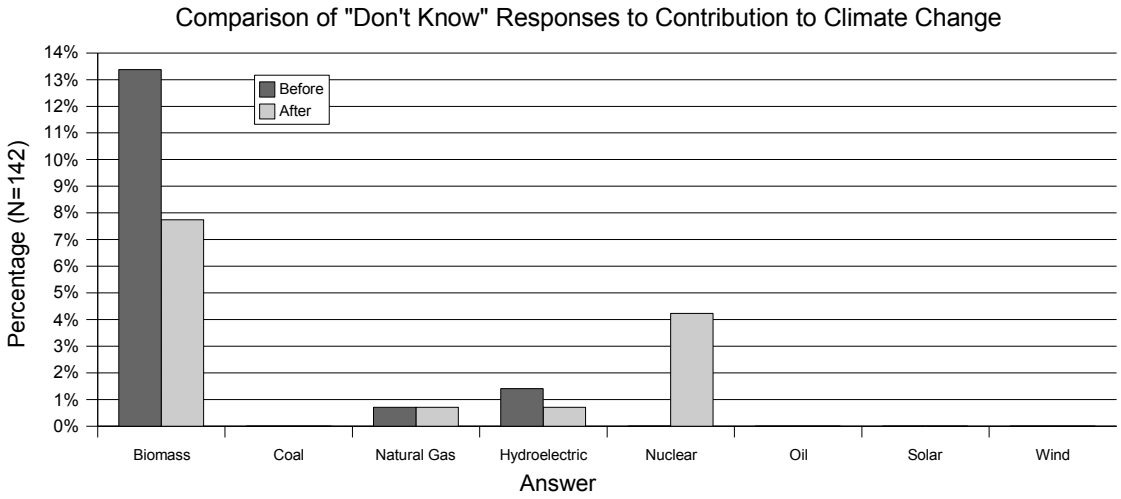

Figure 21: Comparison of Don't Know Responses to Questions about Contribution to Climate Change

More participants thought that nuclear did contribute to climate after the game than before (Figure 22), and fewer thought that it had no contribution.

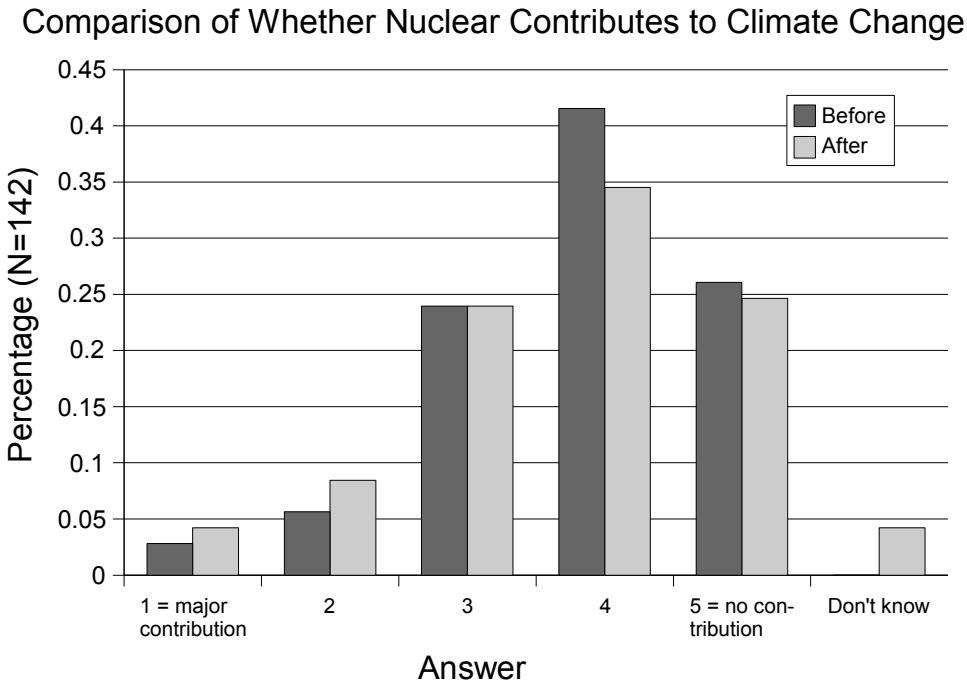

Figure 22: Comparison of Whether Nuclear Contributes to Climate Change

Responsibility for Tackling Climate Change

The post-game question asked participants to rank answers, rather than select three, but a comparison was carried out by summing the top three for each answer. The results are broadly similar, with the largest change being fewer choosing Individuals and their families.

Reducing Carbon Dioxide Emissions

This question involved ranking a set of options, and the first choices are shown in Figure 23.

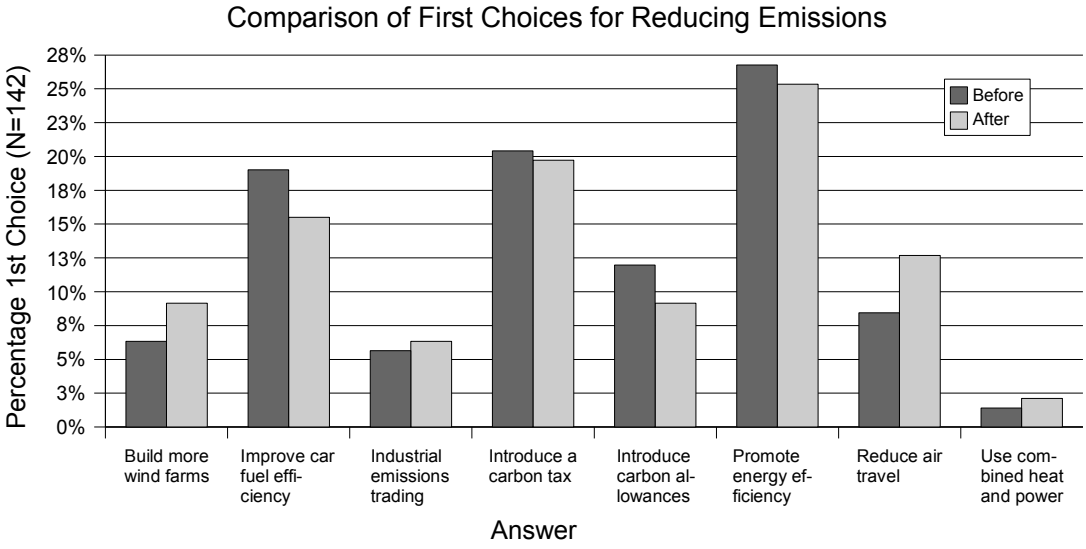

Figure 23: Comparison of First Choices for Reducing Carbon Dioxide Emissions

The responses are relatively similar, although wind farms, industrial emissions trading, reducing air travel and combined heat and power were more popular after the game, whereas improving car fuel efficiency, carbon tax, carbon allowances and energy efficiency were less popular.

Challenges Facing National Governments

From Figure 24, Public Opinion and Ensuring Public Services were seen as more important, after playing the game, whereas Economic Growth and Pressure from Industry and Business were seen as less important. International Pressure was seen as only slightly more important, and there were far fewer Other options.

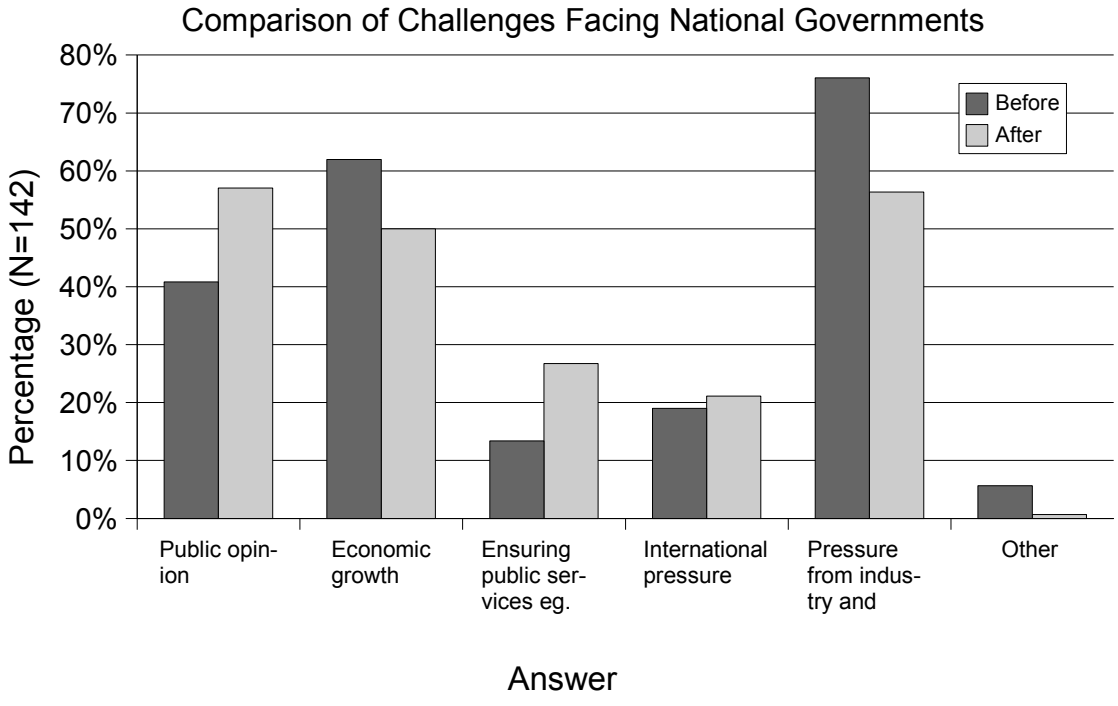

Figure 24: Comparison of Challenges Facing Politicians Question

Future Electricity Generation

The “strongly agree” responses are very similar, with only hydroelectric and nuclear becoming slightly less popular after the game. A similar result is found when comparing the “strongly disagree” responses.

It is interesting to look at the Don't Know responses (Figure 25). As with the earlier question, the number of Don't Know's for Biomass has halved, and the number for nuclear has increased slightly.

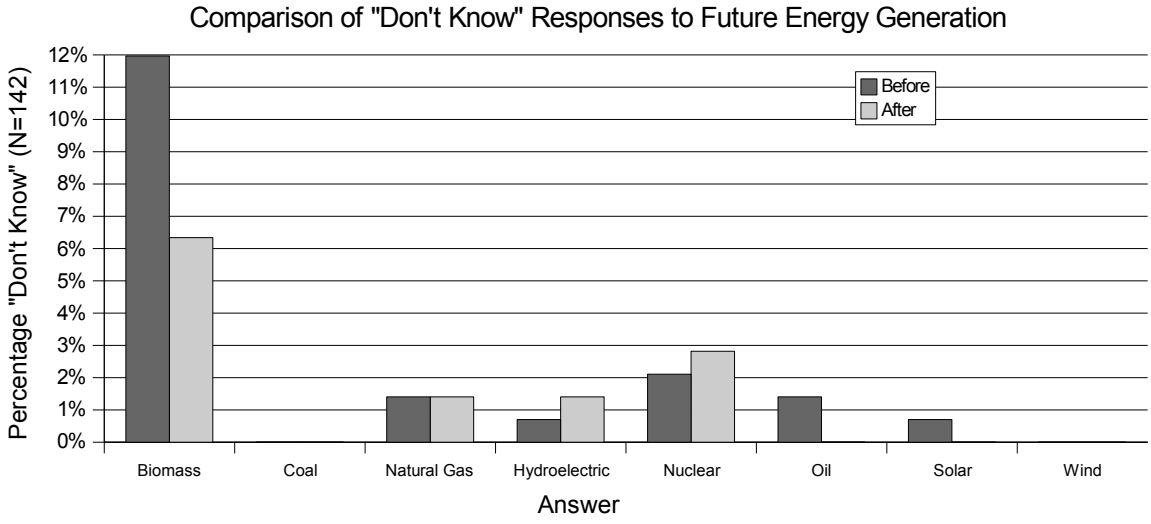

Figure 25: Comparison of “Don't Know” Responses to Contribution to Future Energy Supplies Questions

International Agreements

This question asked participants to reflect on the international negotiation stage of the game and suggest challenges facing such negotiations. The responses to this question were coded into 6 categories, listed in Table 11.

Category	*Frequency*
Economic Concerns	39
Domestic Pressure	33
Differences Between Countries, Achieving Consensus, Fairness	46
Incentives / Free-Rider	17
Proving the Benefits / Consequences	15

Table 11: Table Summarising Responses Challenges Facing International Agreements Question

Most participants talked about the differences between developing and developed countries, the USA not being willing to sign agreements on climate change, or the difficulties in finding a fair agreement. This is typified by the response “finding a deal that is just for all parties”.

Around one quarter mentioned domestic pressures from industry or the public, and a further quarter mentioned economic concerns either in terms of prioritising the economy of the environment or problems in paying for emissions reductions measures.

Around 10% mentioned the challenges of preventing free-riders and ensuring adequate incentives to countries, and the same number felt that many governments did not believe in climate change, did not understand the consequences of inaction at this stage, or did not understand the benefits of such an international agreement.

Changes in Personal Behaviour As A Result of the Game

One third of participants replied that yes, they were more likely to do more to help tackle climate change, such as using energy saving bulbs or generally concentrating on reducing their energy usage, for example

Yes, definitely. I would be really interested in some of the measures proposed - rainwater collection, fuel cells, energy efficiency and carbon allowances. I was amazed by how much of an impact home policies had on emissions.

Another third said no, either because the game had not inspired them to change their behaviour, or because they did not think it was up to individuals to tackle climate change.

The rest said they would continue what they were doing anyway, explaining that they already knew about most of the ideas mentioned in the game, for example

I would probably do these things anyway, but the game acted as a reminder

Questions about the Game

Enjoyment

The first question asked whether the participants had enjoyed the game (Figure 26). 65% responded positively ("Yes" or "Quite a lot") and 15% responded negatively ("Not really" or "Not at all"), suggesting that a majority of participants enjoyed playing the game.

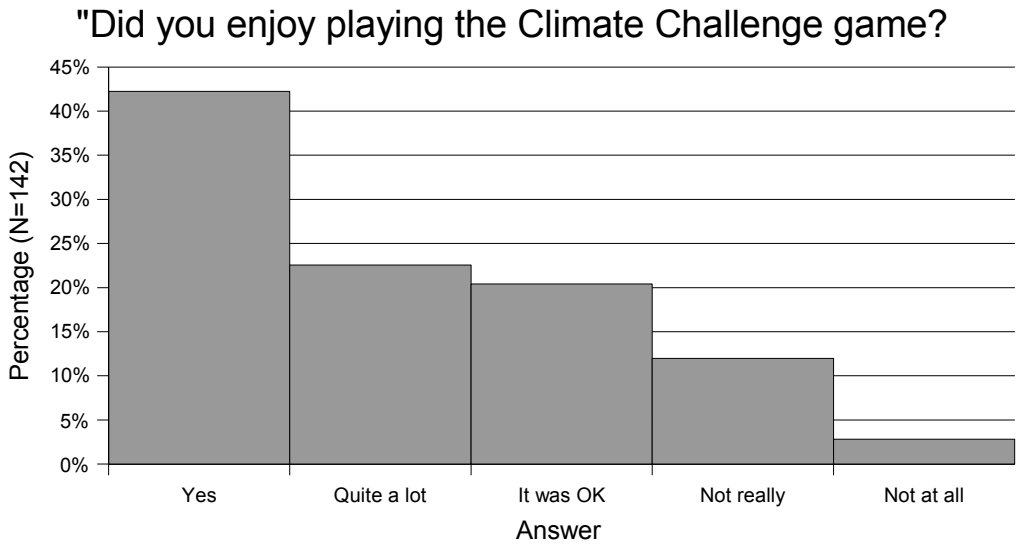

Figure 26: Histogram Showing Answers to Question about Enjoyment

Playability

The participants were asked how they would describe the playability of the game, with a choice of five options, plus space for comments next to their choices, and an "Other" option, and the ability to select more than one option (Figure 27).

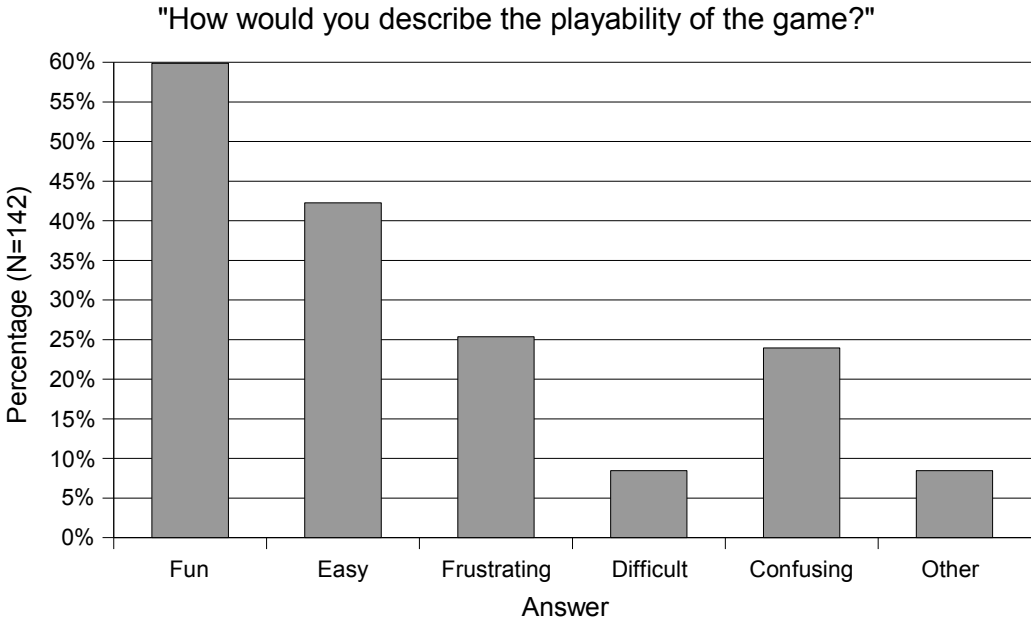

Figure 27: Answers to Playability Question

Comments ranged from “repetitive” and “slow” to “I loved it” and “thought-provoking”. Many of these comments contradicted each other. Some thought the game well made while others thought it full of bugs.

Learning from the Game

The results in Figure 28 show that 39% of participants felt they learnt a bit from the game, which was the modal answer, however the distribution of answers was skewed towards the positive with 34% answering “Yes” or “Quite a lot” compared to 26% answering “Not really” or “Not at all”.

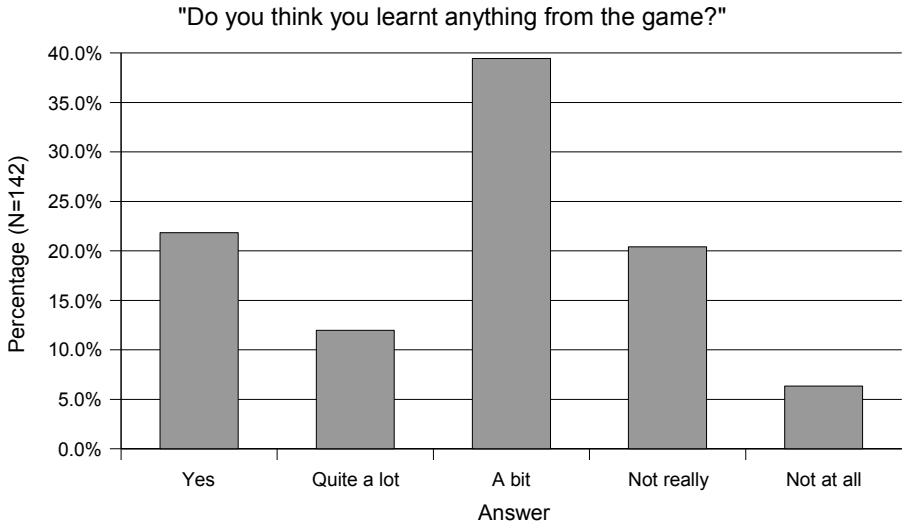

Figure 28: Responses to Learning Question

The participants were also asked what they thought was the key thing they learnt from the game. The answers were coded into eight categories (Table 12)

Category	***Frequency***
Complexity	40
Resources	26
Political	19
Policies	32
Individual Action	15
Popularity	15
Optimistic	5
Game	8
Other	7

Table 12: Categories of Answer to Question about Learning from the Game

The first category contained any answers that mentioned the complexity of climate change, the difficulties posed by it, or the balances and trade offs needed. An answer that typifies this category is “That it is a complex issue and that there are no quick fixes.”

The second category contained answers that mentioned the interaction between climate change and other resources, such as food, water, money and energy, and in particular the need to balance these resources with climate change mitigation.

The third category was the political aspects of climate change. This included the difficulties facing national governments in enacting climate change policies, as well as the challenges of international negotiations, and the way these two levels interact.

The policy options themselves made up the fourth category, including any mention of specific policies that the participant had learnt about, such as biomass or fuel cells, or the relative impact of certain policies, for example surprise at how little an impact recycling or planting trees would have.

The fifth category included those answers which expressed either a positive or negative comment about the role of individuals in tackling climate change. Two responses were totally negative, that there was nothing that individuals could do about climate change. Several were positive about the role of individuals, whilst the rest thought that individuals would have a small impact, but needed to do all they could anyway.

The sixth category concerned public opinion when bringing in climate change policies. A few felt

that the game had made public opinion too easy to sway, and that the public supported any climate change policies. However, others were encouraged by the possibility that public opinion was not as negative as they thought it would be.

The seventh category included comments that the participant now felt more positively about climate change. For example “knowing that the human race still has a chance” or “that there is hope“. Other answers in this category were that the participant had learnt that there were more options than they had thought for tackling climate change.

The eighth category concerned the game itself, including the “game was too simplistic and too easy to really teach anything”, that “well designed games are good at presenting information”, and “Designing climate games must be difficult”.

The other comments, beyond those who did not answer the question fully, were negative comments suggesting the participant had not learnt anything from the game.

Understanding Climate Change

The participants were asked whether they thought the game had helped them to understand climate change better (Figure 29)

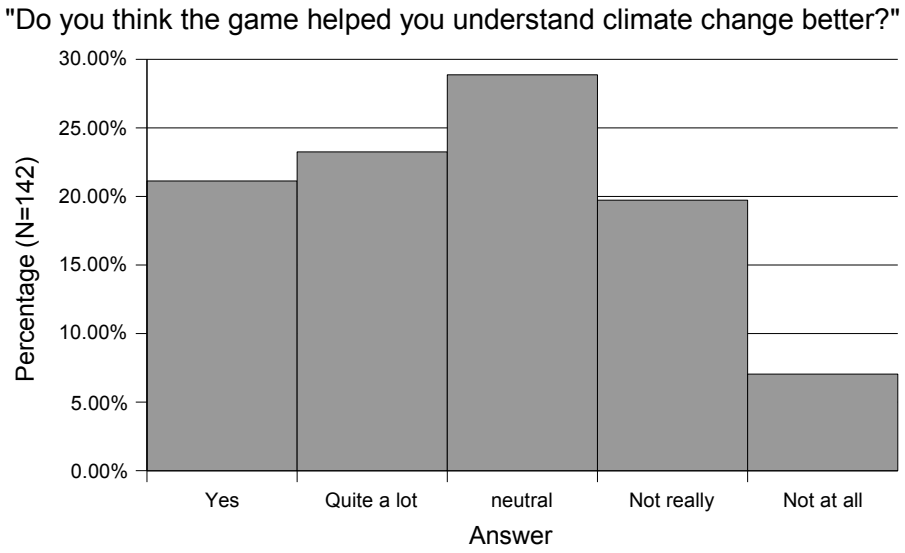

Figure 29: Answers to Better Understanding Question

The distribution was skewed towards “Yes”, and 44% of participants responded positively (“Yes” or “Quite a lot”), and 27% responded negatively (“Not really” or “Not at all”).

Using Games to Teach Climate Change

As can be seen in Figure 30, a majority of responses to this question were positive, with only three participants responding negatively, and one “Don't Know”.

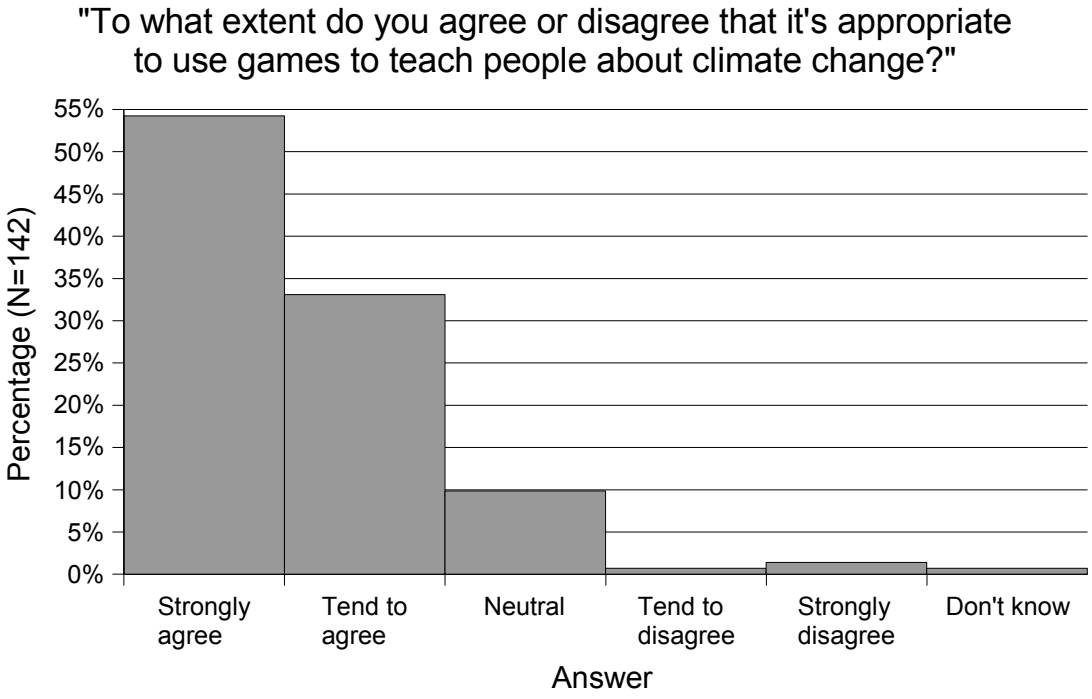

Figure 30: Answers to Use of Games to Teach about Climate Change Question

Repeatability and Recommendation

Table 13 and Table 14 list answers to the questions about whether participants would be interested in playing the game again, and whether they would recommend it to a friend.

Answer	***Count***	***Percentage***
Yes	97	68%
No	45	32%

Table 13: “Would you be interested in playing the game again?”

Answer	***Count***	***Percentage***
Yes	78	55%
Maybe	39	28%
No	19	13%
Don't know	6	4%

Table 14: “Would you recommend the game to a friend?”

Comments about the Game

Participants what they did not like about the game. 26 said they disliked nothing. 20 thought the

game was slow and repetitive. 27 commented on the international negotiation stage, mostly noting that the “persuade” button did not do anything, which was a known bug and was later fixed. Seven thought it was too easy or simplistic, and 16 thought it was too complicated, complaining that the tutorial was not comprehensive enough. As a result, the tutorial was extended for BBC website version. 29 made comments on the local policy stage, mentioning which things they thought were unrealistic or unclear, such as only being able to “play” six policies each decade, regardless of how big a project each policy is.

Discussion

Principal Findings of the Study

This study set out to examine how computer games might be used to communicate the issues of climate change, using the Climate Challenge Game as a case study.

Analysis of the Sample

Analysis of the pre-game questionnaire showed that the participants were largely already knowledgeable about climate change before playing the game. 14% had studied Geography or Environmental Science at university level; 37% described their knowledge of climate change as “extensive” or “expert in the field”; and most gave correct answers to the factual pre-game questions. This meant that it would be unlikely for the game to teach them about climate change.

Around half the sample also had a prior interest in climate change, as evidenced by the 41% who said climate change was the most important issue facing society; the 39% who gave time or money to an environmental charity in the past year; the 52% who strongly agreed that they personally were part of the solution; and the mere 8% who said they were doing nothing to tackle climate change.

Previous surveys (Poortinga et al, 2006) and (Boyes, 2004) found misconceptions about nuclear power and the ozone layer and the causes of climate change. Very few participants in this study held these misconceptions, most likely because of this sample bias.

It was found that 56% of the sample were gamers, which is similar to the 59% found by the BBC survey (BBC, 2005), although they found 48% of their sample played computer games at least once a week, compared to 33% in this study. The most popular type of game was simulation games, of which the Climate Challenge Game is an example. The BBC survey found that simulation games appeal equally to both male and female players, which is important when designing educational games with wide appeal.

Discussion of Pre-Game Questions

The overall pattern of the causes of climate change was of a link between greenhouse gases, carbon dioxide emissions and human activities, which were either the physical processes, such as industry or vehicles, or the social processes, such as industrialisation, globalisation or consumer culture.

The personal effect of climate change was felt to be the direct effect of warmer, more extreme weather or the impact of the social changes due to climate change. Some did not seem worried at all, trusting in the wealth and technology of developed nations to minimise the effects. Others expressed worry about the future, especially for their children.

The first choices for ways to reduce carbon dioxide emissions were interesting. The most popular was to promote energy efficiency, which would not only reduce emissions but save individuals money, similarly for the third most popular, car fuel efficiency. But the second most popular was introducing a carbon tax, which would be financially tougher on individuals, and implies some willingness to accept unpopular policies to prevent climate change.

The questions about the Kyoto Protocol showed a good understanding of the politics of climate change, with participants knowing that what a country says may not be the entire reason for its actions. Some participants said that countries that signed up could see the long term and were willing to work together, whilst some were more cynical, suggesting their participation was only to look good, since their targets were easy.

Testing Hypotheses

Five hypotheses were established, looking at different aspects of the game and its effect on players.

Playing the Climate Challenge Game affects the player's attitudes towards climate change

As already mentioned above, at least half the sample already saw themselves as part of the solution, and only a small number were not doing anything about climate change in their daily lives.

Comments from post-game questions show that many participants did change their attitudes. For example, participants said they learnt

how much of a difference local and individual based policies make

and that

there are more things I can do in my home than I've thought

There were other participants who felt the exact opposite, saying

that as an individual I do not have any power to change things

Several participants also felt more positive, saying that the game

indicated that there were more options that might reduce climate change than I thought

or

knowing that the human race still has a chance

13 participants answered “Neutral” to being part of the solution, and therefore had an unformed opinion about the role of the individual. When asked, after playing the game, if they would change their behaviour, five replied positively, saying they would “switch to green electricity” or “support politicians pushing for climate change legislation”. Two said they would not change because they were already doing what they could, and the others replied negatively. Nevertheless, a small number had formed a positive opinion about their personal involvement in tackling climate change.

Taking only those who ranked climate change as 5th or lower in priority in the pre-game question

produced a group of 18 participants. In the post-game questionnaire, five of these said they would do more to tackle climate change personally, and three ranked Individuals as the most important in tackling climate change. Two thought industry and business should make the changes. Again, this shows that some participants' attitudes changed as a result of playing the game.

Nuclear power lost popularity as a future energy supply, after the game, and more participants replied “Don't know” about it. In the game, nuclear power is good for climate change, although public opinion is against it, so it would seem participants were swayed more by public opinion than the effects on climate change.

Opportunities arising from climate change were mentioned only in the context of international agreements, from which developing and developed countries might gain economically and technologically. Only one participant mentioned personal gain from climate change, and they were an oceanographer hoping for more grants.

Overall, it has been shown that some participants changed their attitudes towards climate change, but many did not. In terms of communicating climate change, it is reasonable to expect a game to positively influence those with relatively unformed opinions about climate change, but that those with strong opinions, whether they think climate change is not happening, or that they must do everything to stop it, will not be influenced so much.

Playing the Climate Challenge Game gives the player an understanding of the wide variety of policy options, from the international to the household level

When asked if they thought they understood climate change better after playing the game, 44% responded positively (“Yes” or “Quite a lot”), and 27% responded negatively (“Not really” or “Not at all”), showing that more participants felt their understanding had increased than had not.

After playing the game, more participants felt that public opinion and ensuring public services were challenges facing politicians, and that economic growth and pressure from industry were lesser challenges. Comments showed that participants had not realised the importance of ensuring public services, and the link with climate change, until they played the game, indicating a greater understanding of how climate change can affect every aspect of society.

Post-game responses about international agreements show a good understanding of the issues, with almost all the participants giving a reasoned response. Many showed an awareness of the interplay between national and international politics and economics, and the different situations of developed and developing countries. It is, however, harder to pin this understanding on the influence of the game, especially since the pre-game questions were generally well answered.

Interestingly, in the post-game question about favoured policy options, more participants wanted to build wind farms and reduce air travel than before, indicating an understanding of the need for renewable energy and the impact of aviation.

It was hoped that the game would bring together informatino about climate change, giving the players a holistic view of the issue, and hence a better understanding. One comment typifies this, commenting that the game

brings together nicely choices governments have to make

Playing the Climate Challenge Game gives the player a greater knowledge of the science behind climate change

To assess learning, it is interesting to look at the 24 participants who said they had “Little or none” or “basic” knowledge of climate change before playing the game. When asked if they thought they had learnt anything from the game, 11 replied “Yes” or “Quite a lot”, 11 replied “A Bit”, and only two replied “Not a lot” or “Not at all”, which shows that 92% of those with less knowledge found the game educational.

Before the game, 19 participants replied “Don't know” when asked about Biomass, which agrees with Poortinga (Poortinga et al, 2006), who found Biomass to be the least known about energy source. It was interesting, therefore, that only 11 replied “Don't know” after the game, showing they had learnt from the game what biomass was and were able to answer the question more knowledgeably.

The failure of the t-test to find a significant decrease in the mean number of incorrect responses to the impacts of climate change question is likely due to the high number of correct responses, so small changes are less likely to be statistically significant. Also, the incorrect answers, such as

ozone layer thinning, are not explicitly mentioned in the game, so participants would not have learnt that it was not an impact except by its absence.

When asked if they thought they had learnt anything from the game, 34% of the total sample answered “Yes” or “Quite a lot”, 39% said “A bit”, and 26% answered “Not really” or “Not at all” meaning that a majority of participants found the game educational.

Before the game, 21 participants gave incorrect responses for the causes of climate change. After the game, of these 21, 13 gave clearer and more accurate responses, and only 7 maintained incorrect responses or reiterated their incorrect pre-game responses, indicating that two thirds had increased their knowledge of the causes of climate change by playing the game.

Comments in the post-game questionnaire support the idea that participants learnt from the game. For example

this was fascinating - I really enjoyed playing it and I felt I learned something

In addition, there several comments such as

while I don't think I learnt much from the game personally,

I believe that there is lots of value in it for people in general

Players find the Climate Challenge Game an effective way of learning about climate change

As already mentioned, a majority of participants said they learnt something from the game. In addition, 87% of participants agreed that computer games were an appropriate way to teach people about climate change and 65% of participants said they enjoyed playing the game (answering “Yes” or “Quite a lot”), so it seems reasonable to suggest that they found the game an effective learning environment that was both educational and entertaining.

Comments from the post-game questionnaire support this:

well designed games are good at presenting information

and the participant learnt

Of those that said they did not learn anything from the game, comments suggest they found the game repetitive and either too complicated or too simplistic. Others said the game was too wordy and serious.

Some participants questioned whether the game was biased, and felt they would not trust a game to teach them. This issue of trust is fundamental to the use of serious computer games, and hinges on the player's attitudes towards games. It is part of the game design process to reassure the player that the information contained within the game is accurate, and to be entirely transparent about any estimates. When the Climate Challenge Game is played on the BBC website, there is an accompanying website explaining the science behind the game, and giving players Internet links to further reading. These were not available for the study, which might account for some of the comments.

Other participants said the game was more suitable for school children or, assuming it was aimed at children, thought it would be too complicated. This is another barrier to a widespread use of serious games, that many people do not think games are suitable for adults to play at all, let alone to use for educational purposes.

Overall, comments from those that did learn from the game show that they learnt about a wide range of issues, but especially the balances and trade-offs needed to minimise the effects of climate change whilst maintaining the current social frameworks.

A wide range of people enjoyed playing the game, regardless of their previous interest in gaming or climate change

Of the total sample, 65% said they enjoyed playing the game, compared to 15% who said they did not.

A comparison of was carried out between the 13 participants who said they played computer games every day, and the 40 who said they never played computer games. As can be seen from Figure 31, there was a strong positive response by both groups, although the frequent gamers enjoyed the game more than the non-gamers.

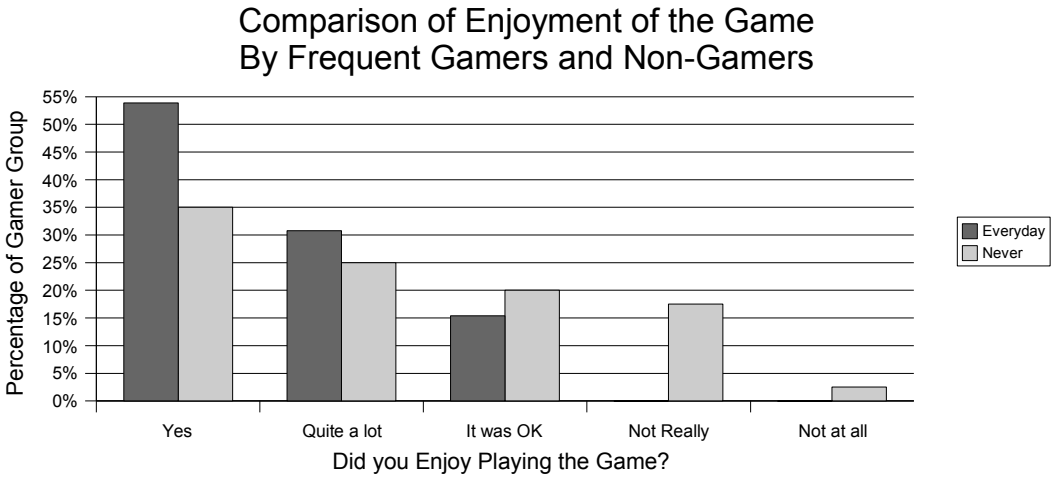

Figure 31: Comparison of Enjoyment of the Game By Frequent Gamers and Non-Gamers

Whether these two groups thought they learnt anything from game is shown in Figure 32.

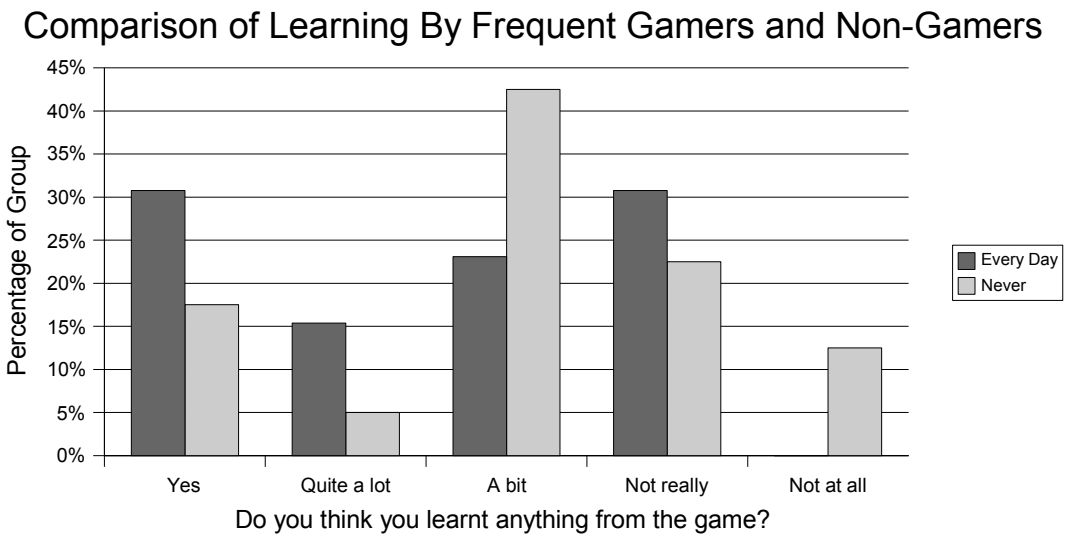

Figure 32: Comparison of Learning By Frequent Gamers and Non-Gamers

46% of the frequent gamers responded positively, compared to 31% who responded negatively, and 23% of the non-gamers responded positively, compared to 35% who responded negatively. This would suggest that the game was most effective as a learning environment for participants who regularly play games.

Of the 24 participants who said they had basic, little or no knowledge of climate change, 17 said they enjoyed the game. And of the 52 participants who said they had extensive knowledge or were experts in the field, 33 said they enjoyed the game, and none said they did not enjoy the game.

This shows that the game appeals equally in enjoyment, regardless of how much players know about climate change.

Strengths and Weaknesses of the Study

The main strength of the study was the unique use of a recent computer game designed specifically to communicate climate change, and the ability to work with the game's development team both on the game and the technical aspects of the study.

Another strength was that the study had a large number of responses, given the short timescales, and that all of these responses were detailed and useful.

The primary weakness of the study was that one third of the participants had extensive knowledge of climate change, or were experts in the field, so that increases in knowledge were hard to discern. This was due to the distribution method, which was focused on universities, and also was voluntary, so those who did not care or know much about climate change were unlikely to take part. However, there was one participant who was a climate sceptic, who nevertheless spent at least an hour completing the survey and playing the game through.

Due to time constraints, the pilot study was quite short. Further pilot work could have determined options for some of the open-ended questions, so that confusing open-ended responses would become options with comments, making analysis more reliable.

Strengths and Weaknesses in Relation to Previous Studies

The advantages and disadvantages of using the Internet for experiments were discussed in the Introduction. One disadvantage was that “subjects appear less attentive in Internet experiments”. This study would suggest that Internet subjects can be very attentive, since every completed survey involved a time commitment of around one hour. The facility to save responses and return later may have helped, although this had the potential disadvantage of removing the immediacy of responses to the post-game survey.

One advantage of the Internet was that the “demographics of Internet users approach

those of the general population". From this study, it can be said that, although Internet users in general may approach the general population, those that are interested enough in the topic of the study will form a specific subset of the general population. A laboratory study may, in fact, be a more reliable way of ensuring a wide population spread when the topic is a controversial one.

Meaning of the Study

Climate change is an issue that is increasingly being seen as a high priority for society, especially in developed countries. It is important, therefore, that the general public are informed about the subject and are willing to support politicians when they bring in policies to cut greenhouse gas emissions. Communicating the issues of climate change needs to be done in such a way that it reaches as wide an audience as possible, and games may be one way of achieving this. This study has shown that it is possible to engage people about climate change in a way that is informative and fun, thus providing another tool for climate change communicators.

Further Work

Future studies involving the Climate Challenge Game should be carried out with a broader sample, in terms of knowledge about climate change. This could take the form of a laboratory study in which participants are paid to take part, bringing in a wider range of the population. This could also lead to focus group sessions with players, to get a deeper understanding of their reactions to the game. A laboratory-style study could be compared with Internet results, to examine the differences when participants are on their own or supervised.

It might be interesting to compare the Climate Challenge Game with other games designed to communicate climate change, or to compare the game with other serious games designed to get across a particular message, such as health or politics.

The results of this study could be used in the development of future climate change games, especially making use of the comments about playability and how players learnt from the game.

Conclusions

This study looked at the use of computer games in communicating the issues of climate change. 142 participants played the Climate Challenge Game and completed pre- and post-game surveys. The sample was already considerably knowledgeable about climate change, and half were already concerned about climate change.

The strongest attitude change was seen in those with unformed opinions before playing the game, although some participants felt more positively about their personal role in tackling climate change as a result of playing the game.

Nearly half the participants said the game had given them a better understanding of climate change, and most gave well-reasoned responses to open-ended questions about climate change politics.

A majority of participants said they learnt something from the game, despite the large number who already know a lot about climate change. In particular, those who knew less before gave clearer and more accurate responses after playing the game, and more knew what biomass is.

The game was seen as an effective learning environment, which was both informative and enjoyable, although there were some issues, such as trust in the accuracy of the game, which would need to be addressed in future games.

A majority of participants said they enjoyed the game, and prior knowledge of climate change did not seem to affect this. Whether or not a participant regularly played computer games did, however, affect enjoyment and learning from the game, suggesting that games may be a more effective learning environment for those who play computer games anyway.

The study attracted a largely informed population of which a majority said they enjoyed the game. Therefore it can be concluded that the game can be an effective learning environment, and so adds to the growing body of work studying and supporting the idea of games used for educational purposes.

Bibliography

Ahmad, R., Bornik, P., Danielson, P. et al (2005) A Web-based Instrument to Model Social Norms: NERD Design and Results

Anderhub, V., Muller, R., Schmidt, C. (2001) Design and evaluation of an economic experiment via the internet. *Journal of Economic Behavior and Organisation* **46**: pp. 227-247.

BBC (2005) *BBC: Games In The UK: Digital play, digital lifestyles* British Broadcasting Corporation

Beard, C., Wilson, J. (2002) *The Power of Experiential Learning*. London: Kogan Page.

Bell, J. (2001) *Doing Your Research Project: A Guide for First-Time Researchers in Education and Social Science*. Buckingham: Open University Press.

Bernard, R. (2002) *Research Methods in Anthropology*. Oxford: AltaMira Press.

Boyes, E. (2004) High school students' beliefs about the extent to which actions might reduce global warming in 15th Global Warming International Conference and Expo

Carmichael, J., Tansey, J., Robinson, J. (2004) An integrated assessment modeling tool. *Global Environmental Change* **14**: pp. 171-183.

Channel 4 (2005) *Climate Control Survey* carried out by ICM Research Limited for Channel 4

Charness, G., Haruvy, E., Sonsino, D. (2003) Social Distance and Reciprocity: An Internet Experiment. *Available at SSRN: http://ssrn.com/abstract=312141*

Climate Challenge (2006) Climate Challenge website, part of the Climate Change Communication Initiative led by Defra, accessed 30 June 2006 (http://www.climatechallenge.gov.uk/index.html)

climateprediction.net (2006) climateprediction.net website, "climate science explained" page, accessed 30 June 2006 (http://www.climateprediction.net/science/index.php)

Csikszentmihalyi, M. (1990) *Flow: The Psychology of Optimal Experience*. New York: Harper Perennial.

Dahlburg, S. (2001) Using Climate Change as a Teaching Tool. *Canadian Journal of Environmental Education* **6**: .

Danielson P., R. Ahmad, et al. (2004) Deep, Cheap and Improvable: Dynamic Democratic Norms and the Ethics of Biotechnology

Defra (2006) *Climate Change: The UK Programme 2006* Department for the Environment, Food and Rural Affairs

Defra (2006) Global Warming educational website for schools, accessed 30 June 2006

(http://www.defra.gov.uk/environment/climatechange/schools/index.htm)

Dempsey, J., Rasmussen, K., Lucassen, B. (1996) *The Instructional Gaming Literature: Implications and 99 Sources* College of Education, University of South Alabama

DTI (2005) *Energy Indicators 2005* Department for Trade and Industry

Elgood, C. (1997) *Handbook of Management Games and Simulations*. London: Gower Publishing Limited.

Energy Saving Trust (2005) *Potential for Microgeneration: Study and Analysis* Energy Saving Strust

European Climate Forum (2006) Climate Games on the European Climate Forum website, accessed 30 June 2006 (http://www.european-climate-forum.net/games/)

Fabricatore, C. (2000) Learning and Videogames: an unploited synergy in Association for Educational Communications and Technology (AECT) 2000 workshop on "In Search of the Meaning of Learning: A Social Process of Raising Questions and Creating Meanings"

Fishkin, James S. (2000) *Virtual Democratic Possibilities: Prospects for Internet Democracy* The Center for Deliberative Democracy

Glasgow Science Centre (2006) Climate Change Challenge on Glasgow Science Centre website, accessed 30 June 2006 (http://www.glasgowsciencecentre.org/kids/games/ccc/)

McCarthy, J., Canziani, O., Leary, N., Dokken, D., White, K. (eds) (2001) *Climate Change 2001: Impacts, Adaptations and Vulnerability. Contribution of the Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

MIT (2006) Games to Teach project, MIT iCampus, accessed 3 July 2006 (http://icampus.mit.edu/projects/GamesToTeach.shtml)

Mitchell, A., Savill-Smith, C. (2004) *The use of computer and video games for learning: A review of the literature* Learning and skills development agency

Nakicenovic, N. et al (2000) *Special Report on Emissions Scenarios (SRES): a Special Report of the IPCC*. Cambridge: Cambridge University Press.

Ohnuma, S. (2005) Environmental Commons Game: Is the Free Rider a "Bad Apple"? in Shiratori, R., Arai, K., Kato, F., Gaming, Simulations, and Society, London: Springer

Poortina, W., Pidgeon, N., Lorenzoni, I. (2006) *Public Perceptions of Nuclear Power, Climate Change and Energy Options in Britain: Summary Findings of a Survey Conducted during October and November 2005. Technical Report (Understanding Risk Working Paper 06-02)* Centre for Environmental Risk

Prensky, M. (2003) Digital Game-Based Learning. *ACM Computers in Entertainment* **1**

Prensky, M. (2001) *Digital Game-Based Learning*. London: McGraw-Hill.

Real Climate (2006) Real Climate website "climate science from climate scientists",

accessed 30 June 2006 (http://www.realclimate.org/)

Shiratori, R., Arai, K., Kato, F. (2005) *Gaming, Simulations and Society*. Tokyo: Springer.

Social Impact Games (2006) Social Impact Games website, accessed 3 July 2006 (http://www.socialimpactgames.com/)

Squire, K. (2002) Cultural Framing of Computer/Video Games. *The International Journal of Computer Game Research* **2**

Stoll, C. (1999) *High Tech Heretic - reflections of a computer contrarian*. New York: First Anchor Books.

Tansey, J., Carmichael, J., VanWynsberghe, R., Robinson, J. (2002) The future is not what it used to be: participatory integrated assessment in the Georgia Basin. *Global Environmental Change* **12**: pp. 97-104.

Tearfund (2006) Climate change pentathlon, on the Tearfund website, accessed 30 June 2006 (http://www.tearfund.org/Campaigning/Climate+change+and+disasters/Pentathlon.htm)

UNEP (2006) United Nations Environment Programme, Interactive Java Climate Model on the UNEP website, accessed 1 July 2006 (http://climatechange.unep.net/jcm/)

van Eck, R. (2006) Digital Game-Based Learning: It's not just the digital natives who are restless. *Educause Review* **41**: pp. 16-30.

Wikipedia (2006) Simulation Game, article from Wikipedia, the free encyclopedia, accessed 3 July 2006 (http://en.wikipedia.org/wiki/Simulation_games)

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Appendix 1: Summary of Pre-Game Quantitative Results

Section 1A: Background to Climate Change

1. How much of a concern do you think climate change is, in the context of other issues facing society?

Answer	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Climate Change	41%	17%	14%	15%	6%	4%	1%	1%	1%
Economic development	7%	9%	8%	17%	11%	14%	11%	11%	11%
Erosion of civil liberties	4%	12%	16%	10%	20%	13%	9%	7%	8%
Immigration	1%	0	4%	6%	7%	10%	11%	24%	38%
Infectious disease	5%	11%	17%	13%	15%	10%	13%	12%	4%
Poverty	27%	32%	10%	8%	8%	3%	5%	2%	4%
Religious fundamentalism	5%	10%	13%	14%	8%	15%	15%	11%	7%
Terrorism	9%	6%	6%	9%	13%	16%	19%	18%	4%
Weapons of mass destruction	1%	4%	12%	7%	12%	15%	14%	13%	23%

3. Which of the following atmospheric gases do you think contribute to climate change?

Answer	%
Argon	2%
Carbon Dioxide	96%
Chlorofluorocarbons (CFCs)	69%
Helium	4%
Hydrofluorocarbons (HFCs)	50%
Methane	87%
Nitrogen	12%

Answer	%
Nitrous Oxide	36%
Oxygen	4%
Ozone	39%
Perfluoromethane	25%
Water vapour	46%
Don't know	6%

4. Of those gases, which do you think, overall, contributes the most towards climate change?

Answer	%
Argon	0%
Carbon Dioxide	77%
Chlorofluorocarbons (CFCs)	4%
Helium	0%
Hydrofluorocarbons (HFCs)	1%
Methane	6%
Nitrogen	0%

Answer	%
Nitrous Oxide	0%
Oxygen	1%
Ozone	4%
Perfluoromethane	0%
Water vapour	5%
Don't know	2%

5. Which of the following do you think are the most likely impacts of climate change?

Answer	%
Air pollution	19%
Decreasing agricultural productivity in some areas	41%
Disease levels increase	21%
Global sea levels rise	74%
Gulf stream failure	25%
Increased flooding in some areas	47%
Increasing agricultural productivity in some areas	19%
Less cold winters	20%
Less drinking water availability	26%
More droughts in some areas	50%
More heatwaves	38%
Ozone layer thinning	20%
Species extinction	42%
Tsunamis	10%
Vegetation zones change	43%
Volcanic eruptions	3%
Don't know	1%
Other	11%

6. How would you describe your knowledge about climate change?

Answer	%
Little or none	3%
Basic	14%
Average	46%
Extensive	33%
Expert in the field	4%

Section 1B: Human Causes of Climate Change

1. Which of the following do you think are the most responsible for causing climate change?

Answer	%
World leaders	35%
National governments	68%
Industry and Business	88%
Local government	4%
Local communities	9%
Individuals and their families	61%
Don't know	1%
Other	5%

2. Which sector in developed countries is the biggest contributor to climate change?

Answer	%
Land use, land use change and forestry	4%
Agriculture	1%
Waste	1%
Industrial processes	20%
Solvent and other produce use	1%
Energy production	51%
Transport	23%
Don't know	1%

3. To what extent do you think the following ways of generating power contribute to climate change?

Answer	Biomass	Coal	Natural Gas	Hydroelectric	Nuclear	Oil	Solar	Wind
1 = major contribution	2.11%	84%	23%	1%	3%	77%	0%	0%
2	2.11%	13%	43%	4%	6%	20%	1%	0%
3	16.90%	3%	22%	15%	24%	3%	1%	3%
4	45.77%	0%	7%	37%	42%	0%	35%	30%
5 = no contribution	19.72%	1%	4%	42%	26%	1%	64%	67%
Don't know	13.38%	0%	1%	1%	0%	0%	0%	0%

4. Would you be happy with the following sources of electricity supplying your home, given the choice?

Answer	Biomass	Coal	Natural Gas	Hydroelectric	Nuclear	Oil	Solar	Wind
Yes	54%	6%	13%	58%	18%	5%	87%	86%
To a certain extent	20%	6%	23%	24%	15%	7%	8%	11%
Neutral	11%	11%	18%	10%	13%	11%	2%	2%
Not really	2%	28%	26%	4%	16%	26%	1%	1%
No	2%	46%	18%	4%	35%	49%	1%	1%
Unsure	11%	2%	1%	1%	1%	1%	0%	0%

Section 1C: Solutions to Climate Change

1. Which of the following do you think should be responsible for tackling climate change?

Answer	%
World leaders	62%
National governments	89%
Industry and Business	78%
Local government	17%
Local communities	17%
Individuals and their families	59%
Don't know	0%
Other	3%

2. What do you think are the most effective ways of reducing carbon dioxide emissions?

Answer	1st	2nd	3rd	4th	5th	6th	7th	8th
Build more wind farms	6%	6%	12%	11%	15%	16%	14%	20%
Improve car fuel efficiency	19%	21%	15%	17%	9%	8%	6%	4%
Industrial emissions trading	6%	15%	15%	11%	16%	15%	13%	10%
Introduce a carbon tax	20%	20%	11%	10%	9%	8%	12%	10%
Introduce carbon allowances	12%	5%	15%	7%	13%	18%	15%	14%
Promote energy efficiency	27%	16%	12%	21%	9%	6%	6%	3%
Reduce air travel	8%	9%	11%	11%	12%	11%	16%	23%
Use combined heat and power in homes	1%	8%	10%	13%	15%	18%	17%	17%

3. What do you think are the main challenges facing national governments in implementing climate change policies?

Answer	%
Public opinion	41%
Economic growth	62%
Ensuring public services eg. power, food, water	13%
International pressure	19%
Pressure from industry and business	76%
Other	6%

4. To what extent do you agree or disagree that the following could help reduce carbon dioxide emissions from electricity generation in the future?

Answer	Biomass	Coal	Natural Gas	Hydroelectric	Nuclear	Oil	Solar	Wind
Strongly agree	33%	1%	4%	46%	30%	1%	76%	77%
Tend to agree	39%	4%	13%	29%	29%	1%	14%	18%
Neutral	8%	6%	23%	18%	18%	4%	8%	4%
Tend to disagree	6%	15%	30%	6%	11%	16%	1%	1%
Strongly disagree	2%	75%	30%	1%	11%	77%	0%	1%
Don't know	12%	0%	1%	1%	2%	1%	1%	0%

5. Which two Annex I countries did not ratify the Kyoto Protocol, and therefore did not take on emissions reductions targets?

Answer	%
Australia	47%
Canada	1%
Czech Republic	1%
Germany	1%
Iceland	1%
Japan	8%
Liechtenstein	1%
Lithuania	1%
Monaco	1%

Answer	%
New Zealand	1%
Russian Federation	21%
Slovakia	1%
Switzerland	1%
Turkey	2%
Ukraine	1%
United Kingdom of Great Britain and Northern Ireland	3%
United States of America	97%

9. To what extent do you agree or disagree that you personally are part of the solution to climate change?

Answer	%
Strongly agree	52%
Tend to agree	36%
Neutral	9%
Tend to disagree	2%
Strongly disagree	0%
Don't know	1%