UNIVERSITY OF SOUTHAMPTON

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Testing Methods of Initiating Inter-Generational Interactions on Energy in the Home

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ABSTRACT

FACULTY OF ENGINEERING AND PHYSICAL SCIENCES

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For the UK to reach the strict emissions targets set within the 2008 Climate Change Act, significant reductions in energy consumption and emissions must be made across every sector. Whilst many new energy initiatives aimed at improving existing homes have been launched (and closed) over the years, the fact remains that the UK now has amongst the worst-performing homes in Europe. To add to this, the rising cost of living, particularly of utilities, is putting ever-increasing strain on residents. To address these issues, alternative solutions that are affordable and achievable are being explored. Improving occupant energy literacy and environmental awareness could be an approach to achieving reductions in home energy consumption. A potentially influencing factor in the home is children. As agents of change, children may disseminate environmental knowledge to older generations. This could be an effective way of improving their parents' energy literacy and in turn their energy behaviour decisions.

This research tested four different methods of initiating inter-generational interactions on energy in the home. It investigated what topics and content would support improvements in energy literacy, for both children and adults, as well as how to teach this content to children. Interventions tested the differences between teaching online at home or teaching in person within the school environment. Differing types of home activities, each intended to create a potential for the interaction to take place, were tested, ranging from simple 'Snakes and ladders' style games for children to play with their parents, to gamified continuous data logging of home energy behaviour by the participating children. A re-playable longitudinal intervention was also tested.

Results overall suggested that children learnt more effectively within the school environment compared to the online home environment. It also highlighted that just one single lesson is enough to improve the energy literacy of children about 'energy in the

home' – although an 'Eco Day', comprising of several lessons and varying environmental topics, seemed to have a longer-lasting effect on the children. When considering the inter-generation interactions, all methods showed promising results when gathering feedback from parents about interactions and conversations with their children. Parents reported that they intended to sustain behavioural changes that they had made due to the intervention.

Method one reinforced the rationale behind the need for inter-generational influences as it showed homes with children consumed more energy than both those without and those with elderly dependants.

Method two (in the school context) found that primary-aged children responded well to scientific topics traditionally not taught until secondary school such as energy sources and embodied carbon. Participating parents stated knowledge was passed on to them through the interactions created by the intervention's home activities.

Method three (in the home context) utilised gas meter readings before, during and after an intervention and showed that as the number of interactions with the intervention's 'Kids4climate website' increased, rates of gas consumption decreased. Having said that, several significant outside factors affected this study; namely the outbreak of COVID-19, war between Russia and Ukraine and most influentially, the UK price cap on energy being increased several times.

Method four (in the school context) reported that "concern for climate change" and "Consideration of environmental impacts of decisions" both declined throughout the study for the control group. Whereas the intervention group maintained their high levels of concern and consideration, suggesting a positive influence from the intervention.

This research has successfully shown that several methods can be used to initiate inter-generational energy interactions in the home. Although their effectiveness varied, both 'online' and 'in-person' interventions can be used to increase and improve child-to-adult interactions and in turn positively influence energy decisions in the home. In terms of the practical applications of this research, it has been shown that at the small scale of this research, improving the energy literacy levels of children and providing the opportunity for inter-generational interaction to take place can lead to better energy decisions being made by the main occupants in the home. It is a recommendation from this research that energy literacy should be incorporated into the next edition of the National Curriculum.

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List of Acronyms

ASHP Air Source Heat Pump

BRE Building Research Establishment

CFSH Code For Sustainable Homes

CO_2 Carbon Dioxide

DHW Domestic Hot Water

EPC Energy Performance Certificate

EU European Union

FHS	Future Homes Standard
FiT	Feed in Tariff
HDD	Heating Degree Days
HEM	Home Energy Model
kWh	kilowatt hours
MEDC	More Economically Developed Country
$MTCO_2e$	mega tonnes of carbon dioxide equivalents
NC	National Curriculum
PICO	Population, Intervention, Comparison, Outcome
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta Analyses
PSHCE	Personal, Social, Health, Citizenship and Economics Educations
SAP	Standardised Assessment Procedure
TOE	tonnes of oil equivalent
UK	United Kingdom
VAG	Value Added Gap
VLE	Virtual Learning Environment

Declaration of authorship

I, Gregory Peter Sewell, declare that this thesis and the work presented in it is my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Parts of this work have been published as: Sewell et al. (2024)

Signed:.. Date:..................

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This research has been based on teaching children science, thus a quiet thanks go to the scientific role models around me during my childhood, without whom I do not believe I would be writing this today. Through my early years; Dexter Morgan, Malcolm Wilkerson, Professor Utonium, Dr Douglas Fargo and Dr Henry Deacon. And through my teenage years; Adam Savage and Jamie Hyneman, Dr Temperance Brenan, Dr Samantha Carter, Dr Daniel Jackson and many others.

Finally to my family. My parents, Mum and Dad, who taught me that if you love what you do, you'll never work a day in your life. My sister, Louise, who taught me all the usual big sister lessons they teach you (and who taught one of the classes used in this research). And to my wife, Kez, who has taught me that anything is possible. Because it is.

1 Introduction

1.1 Background

The United Kingdom (UK) requires vast amounts of energy to fuel the everyday lives of its 69 million people [World Population Review (2024)]. In 2023, the UK consumed 163.8 million tonnes of oil equivalents (Mtoe) [ONS (2024)]. Over a decade ago, the UK government put forward the Climate Change Act of 2008, which initially stated to "reduce carbon emissions by at least 80% from the 1990 levels by the year 2050" [HM Government (2008)]. In April of 2021, this was tightened to 73% by 2035 [HM Government (2021)] and the target is now "net zero by the year 2050" [HM Government (2008)]. Yet even with this increased focus on reducing carbon emissions throughout every sector, in 2023, the final territorial emission total was 406.2 Mega tonnes of CO_2 equivalents ($MtCO_2e$) [Dept. BEIS (2023)]. Breaking this down between sectors and splitting transport between air, sea, road and rail; heating homes becomes singularly responsible for the largest majority of emissions in the UK (25%) [HM Government (2023)c]. This would suggest that domestic heating has the greatest potential for change in any sector. While the technology to build new, highly efficient, low-energy homes already exists, there is very little construction at this high-performance level and only relatively small amounts at the industry standard level. At the turn of the millennium, only 6% of dwellings were constructed in the previous decade, with 60% of them being built pre-1950 [DCLG (2001)]. This disproportion has only increased over the last two decades, meaning that the average UK person likely lives in a house that is significantly lower in performance than is required to meet today's carbon targets.

A variety of factors affect energy usage in the home, which is why it is hard to model and evaluate; even the same aspect will vary considerably between one building to another [De Wilde (2014)]. Putting aside the fact the UK has some of the 'worst performing residential buildings in the European Union (EU) (from an energy efficiency perspective)' [Broad et al. (2020)], other aspects such as 'occupancy behaviour', which indirectly drives building operations such as window opening and duration of heating use, contribute significantly; in some cases, it can be responsible for 10% of variances between identical homes [Xu et al. (2020)].

The thermal comfort of occupants is a considerable influence, with space heating within the home being the largest contributor to home energy consumption at 66% [Palmer and Cooper, 2013]. However, as aforementioned, occupants and their needs vary significantly – WHO's most recent study shows that 'comfort' temperatures can vary between 18C - 24C [Ormandy and Ezratty (2012)]. These high temperatures require considerable energy to reach, especially when occupants unwittingly add strain to the holistic strategy - for example by simultaneously heating and over-ventilating during winter [Wingfield et al. (2008)]. This is a highly inefficient use of energy, completely within the control of the human; to paraphrase Moezzi and Lutzenhiser, perhaps it is time to now see ‘energy efficiency as a measure of humans, as well as machines’ [Moezzi and Lutzenhiser (2020)].

Gupta et al (2018) stated "There is clear evidence that energy use is affected by the occupants’ understanding of the systems, expectations and perception of comfort and their habitual behaviours", going on to state this is because of a "lack of knowledge on the daily and seasonal operation of systems" [Gupta et al. (2018)]. A study by Huebner et al (2015) showed that heating behaviour (and other behaviour) in the home is responsible for 19% of variability in energy consumption; a considerable amount considering it can theoretically be changed for the better with little cost or construction-based intervention. The researchers go on to say "Behaviour change initiatives remain important avenues to reduce consumption" [Huebner et al. (2015)].

Out of the 28 million UK dwellings [BEIS (2020)], almost a third of them are home to one or two adults with one or more children, commonly known as families [OFNS (2019)]. There has been very little previous research into the effect ‘everyday family dynamics’ has on energy consumption [Fell and Chiu (2014)]. It is expected that older generations require inputs that are health-related, such as warmer rooms, but with sustainability now taking the forefront of many governments and company campaigns, children’s exposure to this content could make their generation more prominent in the daily decisions in the home. This opportunity to use the younger generation as ‘agents of change’ within the home creates the basis of research carried out here.

1.2 Energy in buildings

As aforementioned, energy consumption (including electricity from source) in the home contributes 28% of the UK’s total energy consumption [BEIS (2020)]. This shows that action, comparable to that being taken for the similarly sized transport sector, needs to be taken to mitigate the energy consumption of the domestic sector. A contributing factor to this is due to the huge variety of buildings and heating systems seen in the UK. At the turn of the millennium, only 6% of dwellings were constructed in the previous decade, with >60% of them being built pre-1950 [DCLG (2001)]. This means that the performance of these dwellings will be poor compared to homes built in the present day. This is partly due to the reduction in the rate of new homes being produced, but also due to the positive rate of change and improvement that has occurred within the National Building Regulations. These legislative documents control the limits of any new or renovated building in the UK, using the Standardised Assessment Procedure (SAP) to maintain a minimum level of performance. This assessment creates Energy Performance Certificates (EPCs). The one aspect the government cannot model or control, however, is the occupant and the chosen behaviours and use of systems within the home such as heating or lighting.

1.3 Human behaviour in buildings

Energy consumption in residential dwellings is a complex matter that is related to the physical building, the energy systems within it and importantly, the behaviour of the occupants who use the building and systems [Yao and Steemers (2005)]. This is especially important since the outbreak of war in Ukraine, which has seen the gas and electricity price cap increase significantly from around £1000 per year in 2021 to around £2000 in 2022 [Ofgem (2022)a]. It is becoming apparent that occupant behaviour has more of an effect than designers have initially thought and is significant in terms of household energy consumption [Steemers and Yun (2009)][Gram-Hanssen (2004)].

The behavioural factors influencing occupant behaviour have been analysed by Ben and Steemers [Ben and Steemers (2018)] and categorised into the following distinct areas: Socio-economic, Lifestyle, Comfort and Socio-material configurations (in which it is suggested that both social and materialistic factors are actually included within a single entity [Baker (2017)]). How one chooses to behave in these three areas will be detrimental to the overall consumption of energy in the home. Having said this, there are still many factors that influence the behaviour and decisions of these occupants, these will be introduced in the following sections.

Socio-economic factors

Decisions in the home have always had a financial influence behind them; even in 1989 Barrow et al investigated the effects of household social-economic attributes (e.g. income, house size) on individual household demand for gas and electricity, aiming to produce a model that could estimate energy consumption within the home [Barrow and Morrisey (1989)]. As expected for its age, the results of the study and the reason behind it were not due to environmental concerns, but instead influenced by financial decisions. The current energy prices mean that financial influence is now likely to be even more of a powerful influence.

Lifestyle

The term 'Lifestyle' already contains many aspects of the aforementioned influences and makes up much of any occupant's energy demand. This demand has not only increased year on year but also evolved, with shifts towards more time and emphasis put towards leisure and multimedia [Anderson and Torriti (2018)]. This change in how we live is a very important aspect of this research with the potential for generational differences to emerge. Young people and children spend their time very differently compared to the elderly, these also have very different energy demands.

Comfort

Thermal Comfort is very important for humans and is defined as “that condition of the mind in which satisfaction is expressed with the thermal environment” [ANSI/ASHRAE (2013)]. But with such a variance in what comfort actually means in terms of temperature, energy use in identical homes can vary by a factor of up to 4x [Gram-Hanssen (2010)].

1.4 Energy Literacy Levels and Improving Them

The three above overarching categories can be broken down into further detail, which will be explored in the literature review section. One key aspect that affects all three categories is occupant awareness of their actions, their knowledge and their understanding of the repercussions of energy decisions in the home. For example, knowing the difference between fossil fuels, and renewable sources and making the positive choice between them [Dwyer (2011)]. Humans are not inherently born with this type of knowledge, it must be learnt from other sources such as education and media. If it is never learnt, then occupants are making decisions without knowing the effects.

The above knowledge is known as "Energy literacy" - stated by Adams et al (2022) as "The understanding people have about energy" and then importantly, the effect it has on "influencing the way people use energy systems" [Adams et al. (2022)]. This can however be improved - environmental awareness and knowledge are now part of the National Curriculum (albeit it is very limited), thus is being taught to the next generations of homeowners and seen in the media through shows such as BBC’s Blue Planet. This has been thought to have had a very positive impact on plastic usage for example [Science Focus (2019)]. This improvement in energy literacy could be a good alternative or additional solution to costly ideas such as improving the fabric performance of the UK housing stock or switching homes to heat pumps from boilers.

These children, once their energy literacy has reached a good level, are not only prepared for the future but could also be used as agents of change today. "Child-to-parent intergenerational learning", that is, the transfer of knowledge, attitudes or behaviours from children to parents [Lawson et al. (2018)] could prove to be an effective way of increasing the energy literacy of the main occupants within homes, thus potentially reducing emissions from aspects such as heating.

If this opportunity were to be seized upon, it raises questions about what knowledge should be taught that is both easily understandable for children and useful for parents within the home. Then how or when would interactions occur within the home for this knowledge to be transferred from one generation to the other? This research aims to test different methods of initiating interactions on energy between generations in the home. The following sections of this thesis will explore in-depth, the rationale behind the studies and the benefits and drawbacks of different interaction methods as well as how they have been developed.

1.5 Problem statement

Energy consumption levels, and in turn carbon emissions are reducing slowly each year, but this rate will need to increase if the UK is to reach its legislative targets. The UK's largest contributor to this overall emission rate is domestic buildings, specifically heating them during the winter months. Occupant energy behaviour in UK homes is often based on three aspects'; their lifestyle, their socioeconomic level and their comfort. These are indirectly linked to confounding variables such as knowledge, awareness and ethics.

Previous research in this area tends to put more emphasis on physical building properties, geography and technologies, rather than the occupants themselves, even though it has been found that human behaviour plays a pivotal role in energy consumption levels. Improving energy literacy levels, through various means has also been shown to improve energy-related decision-making in the home.

In parallel to this, this knowledge must be installed in people as early as possible. The national curriculum currently only requires GCSE-level children (16-year-olds) to study climate change, thus there is a significant gap that needs to be addressed. Younger children are often seen as higher energy consumers in the home and research has shown that as they get older they increase in their levels of energy required [Yamaguchi et al. (2020)]. Thus they have traditionally played a negative role in home energy consumption.

This research will aim to combine these two issues with a single solution; leverage children as positive agents of change in the home by improving their energy literacy levels, providing opportunities for inter-generational interaction to occur, and in turn, disseminating knowledge to other generations in the home, allowing adults to make better-informed energy decisions when required.

Four different methods of achieving this, separated into four distinct methods will be tested to ascertain which is the most effective at delivering the proposed solution.

1.6 Thesis breakdown

Below, a breakdown of this thesis can be seen. It shows the work carried out and labels the corresponding chapters for ease of navigation within this document. The literature review follows this introduction, a review of methods and results and the works of others in the same and similar fields for existing gaps in knowledge. The topics can be seen broken down further, showing how they are linked to one another. An overarching methodology section follows the literature review, discussing the four proposed phases that will be used for each study. Each of the four studies then has its own chapter, within which background, methodology, results and finally discussion are considered. The discussion within each of these study chapters will solely be about the study itself, a comparative discussion of the four method studies then found in the following chapters, before a conclusions chapter.

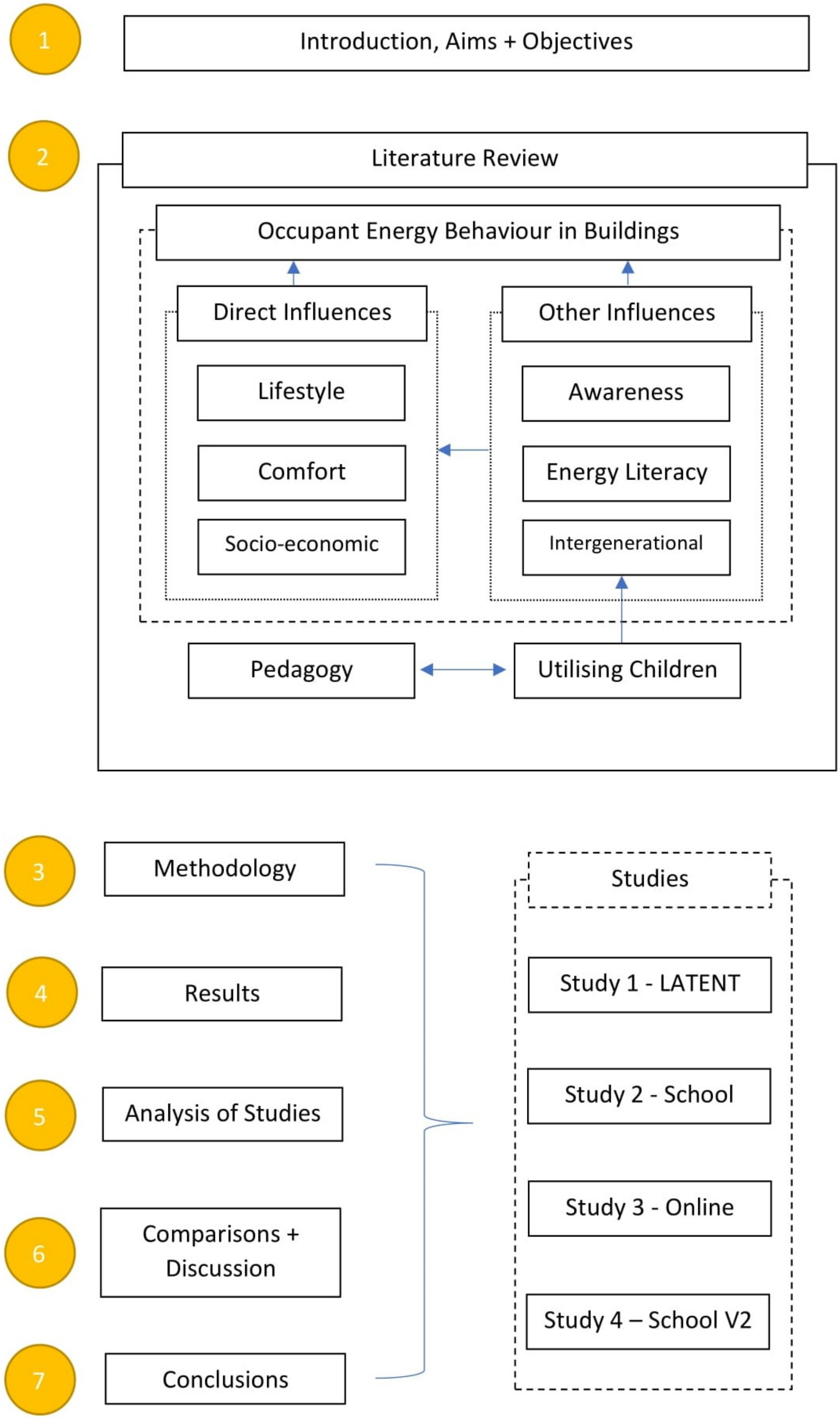


Figure 1: Breakdown of Thesis - Chapter numbers found in the corresponding circles

1.7 Research Questions, Aims + Objectives

1.7.1 Initial Research Question

- How to initiate intergenerational interactions on energy in the home?

1.7.2 Main Aim

- To develop and test methods of initiating energy interactions between generations in the home.

1.7.3 Objectives

1. To assess the context of inter-generational influences on energy in the home and establish a baseline for key performance indicators.
2. To develop and test an 'in-person, classroom' based intervention intended to improve energy literacy levels and promote interactions on energy between generations.
3. To develop and test an 'online, home' based intervention intended to improve energy literacy levels and promote interactions on energy between generations.
4. To develop and test a 'larger scale in-person, classroom-based longitudinal' intervention intended to improve energy literacy levels and promote interactions on energy between generations.
5. To develop content that can be used to further benefit the teaching of the environmental curriculum in schools.

1.8 Disruptions to this research

This research has occurred during a turbulent and unpredictable time in modern history. Most recently and as aforementioned, the outbreak of war in Ukraine has seen the gas and electricity price cap double from 2021 to 2022 [Ofgem (2022)a]. The Price Cap is a mechanism to create an upper limit to energy prices (per kWh), which the government controls to maintain fair prices for citizens and competing providers. The UK government has since announced several schemes to aid citizens financially during the 2022 winter period [DBEIS (2022)]. Due to these increases, several smaller energy companies went out of business. This included Igloo Energy, the industry partner with Southampton for the LATENT Study. This was a five-year study investigating Heat Pump usage in homes which meant that a potentially accessible pool of participants that would be leveraged within this research, would no longer be accessible [Ofgem (2021)]. COVID-19 also had an initial impact and will be discussed in the next section. Below is a timeline of some key events that have occurred during this research.

1.8.1 Timeline of "energy price cap" changes during this research

- 03/2020:- Covid-19 Lockdown measures start
- 24/09/2020:- PhD Research starts - **UK Energy Price Cap = £1164***
- 07/2021:- Covid-19 Lockdown eased
- 29/09/2021:- Igloo Energy cease trading
- 24/02/2022:- Russia invade Ukraine - **UK Energy Price Cap = £1309***
- 01/04/2022:- 'Energy Bills Support Scheme' - £400 discount to eligible households
- 28/04/2022:- **UK Energy Price Cap = £2017***
- 26/05/2022:- 'Cost of Living Support Package' - £400 non repayable grant
- 06/09/2022:- Liz Truss becomes Prime Minister
- 21/09/2022:- 'Energy Bill Relief Scheme' announced
- 01/10/22:- 'Energy Price Guarantee' – protect households for the next two years
- 18/10/22:- 'Energy Price Guarantee V1' – Reduced from two years to 6 months
- 25/10/2022:- Rishi Sunak becomes Prime Minister
- 01/03/2023:- **UK Energy Price Cap = £4301***

- 30/06/2023:- **UK Energy Price Cap = £3309***
- 30/09/2023:- **UK Energy Price Cap = £2108***
- 31/12/2023:- **UK Energy Price Cap = £1959***
- 31/03/2024:- **UK Energy Price Cap = £2058***
- 30/06/2024:- **UK Energy Price Cap = £1796***
- 04/07/2024:- Labour come into power
- 30/09/2024:- **UK Energy Price Cap = £1668***
- Until 31/12/2024:- **UK Energy Price Cap = £1829***

* per year for a typical household that uses electricity and gas and pays by Direct Debit

1.8.2 The impact of COVID-19

Although now seemingly at an end, the outbreak of COVID-19 raised significant issues in the exploration of topics in this research, as well as with the wider university and daily life. In line with UK Government and University guidelines, in-person interventions were no longer allowed in any form. This included teaching classes and large groups (assemblies), interviews and focus groups and even one-on-one discussions. This meant changes were forced upon the initial year of research, especially regarding how participant interaction was undertaken. As the UK eased rules in 2021, university guidelines returned almost to normality and thus research could continue.

1.9 Papers, grants and awards

1.9.1 Grants

Awarded £7500 as part of the Southampton University Public Policy New Things Fund in the summer of 2023. This was a competitive application process run internally within Southampton University to promote research that aids in improving public policy and engagement. The money was put towards professional graphic design to aid in the creation of a school intervention providing games and activities for 400 children. This formed part of the main body of work within Study 4.

1.9.2 Awards and qualifications

Awarded 'Best Presentation' at the "International Conference for Evolving Cities" in September 2023, with over 60 presentations being shown.

1.9.3 Journal papers

At the time of writing, one paper has been published and a second has been submitted for review. The abstract of the published paper and title of the second can be seen below, whilst the full published paper can be found in Appendix 7.6.4

Paper 1 - Predicting UK domestic electricity and gas consumption between differing demographic household compositions.

Paper published in: Energies 2024, 17(18), 4753; https://doi.org/10.3390 /en17184753 (registering DOI)

This paper examines the influence of building characteristics, occupant demographics and behaviour on gas and electricity consumption, differentiating between family groups; homes with children; homes with elderly; and homes without either. Both regression and Lasso regression analyses are used to analyse data from a 2019 UK-based survey of 4,358 homes (n=1,576 with children, n=436 with elderly, n=2,330 without either). For each group, three models (building, occupants, behaviour) were tested against electricity and gas consumption. Results indicated that homes without children or elderly consumed the least energy. Property Type emerged as the strongest predictor in the Building Model (except for homes with elderly), while Current Energy Efficiency was less significant, particularly for homes with elderly occupants. Homeownership and number of occupants were the most influential in the Occupants Model, though this pattern did not hold for homes with elderly. Many occupant and behaviour variables are often considered ‘unregulated energy’ in calculations such as SAP and thus would be ignored. However, this study found them to be significant, especially as national standards improve, recommending that incorporating occupant behaviour in energy modelling could help reduce the energy performance gap.

Paper 2 - Testing methods of initiating inter-generational interactions on energy within the home.

This has been submitted to the journal "Environmental Education Research" and is currently under review.

2 Literature Review

This section looks at the existing literature and studies that have been developed around the key themes and ideas of this research. This literature search will help collate existing studies, methods and results and then analyse existing studies that can be used as precedents for this research. The review will determine substantial gaps in knowledge to be addressed by this research.

A systematic literature review was carried out to make certain a rigorous and logical method of analysing the current literature was completed. This was based on the PRISMA 2020 updated statement on guidelines for systematic reviews [Page et al. (2021)]. PRISMA stands for Preferred Reporting Items for Systematic Reviews and Meta-Analyses, and the guidelines include ways to maintain transparency as well as methods to identify, appraise and professionally synthesize studies.

Initially, the research question was broken down using the PICO framework (Population, Intervention, Comparison, Outcome) [Richardson et al. (1995)]. This allows key elements of large research questions to be divided into more appropriate parts to prepare for a systematic literature review. The list below shows the PICO framework of this research.

Population

- Primary-aged school children
- Parents/carers/guardians of the above school children
- Potential to leverage the participant group of the existing University of Southampton LATENT Study

Intervention

- Initial baseline energy behaviours and influences of parents surveyed.
- Intervention to improve the energy literacy of children.
- Home-based intervention to promote inter-generational interaction.
- Re-assessment of parental energy behaviours and influences.

Comparison

- Initial baseline to final re-assessment.
- Method-to-method comparisons

- Intervention group and control group surveys.
- School-to-school comparisond.

Outcome

- Parental energy knowledge and behaviour will be improved.
- One method of initiating inter-generational interactions will be more successful.
- The intervention group may see more improvement compared to the control group.
- Results from different schools or age groups show significant differences.

Developing Keywords
Initial keywords were established using the research question and PICO framework above. These were as follows:

- Method (testing)
- Occupant behaviour
- Influences (on behaviour)
- Initiating interaction
- Inter-generational interaction
- Improving behaviour
- Energy (in the home)

Several early-stage database searches of these keywords led to the inclusion of several others. The final list can be seen below in alphabetical order. Also noted are synonyms that are often used in industry or academic work and will also be included [Bramer et al. (2018)].

- Behaviour Change
- Children / Generations
- Domestic / Dwellings / Residential / Home
- Education / Knowledge /Energy literacy
- Energy / Emissions
- Inter-generational
- Interaction

- Occupant Behaviour
- Occupant Influences (on energy / decisions)

Limits within the searches
Limitations have been created in line with methods research into systematic reviews [Nightingale (2009)][Torres-Carrion et al. (2018)]. Articles searched were all in the English language, with no initial limit on the date of writing. Publications were not limited by the type of study (for example case studies, literature reviews etc.). Geographic limits were also included – studies that were based in 'more economically developed countries' (MEDCs) were favoured as these show similar issues to the UK. Population limits were included when searching keywords regarding generational influences, child-to-parent interactions etc. However research will not be dismissed due to the study populations. A limit of 10 pages of results has been chosen to mitigate significantly large numbers of studies being found in the first phase. There are ten results per page, thus 100 results will be analysed in each search.

Rationale for using Gooogle Scholar
The research and studies explored in this literature review include only one database: Google Scholar. Google Scholar has traditionally been viewed as a contentious database. Some research has suggested that the ranking and ordering systems used by Google are not to the standard required, nor is repeatability guaranteed [Giustini and Kamel Boulos (2013)] [Herman (2013)]. However, its use within systematic literature searches is becoming more common. In 2013, a study by Gehanno et al found that Google Scholar included all studies which had been included in 29 Cochrane Systematic Reviews (738 original studies). The conclusion drawn by Gehanno et al was that the authors of these systematic reviews could have searched only Google Scholar rather than all the bibliographic databases they did and found the same results [Gehanno et al. (2013)].

Search strategies
A comprehensive search consists of several strategies, three of which are discussed below and used in this systematic review [Murdoch University (2020)].

Line-by-line: Individual keywords or phrases are searched on their own line.
Block-by-block: each search concept (PICO element) is searched on its own line.
Single Line: all searches are combined into one line.

Block-by-block searches based on the four parts of the 'intervention' section from the PICO framework:

1. Initial baseline energy behaviours and influences of parents surveyed.
   - Behaviour AND (Influence OR influencing) AND (Residential OR home OR dwelling OR domestic) AND (energy OR Emissions)
2. Intervention to improve the energy literacy levels of children.
   - "Energy literacy" AND (energy OR Emissions) AND (Teach OR school OR learn)
3. Home-based intervention to promote inter-generational interaction.
   - (Intergenerational OR inter-generational OR generational) AND (Residential OR home OR dwelling OR domestic) AND (energy OR Emissions)
4. Re-assessment of parental energy behaviours and influences.
   - ("Behaviour Change" OR "behavioural change") AND (Residential OR home OR dwelling OR domestic) AND (energy OR Emissions)

PRISMA Flow Diagrams of block-by-block systematic search reviews The following four diagrams (figure 2) below show the PRISMA flow diagrams for each of the searches completed. It can be seen that Search 1 Population returned 34 pieces of work after the screening, Search 2 Intervention returned 15, Search 3 Comparison returned 19 and Search 4 Outcome returned 45. This totals 113 articles reviewed for relevance to this research. These are detailed in Appendix Figures 165 to 183 and included in the systematic literature review in the following sections of this chapter.

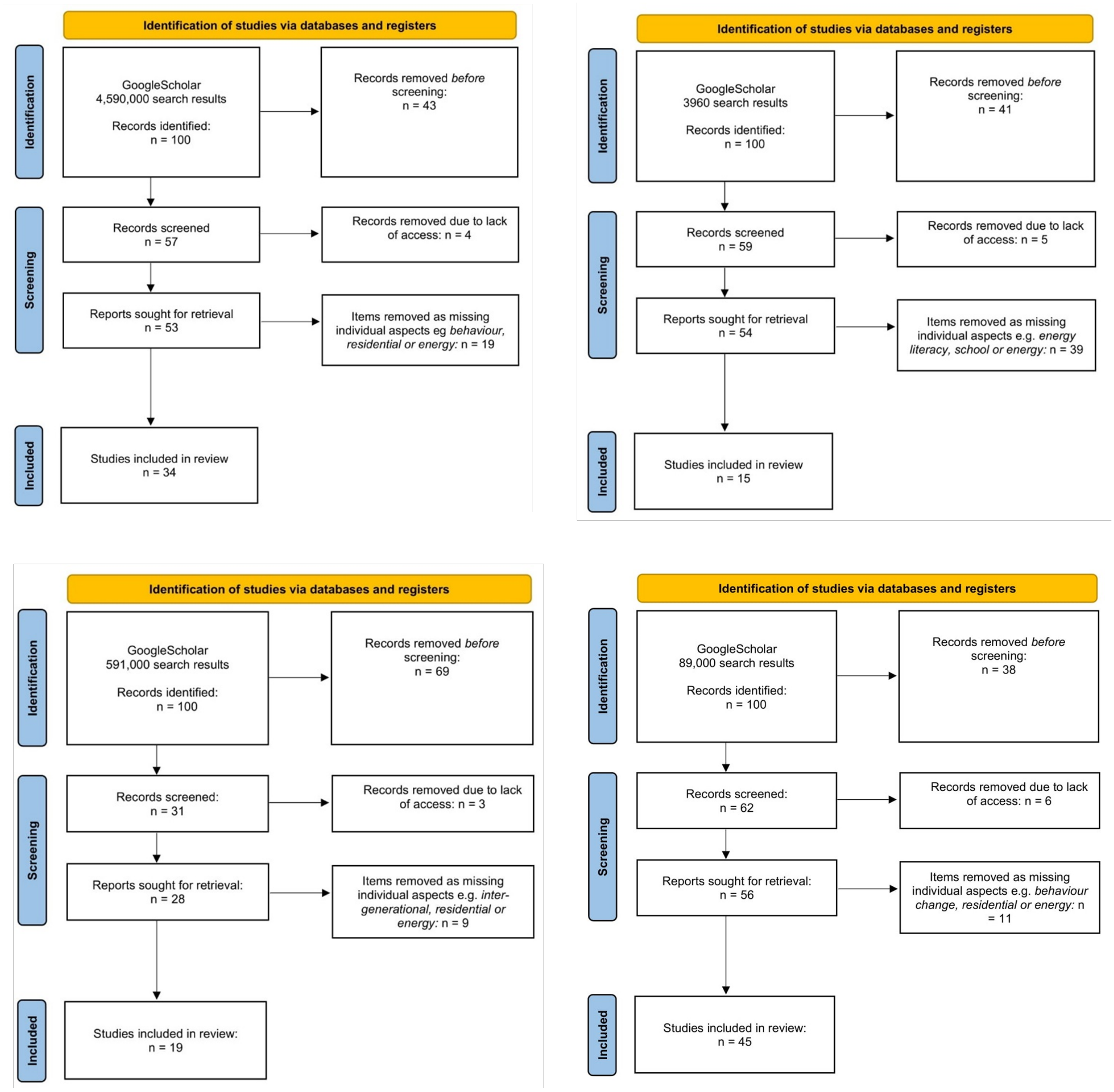


Figure 2: PRISM Block-by-block Flow Diagrams - Top left search 1 Population. Top right search 2 Intervention. Bottom left search 3 Comparison. Bottom right search 4 Outcome.

2.1 The current state of energy and emissions

In 2008, the United Kingdom (UK) government put forward the Climate Change Act, which stated to *"reduce carbon emissions by at least 80% from the 1990 levels by the year 2050"* [UK Government (2008)]. In April 2021, this was tightened to 73% by 2035 [HM Government (2021)]. Yet in 2023, the UK consumed 163.8 million tonnes of oil equivalents (Mtoe) [ONS (2024)], thus making the UK the 16th biggest energy consumer in the world [World Population Review (2024)]. Breaking down the energy mix, energy consumption from domestic buildings is responsible for over 32% of the overall UK consumption [ONS (2024)]. Space Heating (SH) is singularly responsible for nearly 61% of UK heat consumption [Reguis et al. (2021)]; it is the largest contributor of carbon emissions in the home and thus has the greatest potential for positive change of all factors in the home.

It is important to note that the year 2020 saw the global outbreak of COVID-19, leading many countries to alter daily life to mitigate the spread of the virus, which, unfortunately, is still prolific in some parts of the world. This led to various changes in the consumption of energy as the country shifted to home working where possible [Beno (2021)][Fu et al. (2012)]. For this reason, data gathered at a national level will not be truly comparable with previous years.

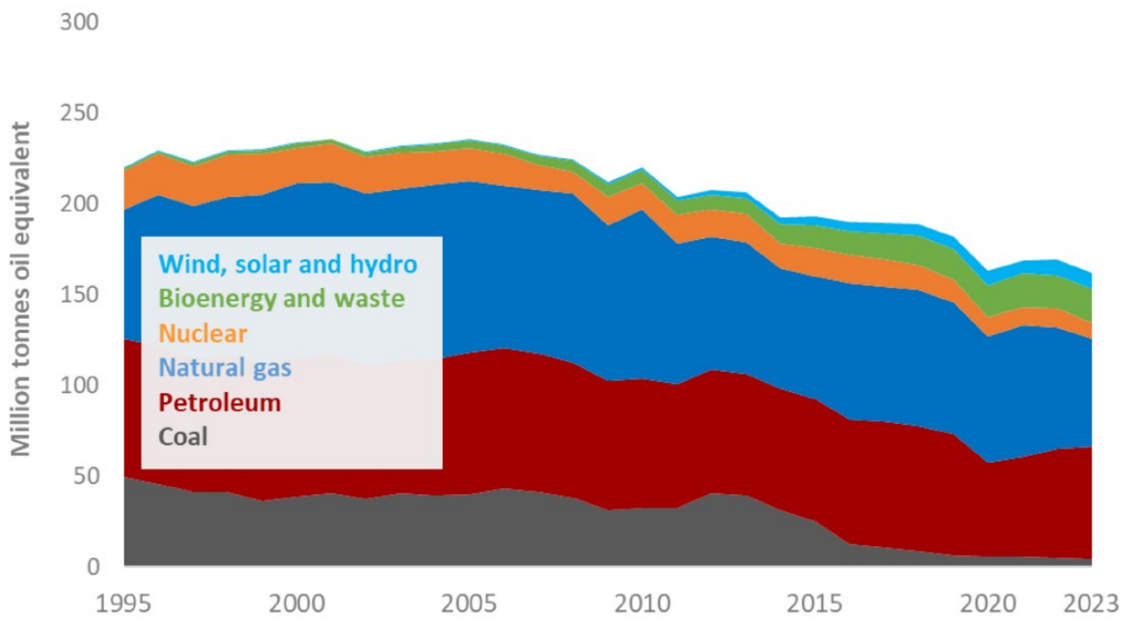


Figure 3: Consumption of fuel 1995-2023

Source: [ONS (2024)].

Although a decrease in consumption sounds positive when looking at figure 3, it can still be seen that (although independently falling by several per cent) the majority of the UK's energy comes from fossil fuels; petroleum and natural gas are both at least twice as high as electricity in third place. Heat, bio-energy and waste are still significantly lower, together making up less than 10% of the UK's requirements. These are the only fuels to see an increase in the last year, showing we are experiencing a positive transition, even if it is very small.

Unlike the numerous incentive schemes put forth by the government to increase the uptake of electric vehicles, for example, there have been relatively few successful schemes or initiatives aimed at reducing domestic energy consumption or improving homes. These have included The Green Deal, Feed In Tariffs (FITs) and Code for Sustainable Homes (CFSH), all of which have had incentives reduced over time or closed entirely [Ofgem (2019), HM Government (2010)]. Households' participation is often low, and many schemes have shown little success; for example, 4 years after the launch of the Green Deal in 2013, only 2% of those homes assessed had completed installation of upgrades [Constable (2017)]. As aforementioned, the UK now has some of the 'worst performing residential buildings in Europe' [Broad et al. (2020)].

It is apparent, with the removal of fabric-first approaches such as Code For Sustainable Homes [HM Government (2010)] and the addition of Air Source Heat Pumps (ASHP) in 2022 introduced into the Boiler Upgrade Scheme (BUS) [HM Government (2022)b], that the UK government has chosen a technology-centric approach to reduce residential emissions, rather than a fabric first approach. This contradicts the well-established 'Energy Hierarchy', which states that 'Energy Conservation' (using less energy by having better envelopes and less heat/energy wastage) is the most influential factor. Whereas utilising 'Renewable Energy' sits third on the hierarchy, as it is considerably less effective [Nat Geo (2021)]. Having said this, fabric-first improvements are often more expensive and disruptive to occupants, hindering their uptake, especially when considering the relatively low price of energy before 2022 [Bolton (2024)]. Approving technological improvements at a legislative level also raises another issue - it presumes occupants heat their homes to a 'normal' level, but many low-income households may be choosing to spend money in other places, for example, the "heat or eat" trade-off in winter, which may lead to serious health consequences [Beatty et al. (2014)].

Periodically, the government releases further detailed breakdowns of emissions; below, the 2023 UK consumption of energy (mtoe) percentage per sector can be seen, taken from the *'DUKES 2023'* document [ONS (2024)]. This graph shows the different consumption between the varying sectors and interestingly does not split transport into its constituent sub-categories (air, sea, rail, road). When this is done, Domestic becomes the largest at around 33 mtoe.

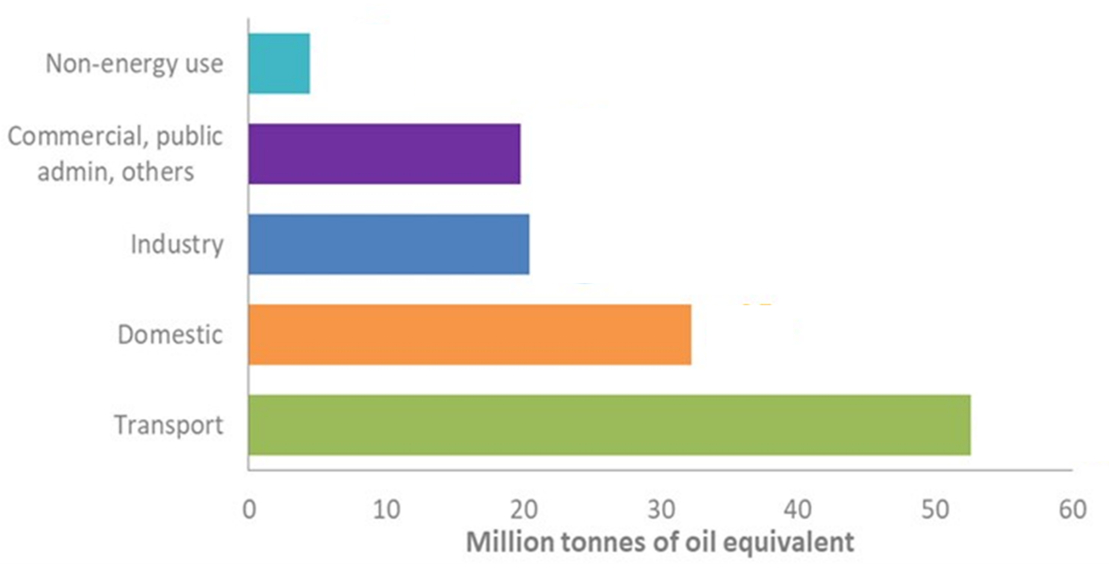


Figure 4: 2023 UK consumption of energy (mtoe) percentage per sector (transport includes all sub catagories - air, rail, road, sea)
Source: [ONS (2024)].

2.2 Energy in UK buildings

The UK has great potential for positive change in reducing emissions from the residential sector if the right steps are taken. As a country, it is already seeing the start of some positive changes, with heat pumps now readily available and discussions about banning the sale of new gas boilers being prominent in the news [BBC (2021)b]. Recent discussions (by the previous government) in April 2024 saw what was a complete ban on the sale of gas boilers reduced to an 80% ban by 2035 [The Eco Experts (2024)]. This negative watering down of a target happened even though the continued war between Russia and Ukraine has led to several years of turbulence regarding gas supplies and energy security. Having said that, as this transition to cleaner energy becomes more influential, proposed electric heating systems for water and space must be well established in policy and public opinion. An ASHP is not the only option, and alternatives are available; this may be the reason behind the reduction in the target. It is also that the public's level of knowledge is of a high enough standard to understand the role they play as the user in the home, and potentially of new strategies that will be needed.

In Autumn 2025, the Future Homes Standard (FHS) will replace the current Approved Document Part L of the Building Regulations [[Elmhurst Energy (2025)]]. Elmhurst Energy, which is creating a Home Energy Model (HEM) program that will run compliance calculations against the FHS for new build dwellings, states that the largest single change will be that 'Gas boilers will no longer be able to provide heating in new homes'. Thus, although the government has been discussing this approach for several years without committing either way, it seems that a decision has been made and a future direction chosen. This is, however, still in the future and may change again. It is important to note that this strict ban would only apply to new build dwellings; all existing (and likely conversions) may still be able to install new boilers, but it has not yet been confirmed [[Elmhurst Energy (2025)]]. Electric heating systems such as ASHPs are not suitable for all dwellings; thus, leeway should be provided in extreme circumstances.

Unfortunately, research so far shows that knowing more does not always lead to better energy behaviour in the home, and even if it does, it does not always lead to a reduction in energy consumption. There is still a 'Value-Action gap', whereby people's values are well aligned, but their behaviour is not [Barr (2006)]. This is seen often in many aspects of life, especially in cases of an environmental nature. This can also be seen when people with good levels of environmental concern or knowledge still choose bad decisions because they "fear being exploited by free riders", for example, over-using heating because everyone else does it [Tam and Chan (2018)].

Understanding how differing influences can impact energy consumption in the home is key to achieving the reduction required to meet national targets and mitigate the effects of climate change. Climatic and physical building factors have been shown to explain over 40% of variability in domestic energy use [Guerra-Santin and Itard (2010)], but many other factors also influence the overall consumption of energy. Factors such as occupants' demographics and behaviour can play a significant role that is often noted but overlooked in place of factors that can be measured and improved through building efficiency retrofits [Guerra-Santin and Itard (2010)]. The ever more energy-consuming modern way of life, including unregulated energy from working from home and a greater number of devices and appliances means occupant behaviour is becoming increasingly important in terms of domestic energy consumption and future flexible energy grid management [Bresa et al. (2024)][Nord et al. (2018)].

A contributing factor to this large consumption of energy is the huge variety of buildings and heating systems seen in the UK. This country has a vast history, with dwellings dating back many hundreds of years. At the turn of the millennium, only 6% of dwellings were constructed in the previous decade, with >60% of them being built pre-1950 [DCLG (2001)]. This age of home represents the majority of occupied dwellings in the UK, meaning that the average person lives in a house that is theoretically at the end of its lifespan. For this to have happened, dwellings are being used far longer than they were originally designed, meaning that the performance of these dwellings will be poor compared to homes built in the present day. This is in part due to the reduction in the rate of new homes being built, for example, only 37,164 homes were completed in the tax year ending 31st March 2022, a decrease on the previous year of 2% [HM Government (2022)a], but also due to the positive rate of change and improvement that has occurred within the National Building Regulations. These legislative documents control the limits of any new or renovated building in the UK, often using the Standardised Assessment Procedure (SAP) to maintain a minimum level of performance.

Developed in 1992 and still used to this day, SAP remains integral to the process of new building and retrofitting residential buildings across the UK [DCLG (2006)]. Calculating the combined fuel efficiency of both the heating system and the thermal efficiency of the building fabric [DCLG (2006)]. It was developed by the Building Research Establishment (BRE) in 1992 and has since been cited within the National Building Regulations as a key method in determining the performance of a dwelling [HM Government (2013)]. The assessment produces finalised data on aspects such as total energy usage and emissions of Carbon Dioxide (CO_2). It has seen many iterations over the past 30 years and has also been incorporated into several larger schemes such as the 'Code for Sustainable Homes' (CFSH), which was briefly introduced in the early 2010s. All newly built dwellings and retrofit dwellings must be assessed with SAP and achieve at least an 'E Rating'. The certification aims to maintain minimum standards in the performance of dwellings in terms of their energy consumption and the production of emissions. However, with the assumptions SAP makes regarding the heating levels of homes, it can be misleading, for example when applied to low-income households where there is a greater chance of under-heating [Hughes (2016)].

Although this significant legislation is in place to predict energy consumption before construction and then again before handover [Mitchell and Natarajan (2020)], this process dismisses substantial parts of the overall consumption because they are deemed to have too much variation and an unpredictable nature [HM Government (2017)]. These 'unregulated emissions' essentially include any electrical item that uses a mains plug, rather than being wired into the house and have increased substantially as people have more electrical items [Anderson and Torriti (2018)]. This non-inclusive modelling not only contributes to the energy performance gap [Mitchell and Natarajan (2020)] but also hands the decision to consume or save energy to the occupants, whose choices can often be impetuous [Wingfield et al. (2008)]. This behaviour in turn often leads to excessive energy consumption in the home.

Guerra Santin et al (2013) found that 42% of variation in energy use can be attributed to building characteristics, whilst Huebner et al (2015) found a similar 39% of variability came from building factors alone. Both studies estimate building characteristics as the largest influence on energy use[Guerra-Santin et al. (2013)][Huebner et al. (2015)]. These characteristics include the 'floor area', 'year built', 'built form' and 'construction type' of the dwelling. Some of these factors, such as 'year built' and 'built form' (e.g. flat, terraced, detached), cannot change or be improved through retrofit. Similarly, larger properties have a greater surface area of external walls and will require more energy to heat than smaller homes. These factors cannot be altered with typical remedial works or technologies, thus, alternative improvements must be found. Building envelope improvements, which can drastically change the building energy performance, are not represented in variables such as 'year built'; a more accurate measurement would be 'wall construction', which expresses the dwelling today. Building characteristics not only produce the most variability in energy consumption [Huebner et al. (2015)] but also often require the most financial or invasive retrofitting to improve them. Larger properties will require substantially more capital to be invested upfront, often leading occupants to choose cheaper or less effective methods of house improvement. Also, improvements such as zonal space heating may lead to ignoring areas of the home, resulting in poor ventilation and the build-up of mould [Sharpe et al. (2015)]. Furthermore, building characteristic improvements are unattainable for occupants who are not homeowners due to their invasive nature and/or changes to physical building aspects that are not allowed.

Energy in buildings, both regulated and unregulated must be at the forefront of government strategies in fighting climate change. The construction industry is a powerful entity in politics and is responsible for ten times the GDP of agriculture [Trading Economics (2021)]. The pace of positive progression in the construction industry is slow, and house builders often fight the positive change that is coming [The Guardian (2021)b]. It also raises questions on who will pay for the higher performance levels of buildings that each new iteration of the Building Regulations brings; will it be the developer? Or more likely, will it be the buyer? The economic aspect of sustainability in buildings must be planned just as effectively by the government.

2.3 Building occupants - influences and behaviour

Residential dwellings are only recently making their way to the public forefront of sustainability legislation and grant schemes, take Electric Vehicles for example, which have seen far more public news in recent times [BBC (2021)a]. Yet in 2019, research by Dubois et al (2019) suggested households were responsible for 72% of global greenhouse gas emissions, stating "households in climate policies are neither well understood nor do they receive sufficiently high priority in current climate policy strategies" [Dubois et al. (2019)]. Their research then investigated how behavioural changes can achieve emission reductions in European high-income countries. It found "short-term voluntary efforts not sufficient by themselves to reach the drastic reductions needed, instead, households need a regulatory 'framework' supporting their behavioural changes". finding a solution to improve occupant energy behaviour is a large task that will take many years of research.

As aforementioned, the Value Added GAP (VAG) refers to the discrepancy between individuals' expressed pro-environmental values and their actual behaviours. Blake (1999) first articulated this problem as a persistent challenge for policy makers, arguing that possessing pro-environmental values does not necessarily translate into action. This gap is particularly visible in the domestic sphere, where individuals often articulate concern for the environment but continue with unsustainable consumption patterns. Blake (1999) identified structural constraints, lack of information, and practical obstacles as major barriers to converting environmental concern into meaningful change [Blake (1999)].

In the home, Barr (2006) provides a detailed analysis of the gap by categorising household environmental actions into three: kerbside recycling, purchase decisions, and habitual energy/water conservation behaviours. His findings suggest that while recycling is widely adopted—likely because it is convenient and supported by infrastructure—other actions that demand lifestyle changes or financial investment (such as purchasing energy-efficient appliances) show a much lower uptake. This supports the argument that convenience, cost, and habit formation are key mediators of the value–action relationship in domestic settings [Barr (2006)]. This could be an important part of the research going forward, potentially putting into question any behavioural change that may occur, particularly in the long term, as occupants may regress to their known behaviours post-intervention.

Barr, Gilg and Ford (2006) explored this further in their study of the "household energy gap," distinguishing between habitual and purchase-related behaviours. They found that householders are more likely to perform low-cost, low-effort energy-saving actions (e.g. switching off lights) than to engage in capital-intensive measures (e.g. installing insulation), despite recognising the latter's environmental importance. Similarly, Barr and Gilg emphasised that lifestyle is very important, considering the interplay of environmental values, social norms, and situational constraints — helps explain why some households bridge the gap more effectively than others [Barr and Gilg (2006)].
The topic of energy and the VAG in the home is especially important since the outbreak of war in Ukraine, which has seen the gas and electricity price cap increase significantly from around £1000 per year in 2021 to around £2000 in 2022 [Ofgem (2022)b]. The

UK government included energy rationing in its worst-case scenario for the 2022 winter months [The Guardian (2021)a] with companies such as OVO Energy also promoting better behaviour with monetary incentives to make sure resources are not wasted [Energy Live News (2022)]. How occupants use the energy in their homes is becoming equally as important as the improved technologies that have previously been promoted as the route forward by the UK government [HM Government (2022)b]. Kollmuss and Agyeman (2002) provide a useful conceptual model for understanding these dynamics, identifying a complex set of internal (motivation, values, knowledge) and external (infrastructure, social pressures, economic incentives) factors that shape pro-environmental behaviour. When applied to the home, their framework highlights how the value–action gap is rarely the result of a single missing element but is instead a product of competing priorities, habitual routines, and contextual barriers. Addressing the gap, therefore, requires not only raising awareness but also redesigning domestic systems, reducing financial and practical barriers, and supporting long-term behavioural change. Any intended changes to these elements, such as improving energy behaviour and reducing energy consumption in the home, will require significant effort and implementation.

Energy consumption in residential dwellings is a complex matter that is related to the physical building, the energy systems within it and importantly, the behaviour of the occupants who use the building and systems [Yao and Steemers (2005)]. Occupants control far more than just the unregulated emissions excluded from SAP - they are responsible for almost every decision in the home, and the efficacy of their decision-making can positively or negatively affect the total energy usage of a home. At the detrimental end, Summerfield et al have found energy use in similarly physical residential properties can still vary by two or three times relative to each other [Summerfield et al. (2010)]. It is clear that occupant behaviour has more of an effect than designers have initially thought and is significant in terms of household energy consumption [Steemers and Yun (2009)][Gram-Hanssen (2004)].

Labanca and Bertoldi's (2018) research states "Energy efficiency improvements in human activities can greatly contribute to facing the challenge of climate change". This is especially true of resource management; if people use less, there is more to go around. This 'sharing' is an important aspect that all people are taught at a young age, but seem to only apply it to certain things. Is there a way to make people think more carefully about their energy behaviours before they make their decision? Unfortunately, most decisions in the home often stem from "subconscious habits" or simple "cause and effect" [Labanca and Bertoldi (2018)]. The conclusion was to alter policies to encourage people to 'do better'; they suggest they are designed to encourage people to 'do more'. This returns to their initial idea of sharing, but rather than sharing a physical item, all people are sharing the 'cost' of the environment by each changing slightly for the better. Another promising direction emerges from a 2025 field experiment conducted in Polish university dormitories, which combined behavioural messages with technical adjustments to heating systems. The study found that a collective psychological prompt—emphasising the shared environmental contribution of all residents—paired with an automated reduction in the heating curve, resulted in the most significant energy savings. Intriguingly, messaging alone or technical tweaks alone were less effective; their synergy yielded the greatest impact. Moreover, explicit acknowledgement of their shared participation helped reinforce emerging social norms among residents [Bielig et al. (2025)]. This exemplifies how policy measures could be designed to move people from "doing better" as individuals to "doing more" collectively, harnessing both habit nudging and system design.

Similarly, when households receive feedback comparing their energy patterns to neighbours, it can motivate reductions—even outperforming motivations rooted in cost savings or environmental ethics [Gołbiowska et al. (2020)]. However, the effectiveness of such social comparisons can depend on how the feedback is framed. For instance, norm-based interventions that include injunctive norms—messages about what society approves—can prevent the so-called "boomerang effect," where low-energy users increase consumption after seeing they're already performing well [Caballero and Della Valle (2021)]. These findings suggest that embedding norms within feedback mechanisms could subtly recalibrate energy habits through social influence. It may also show that potential intergenerational influences and feedback may be an additional motivator to reduce energy consumption.

Large-scale behavioural studies emphasise that simply providing information is not enough - effective energy interventions must be thoughtfully designed to align with everyday practices and motivations. A comprehensive scoping review of 584 empirical studies found that the most common behaviour-change tools include timely feedback, social norms messaging, commitments, and choice architecture like defaults—but their effectiveness varies depending on context and combination [Composto and Weber (2022)]. Similarly, research in the Nordic countries cautions that many energy interventions lack clarity on how they activate psychological mechanisms. Interventions grounded in local cultural routines and delivered through trusted intermediaries are more likely to change behaviour [Johansson et al. (2021)]. This highlights the importance of not only what is communicated, but also how and by whom, ensuring interventions resonate with target audiences and disrupt habitual patterns effectively. This is an aspect that will be discussed repeatedly throughout the research.

Looking at other interventions that have already occurred, Frederiks et al 2014 found that occupants can actually "sometimes respond in unexpected and undesirable ways to rewards and sanctions intended to shift consumers' cost-benefit calculus in favour of sustainable behaviours". This research, like some of those above, attempts to answer why people, particularly in the home, act and respond in the ways they do. They conclude that "consumer choices and behaviour are, to a large extent, driven by cognitive biases, heuristics and other 'predictably irrational 'tendencies"[Frederiks et al. (2015)]. This shows that any interventions aimed at improving behaviour or similar aspects in this research must be produced with significant "psychological, economical and behavioural key principles" as the foundations.

Occupants' socio-demographics and behaviour are other major influencing factors in UK domestic electricity and gas consumption. Aragon et al (2022) undertook a two-year heating use study on five identical tower blocks and found significant differences in energy consumption between identical flats, which the authors associated with occupant behaviour. Many factors affect occupants' behaviour in the home [Aragon et al. (2022)]. Looking from a bottom-up approach as put forward by Swan et al, which is to say using household data such as physical, social, demographic and behaviour at the local scale [Swan and Ugursal (2009)], it is possible to analyse occupants for reasons such as modelling and prediction of energy use. The behavioural factors were analysed by Ben and Steemers [Ben and Steemers (2018)] and categorised into the following distinct areas: Socio-economic, Lifestyle, comfort and Socio-material configurations (in which it is suggested that both social and materialistic factors are actually included within a single entity [Baker (2017)]. How one chooses to behave in these three areas will be detrimental to the overall consumption of energy in the home. Having said this, there are still many factors that influence the behaviour and decisions of these occupants, and these will be introduced in the following sections.

Socio-economic factors

Delving into older research first, decisions in the home have always had a financial influence behind them. In 1989, Barrow et al investigated the effects of household socioeconomic attributes (e.g. income, house size) on individual household demand for gas and electricity by using data from over 50,000 households pooled from 12 consecutive years of Family Expenditure Surveys (1972–1983). Although now over thirty years since its publication, Baker attempted to answer some questions still relevant today, aiming to produce a model that could estimate energy consumption within the home [Barrow and Morrisey (1989)]. As expected for its age, the results of the study and the reason behind it were not due to environmental concerns, but instead influenced by financial decisions. Interestingly, a similar paper by Baker and Rylatt in 2008 looked at developing these predictions further by using data from individual household surveys, annual gas and electricity meter data and floor-area estimates. The authors found that two variables, the number of bedrooms and regular home working, have a significant influence on household energy consumption in the UK [Baker and Rylatt (2008)]. Larger houses (with more bedrooms) will of course lead to larger energy consumption, but the latter of these (working from home) is more prominent today than it has ever been due to the COVID-19 pandemic and may remain a large part due to the shift in working environments. The effects of COVID on social home energy consumption are discussed in their own section further on.

As aforementioned, the current price of gas and electricity, although almost returning to pre-price cap increased prices, has seen higher values than it has ever been [Ofgem (2022)b]. So much so that the 2022 and 2023 winters may have forced changes to certain behaviours due to the economic pressures that were experienced during Barrow's 1980s research. It may be likely that this pressure is more influential than other aspects of traditionally powerful influences, such as thermal comfort. The price cap increased every quarter from October 2021 to March 2023, meaning that in recent winters, there has been ever-increasing financial pressure on home occupants. This also means that there has been a constantly increasing baseline by which comparison of results for longitudinal studies becomes difficult. The Energy Price Cap is now slightly under half of the peak it reached but has still not returned to the value before the Russian invasion of Ukraine [Heatable (2024)]. Discussing more on the social side of socio-economic, Wolske et al (2020) found that peers (local and neighbours) with solar panels would often influence other properties around them into adopting the same technologies [Wolske et al. (2020)].

Lifestyle factors

Understanding of our environmental impact has increased year after year and is now the main driving force behind much of the research into buildings and occupant behaviour. Looking at lifestyle a generation ago, as these children are now the main occupants age; in 1996, Mansouri et al carried out householder surveys for residents in the southeast of England. Focusing on environmental attitudes and beliefs, appliance ownership, along with their utilisation patterns and energy-use behaviour. The results showed that only 7 years after Baker's surveys, occupants were now not only interested in learning more about the environment and its impact but also willing to implement behavioural changes to mitigate their aforementioned impact [Mansouri et al. (1996)]. A similar study by Brandon and Lewis (1999) found that participants with positive environmental attitudes, but who had not previously been engaged in many conservation actions, were likely to change their consumption in response to energy information provided to them [Brandon and Lewis (1999)].

The term 'Lifestyle' already encompasses many aspects of the aforementioned influences and accounts for a significant portion of any occupant's energy demand. This demand has not only increased year on year but also evolved, with shifts towards more time and emphasis put towards leisure and multimedia [Anderson and Torriti (2018)]. This change in how we live is a crucial aspect of this research, with the potential for generational differences to emerge. Young people and children spend their time very differently compared to the elderly; they also have very different energy demands.

A UK study by Lorincz et al (2021) using the 'Time Use Survey' (2014–2015) linked daily activities—like dishwashing, laundry, food prep, cleaning, ironing, and TV watching - to energy usage through appliance load estimates. Energy consumption varied considerably depending on how much time occupants spend on these daily tasks and when during the day they occur [Lőrincz et al. (2021)]. The same study also found that not just the amount, but the timing and regularity of work (including working from home) shapes energy use. Irregular or hybrid work schedules can shift high-energy activities into or out of peak hours, potentially increasing overall home electricity consumption [Lőrincz et al. (2021)].

A study by Jones and Lomas (2015) examined electricity consumption across 315 homes in Leicester, UK, using detailed socio-economic and dwelling data from a city-wide survey conducted in 2009–2010. The researcher's analysis determined which factors most strongly predicted high household electricity use. Among the strongest identified as significant was the 'presence of teenagers'. This is likely simply due to increased loads on energy from aspects such as clothes washing and showering [Jones and Lomas (2015)].

Lifestyle saw some changes due to the COVID-19 pandemic, and despite a clear decline in national electricity and gas demand due to COVID-19 lockdowns, residential energy usage bucked the trend. One UK study reported that overall electricity demand dropped by 15.6% and gas (dual-metered) demand by 12% during the first lockdown; the second lockdown saw reductions of 6.3% and 4.1%, respectively [Mehlig et al. (2021)]. However, the residential sector differed—total domestic energy consumption rose by 2.1%, and domestic gas demand by 0.8% in 2020 compared to 2019. Specifically, between April and June —the heart of the first lockdown — domestic energy use was up by 6.5% after adjusting for seasonality and weather [Huebner et al. (2021)]. A similar analysis of household-level smart meter data across England and Wales (comparing April 2020 – March 2022 to pre-pandemic projections) revealed average increases of 7.8% in electricity and 5.7% in gas during the pandemic's first year. In the second year, consumption increased by 2.2% (electricity) and 0.2% (gas). The winter lockdown of 2021 drove the largest spikes: 11.6% for electricity and 9.0% for gas. By early 2022, electricity remained 2.0% higher, while gas usage was slightly lower than predicted [Zapata-Webborn et al. (2023)].

Modern UK lives often revolve around technology-rich environments. A study on "unregulated energy" — the energy consumed by appliances, electronics, and other non-heating devices by foster and Poston (2023) revealed upward trends. Between 1970 and 2011, appliance-related energy rose by approximately 3% annually. In particular, aged devices like older fridges or freezers - common in low - income or social housing—can consume 27% more energy than when new. In some social-housing kitchens, appliances accounted for 14–35% of total household electricity use, and in one instance, as much as 57%. These data underscore how appliance proliferation and retention of inefficient devices escalate energy demand [Foster and Poston (2023)].

Comfort factors

Thermal comfort is very important for humans and is defined as 'that condition of the mind in which satisfaction is expressed with the thermal environment' [ANSI/ASHRAE (2013)]. But with such a variance in what comfort means in terms of temperature, energy use in identical homes can vary by a factor of up to 4x [Gram-Hanssen (2010)]. As another example, this significant variation in perceived comfort can lead even to high-performing retro-fitted homes being 40% less energy saving than anticipated [Galvin and Sunikka-Blank (2017)].

A project by Sovacool et al (2021) found that occupants (of Germany, Italy, Spain, Sweden and the UK) currently have very high satisfaction with existing heating systems and would not change their heating system in the near or far future [Sovacool et al. (2021)]. This is unfortunate as currently, the majority of heating in Europe (and 90% in the world) comes directly from fossil fuels [IEA (2020)]. In addition to this, the world is in transition to a far more electric-based grid with the implementation of more renewable sources. Interestingly, as homes are improved in terms of their energy efficiency and services get cheaper, it encourages a 'rebound effect'; increased consumption becomes the norm and offsets any energy savings that may have been intended or potentially achieved [Sorrell et al. (2009)]. This is an increasingly seen issue and should be included within models and predictions.

The concept of the rebound effect refers to situations where energy savings from efficiency improvements are partially or entirely offset because occupants adjust their behaviour, such as by increasing comfort levels or consuming more energy services. Specifically, in low-income or fuel-poor households, energy efficiency gains frequently translate into increased indoor temperatures, which residents previously could not afford. This behaviour, termed temperature take-back or a comfort factor, significantly reduces net energy savings. A study by Coyne et al (2018) found that low-income households often recover just half the anticipated savings (from the implementation of new technologies) because the rest is used to raise thermal comfort [Coyne et al. (2018)]. A long-term study by Penasco and Anadon (2023) of over 55,000 UK homes across England and Wales (2005–2017) tracked gas usage before and after insulation (cavity wall and loft). The energy savings were initially moderate—dropping about 7% with cavity wall insulation in the first year - but these gains diminished substantially over time, becoming negligible by year four. For low-income households in deprived areas, reductions were only around 3%, and some even experienced increased gas consumption immediately after retrofit, as the energy saved was redirected toward greater heating usage for comfort [Peñasco and Anadón (2023)].

Awareness factors

The 'energy literacy' of occupants and users can have a substantial effect on a home's energy consumption. Dwyer (2011) states that Energy Literacy is "the baseline fluency and knowledge of complexities related to energy use" [Dwyer (2011)] and goes on to discuss what this means in real-world terms - knowledge in 'topics such as fossil fuels and their alternatives' and most importantly 'the link between consumption decisions and environmental impact' [Dwyer (2011)]. Breaking down this research, it is this link that forms one of the fundamental aims; will improving energy literacy improve decisions made regarding energy in the home?

Investigating this link further, Gadenne et al (2011) found that general environmental beliefs and awareness do influence norms on environmental actions, but cost barriers may have a negative influence on this in real terms. Interestingly, a strong association between environmental attitudes and energy-saving behaviours was also found, but the latter was not influenced by government policies or subsidies [Gadenne et al. (2011)]. Similarly, Pothitou et al (2016) found *"significant correlations that indicate residents with positive environmental values and greater environmental knowledge are more likely to demonstrate energy behaviours, attitudes and habits which lead to energy saving activities in households"* [Pothitou et al. (2016)]. These two papers support the theory that improving the energy literacy levels of occupants may lead to better energy decisions and behaviours in the home. However, several studies, notably by Sweeney et al, (2013) and Abrahamse et al (2005), both suggest that attitudes and awareness are not sufficient to result in energy-saving behaviours. Sweeney states that people's desires to reduce energy can be thwarted by a variety of factors [Sweeney et al. (2013)], whilst Abrahamse similarly states that information results in improved knowledge levels, but not in behavioural changes or energy savings [Abrahamse et al. (2005)].

Awareness factors of the young

As far back as 1989, it was found that levels of energy literacy can vary significantly between demographics as well as location and gender; Barrow and Morrisey (1989) found that males were significantly more energy literate than females (of the same age and school – 9th grade Maine, USA), but when compared to the same age group in a school in New Brunswick (Canada), it was the female students that were significantly more energy literate than male [Barrow and Morrisey (1989)]. Ironically, this research was not completed for environmentally conscious reasons but was carried out as a result of the oil embargo years (1973-1981), to find out if young people were aware of alternatives to oil and if political issues led to similar events in the future.

During this literature review, there has been a considerable amount of literature regarding environmental awareness and energy literacy within the secondary school ages (12-16) and higher/further education (17+), but far less for ages younger such as middle/primary school (4-11). For this reason, and with originality in mind, this research will be aimed at the primary school age, rather than secondary.

Improving occupant behaviour of adults

Gyberg et al (2009) suggest that the main reasons for a change in an occupant's behaviour are motivated by both energy costs and a reduced impact on the environment - fitting well into the socio-economic category [Gyberg and Palm (2009)]. Of course financial incentives are often powerful techniques to affect someone, but Iweka et al (2019) analysed 46 different studies and methods of influencing occupant behaviour (including the use of energy labels, energy performance certificates, energy auditing, prompts, norm appeals, commitments, economic incentives and disincentives, feedbacks, community- based initiatives, benchmarking, goal setting and gamification) and found that feedback, gamification, goal setting and community-based initiatives proved to be the most effective (recording an average energy savings of above 20%) [Iweka et al. (2019)]. The comparison between these incentives is important for taking this thesis research forward. Gamification may appeal to both adults and children and thus be a potential route.

Well-designed gamification can produce small-to-moderate, reliable improvements in knowledge, motivation, and some behaviours — but effects vary a to-a-lot by context, which game elements are used, and how they're designed. In terms of education and learning; meta-analyses find small-to-moderate positive effects of gamification on cognitive, motivational, and behavioural learning outcomes [Sailer and Homner (2020)]. This could be used to the advantage of this study to promote better learning journeys for both children and adults. Now regarding behaviour improvement, systematic reviews and recent randomised trials show gamified apps can increase physical activity and some health behaviours, but results are mixed and effect sizes are often modest and dependent on design (social incentives and length). Some studies found sustained increases in activity when gamification included competition or support [Balci et al. (2022), Park and Kim (2021)]. Similarly, leaderboards and rewards can increase short-term engagement, participation and effort by providing clear performance feedback and satisfying competence and achievement needs [Khoshnoodifar et al. (2023)]. A leaderboard scope, direction (who you compare to), anonymity, and reward type strongly shape whether the element helps or hurts motivation [Park and Kim (2021)]. It is very important that the correct amount of competitiveness is designed into the leaderboard and the website as a whole.

Improving energy literacy can change energy behaviour by (1) increasing accurate knowledge and skills (so people choose and use efficient technologies correctly), (2) shaping attitudes, values and 'self efficacy' (so people want to act), (3) enabling effective feedback and decision-making (so people translate knowledge to action), and (4) leveraging social pathways (children, peers, social norms). many studies and systematic reviews show small-to-moderate average reductions in energy consumption when education is combined with feedback or norm-based messaging, but effects vary by context and often shrink over time[Santillán and Cedano (2023)] [DeWaters and Powers (2013)] [Wang et al. (2025)] [Jorgensen et al. (2021)].

Improved knowledge can lead to an increased capability to act. Energy literacy gives households the factual basis to spot wasteful practices, compare appliance efficiencies, and adopt appropriate behavioural or technical fixes. Systematic reviews define energy literacy as including these cognitive components and conceptually linking them to behaviour change [Santin (2011)].

Similarly; attitudes, values and self-efficacy can lead to better energy behaviour. Measurement frameworks from Dewaters and Powers (2013) found energy literacy was three-dimensional (knowledge, affect/attitude, and behavioural/self-efficacy components). Improvements in knowledge alone are often insufficient unless they also increase people's confidence and motivation to act [DeWaters and Powers (2013)]. This three-dimensional aspect will need to be included in the studies in order to gain the most out of them.

2.4 Current inter-generational influences on energy in the home

To what extent is energy performance determined by interactions between occupants, behaviour and building systems? A question posed by Steemers and Yun (2009) and one very much in line with this research. Their research looked at "actual energy consumption along with detailed energy-related characteristics of the housing units and their occupants" to understand interrelationships between different aspects of the home. They found that the most influential variable was Heating Degree Days as this directly influenced heating use and thus gas consumption in the home. Occupant behaviour was responsible for over 10% of variance in the winter [Steemers and Yun (2009)]. It is important to look at climate and seasonal change in this context, as these play the biggest role in direct energy consumption, but are out of the control of the occupants, thus looking to change or improve behaviour may be a realistic way forward.

As discussed above, behaviour is a factor that has traditionally been difficult to model and understand, but is an important aspect of energy use in the home. Attempting to understand the human perspective, Hargreaves and Middlemiss (2020) carried out research "to show how social relations shape how much energy people use, when and where they use it, as well as how they respond to interventions". The research found interactions between 'family and friends' lead to "Learning and shaping practices, sharing energy services, and energy consumption advice" [Hargreaves and Middlemiss (2020)]. It is important for this research to know that interactions are taking place in the home, potentially between family members; it is not stated if these are between inter-generational family members, however, meaning there may be space for further research.

Traditionally, when inter-generational influences are examined, the effects of having elderly relatives in the home are predominantly discussed [Bardazzi and Pazienza (2020)] [Zhu and Lin (2022)][Estiri and Zagheni (2019)][Kane et al. (2015)]. With increased life expectancy, these issues are intensified; Pais-Magalhaes et al (2022) stated 'it is universally predicted that an ageing population will increase energy consumption in households'. This is due to longer occupancy hours (and thus longer heating periods), levels of comfort requiring a higher temperature and finally concerns of ill health [Pais-Magalhães et al. (2022)] [Kane et al. (2015)]. There is also another generation that occupies dwellings, which have seen less research than elderly occupants, these are younger generations – children and teenagers. The generational change also brings a change to energy consumption. Young people now lead a more energy-intensive lifestyle than their parents did at similar ages – particularly in terms of electricity consumption [Estiri and Zagheni (2019)]. Having said that, children and teenagers are now also exposed to more environmental knowledge than their parents were; an example of this being the Greta Thunberg Effect, significantly improving exposure and energy literacy of children and teenagers around the world [Sabherwal et al. (2021)]. Not only do households with children use more energy than those without, but that consumption increases as the children get older [Brounen et al. (2012)]. To add to this, although children use far less energy outside the home than their parents, Japanese studies have shown that inside the home, children's rate of consumption is almost identical to that of adults [Yamaguchi et al. (2020)]. This could be expected as all occupants need to complete the same generic activities in the home (i.e.washing) and the hobbies of children now often include electronic devices.

There has been research to show that different types of upbringings (high income vs low income for example) can lead to different behaviours when adult life is reached. Hansen (2018) found during their research, that "growing up in a household with more economic means correlated with higher energy consumption today regardless of the present economic situation" [Hansen (2018)]. This may show that the underlying behaviour that we can not consciously control may play a far larger part than expected. It will be very hard to alter an occupant's behaviour if they are reverting to behaviours they learnt in their childhoods.

Similar family trends were found again by Hansen and Jacobson (2018) when researching inter-generational transmission of energy consumption practices. The research suggested that "practices are shared and reproduced within the family" [Hansen and Jacobsen (2020)]; importantly, this is not between young children and parents, but adults and their parents, thus there is likely to often be interaction between the two parties regarding mature topics such as energy. This is an important link that is being under-utilised as a medium to transfer knowledge from one generation to another. This research will look to find if knowledge can go from younger to older, rather than older to younger; an interesting change of approach.

As aforementioned, there has been relatively little research specifically into the snowballing of sustainable knowledge between generations within a household [Fell and Chiu (2014)]. This is a shortfall that could have increasingly positive effects on energy consumption if properly managed. There appear to be very few studies analysing energy knowledge transfer between children and adults, nor regarding the creation of opportunities for this inter-generational transfer to occur. The following study looked into teaching children about energy in attempting to improve their behaviour, but the researchers carried out no data collection to ascertain if their theories were successful. The study carried out by Fell et al at UCL (2014) took children and parents from two primary schools and encouraged responsibility for the children to save energy at home. It was found that 'Children derived more motivation to save energy from responsibility conferred by school activities than environmental concerns' and 'Parents' environmental attitudes meant that it was sometimes difficult for children to save energy even when motivated'. However, importantly for this research, 'Parents showed a greater inclination to pay attention to energy saving when framed as supporting their child's learning [Fell and Chiu (2014)]. This last point suggests that the parents of participant children in this research may well change their behaviour to support the positive outcome for their child. This study was looking at the behaviour and activity of the children, rather than that of the adults or the discussions/transference of knowledge between the two groups.

The paper also goes on to discuss another study about ‘inter-generational learning’ and how it is promoted by activities that involve both child and parent [Ballantyne et al. (2001)]. Ballantyne et al carried out an intervention in a school and found that ‘the impact of the program was such that the majority of students self-reported that they changed their behaviour and carried discussions of the issue beyond the bounds of the classroom’. The paper summarises some key learning points for future school interventions that were taken on board when designing interventions within this research [Ballantyne et al. (2001)]:

- Combining research activities, environmental experiences and class discussion
- Focusing on a local environmental problem
- Providing positive experiences which demonstrate to students that they can influence their own local environment
- Involving students’ parents in activities such as homework assignments, research activities and class presentations
- Involving community members in programme activities by conducting surveys and interviews, presenting project reports and research findings in a public forum, having the programme reported in the local newspaper, asking local industries to demonstrate their environmental management strategies and involving local business and community groups in environmental action projects.

A 2018 thesis by Andersen looked specifically at using *"Children as intergenerational environmental change agents"*. The findings show children had mixed success in negotiating social forces such as the dominance of adults in the family domain and point to the need for school-based environmental educators to produce programs that openly enhance children’s opportunities to have an active voice in their schools, communities and families [Andersen (2018)]. In a similar vein, Meeusen found in 2014 a Belgian study that in families that communicate regularly about the environment, transmission (of environmental concern) was more effective [Meeusen (2014)]. This would suggest that interactions are an important aspect of teaching the next generation about key aspects such as environmental concern. This study was however, looking at adult-to-child transfer, unlike this thesis research

It has been shown above that although there are many influences on behaviour in the home, ’awareness and knowledge of the environment’ (learnt at school or potentially elsewhere), can have a positive change on occupant behaviour.

2.5 Utilising children as influencers

In recent years, there have been several studies carried out that analyse very similar situations and interventions to this research. Notably, Lawson et al (2018) have published three papers assessing whether children can foster climate concerns among their parents. In 2019, the research found that although promising, many factors affect the success rate of knowledge transfer: Age of children, Sex of children (and parent), as well as many existing opinions such as political stance and religious beliefs, have an influence [Lawson et al. (2018)]. The research succeeded in spreading concern from teachers to children to parents, but it does not show or record how interactions within the home took place. This would have been interesting to see. The study also took place over two years, with persistent interventions in the school class; this reinforcement of messaging was likely to be very influential.

Diana Varaden of King's College London presented a lecture in 2020 about her work regarding 'Engaging School Children in Monitoring Air Pollution', and it became apparent that a similar route could be undertaken within this research. Children could not only be used as agents of change to disperse knowledge, but could also be used to gather more data whilst they were learning about the very same topics. Although her work is based on air pollution, her discussions about 'using research as a tool to engage people' still very much hold merit in the field of energy [Varaden et al. (2018)]. Further reading into similar themes highlighted 'the value of involving children in the research process for raising awareness and stimulating positive changes in practice' [Coates (2016)]. By creating a take-home activity that engages the children in an analysis of their own home and behaviours, they would feel much more involved as a whole.

There have been several studies into using activities, games and apps as 'stealth interventions' to improve attitudes and behaviour [Jansz et al. (2021)]. Such a relevant example includes the mobile game 'Gaea', which was used to improve attitudes towards recycling for a study by Centieiro, Romão, and Dias, [Centieiro et al. (2011)]. It has been shown that games can often be used as 'powerful sites for enculturation' [Flanagan (2010)]. This means the act of children investigating is more important than the results they collect.

Knowing the age of the participating children will be primary/preparatory (4-11/13 years of age), it was important to take note of the varying abilities in this group. The activity must be simple enough for the youngest to play, but stimulating enough for the oldest to also play. Having said that, it should also encourage discussion between the child and the parents/carers, so it should be complicated enough to do this for all ages. The activity must also be able to work within any online school portals; thus, simple printable sheets and limited accessories only should be required. A simple board game would be ideal, with easy rules and a simple playing mechanism such as Ludo or Snakes and Ladders. The route/board needs to be their own home, which they could draw themselves, allowing for personalising. These games need only a dice and a token to play, both could be provided in nets to allow more interaction and world-building to take place.

Children are a potentially untapped and under-utilised source of positive behavioural influence in the home. By teaching children, knowledge can be positively spread throughout the public. There are many examples of this not specifically about environmental awareness, but other factors: Nisbet et al (2007) found that initially "people are rarely well enough informed or motivated to weigh competing ideals and arguments and often use their predispositions when faced with new ideas", but then found that messages regarding new ideas told in a positive way often succeed - they use the teaching of evolution, which is now widely regarded as common knowledge as a good example [Nisbet and Mooney (2007)]. Climate change has often been portrayed negatively. NASA's website states that 'the effects of climate change will be profound' [NASA (2022)] whilst the Intergovernmental Panel on Climate Change states "Increasing magnitudes of warming increase the likelihood of severe, pervasive, and irreversible impacts" [Physical and Basis (20 These are two examples of how negatively climate change is spoken of. This may not be the best way to discuss the matter, and maybe a more positive discussion, as Nisbet et al showed (maybe about the ways humans are helping mitigate the effects), would lead to better acceptance of the issue. Similarly, Gerend and Shepard (2007) and Long, (2011) both also discuss how ideas of significant importance can successfully be passed on to children, in this case, vaccinations and climate change, respectively [Gerend and Shepherd (2007)] [Long (2012)].

An important aspect of the above three examples is where the knowledge comes from, or in fact, who directly teaches it. For example, Lawson (2018) discusses how a church leader delivering a speech about climate change will have more of an impact on the audience than hearing it from elsewhere, as that audience has tremendous 'trust in the teacher' [Lawson et al. (2018)]. This aspect will be discussed more in the next section, where it is scaled down from people such as organisation leaders to normal school teachers compared to online videos.

To summarise, as discussed above, if knowledge regarding the environment and climate change is delivered to children properly, positively and from a trusted source, it should then be accepted by children and potentially spread without hesitation among others. Thus children could be used as 'agents of change'.

2.6 The energy literacy levels of children

The Current State of Environmental Education in Schools

As aforementioned several times, education and awareness can play a role in the fight against climate change, from improving basic awareness to innovative science; it is a vital aspect that has the potential to lead to more environmentally concerned decisions being made. The recent surge in campaigns such as the 'School Strike for Climate' is a perfect example of how young people are trying to make a difference. Starting with the teachers, 'Teach the Future' has recently completed a Climate Education Study [Teach The Future (2021)] including 7500 teachers across the UK. It produced some very interesting results that are discussed below:

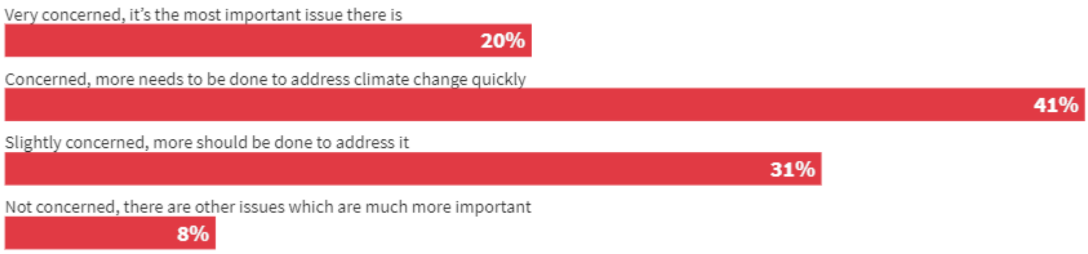


Figure 5: Results from the 'Teach The Future' teacher survey question: Rates of Teacher Climate Change Concern

Source: [Teach The Future (2021)].

Figure 5 clearly shows the concern teachers have regarding climate change, with only 8% not being concerned. Interestingly, breaking this down to Primary vs Secondary teachers, the latter sees an increase at both ends of the spectrum. This may be because the specialities of secondary school teachers vary considerably, whereas primary teachers cover all subjects. Overall, however, there is evidence that the initial concern is there, and things will need to change.

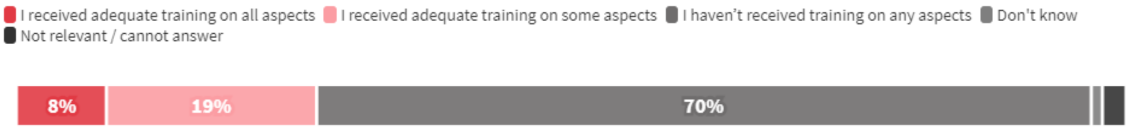


Figure 6: Results from the 'Teach The Future' teacher survey question: Have you received Training on Teaching Climate Change Topics

Source: [Teach The Future (2021)].

It can be seen from figure 6 above that teachers overwhelmingly feel that they are not prepared to teach topics around the environment (even though they have just said they are concerned). This goes beyond the scope of schools to higher education; one would expect universities to already be ahead of the curve (and they may well be in the last decade), but teachers who qualified before the 2000s may not have any Energy Literacy level to speak of, and also make up the majority of the country's teachers. Ideally, environmental awareness should be achieved across all levels and ages of the country (and world), from primary education to businesses to government.

The study goes on to look at many other aspects, including reasons for/against teaching Climate Change in schools; the greatest barrier being the already substantial workload that teachers have [Teach The Future (2021)]. This is a very common issue in all of education that seems to have no immediate or obvious solution.

Moving onto the students and children, within the same study, it was found that only 4% of students feel they know a lot about climate change and 68% want to learn more about it [Teach The Future (2021)]. It was also found that children in primary and secondary were suffering from 'eco-anxiety', with 59% very or extremely worried about climate change, and 84% at least moderately worried in a study by Hickman et al (2021). Emotional impacts included being sad, anxious, angry, powerless, helpless, or guilty, and over 45% reported these feelings negatively affected their daily functioning, with a significant finding was that frustration and perceived betrayal in response to governmental inaction exacerbated distress [Hickman et al. (2021)]. It is clear that there are consequences beyond those that climate change physically brings for children, and these could be mitigated by improving the school system and the National Curriculum.

Environmental education within The National Curriculum

The National Curriculum is the framework by which all schools in England create lessons and activities. This maintains an even measurement for progression and testing, and makes sure children are at similar levels as they transition to secondary and then further education. It often sees changes when new governments come into control, with smaller changes ebbing and flowing as budgets and national priorities change. The last decade has seen a significant emphasis on 'STEM', for example, which covers Science, Technology, Engineering and Maths. This has been particularly focused on engaging female students, as it became apparent there was an imbalance in the adult workforce in these areas. Of course, these trends will always change throughout the years as more prominent ideas become apparent to the government and nation.

The latest edition was published in October 2013, is almost 300 pages long and contains the phrase 'Climate Change' exactly once. Under the topic of Earth and Atmospheric Science, it specifies teaching of 'evidence, and uncertainties in evidence, for additional anthropogenic causes of climate change' [Department for Education (2014)]. This comes under science for Key Stage 4, which is 15- and 16-year-olds undertaking their GCSEs. Students have already been in school for 10 years at this point, with only 2 to go until they leave permanent full-time education. There is clearly a significant gap that can be utilised with the introduction of climate change topics much earlier than specified by the government. Additionally, the phrasing of 'uncertainties in evidence for climate change' shows a certain viewpoint that may not help promote good levels of energy literacy [Department for Education (2014)].

Large studies have been conducted with secondary-age children on their opinions of the National Curriculum in terms of sustainability and the environment. Walshe et al (2025) interviewed students from over thirty schools and found 92% of students reported learning about climate change and sustainability in school; 78% from media, 61% in primary school, and 43% through extracurricular activities. Yet, disparities emerged: students from more advantaged backgrounds consistently reported higher exposure via media, family, and learning activities outside school than less advantaged peers. Interestingly, most exposure came via geography (90%), assemblies/tutor time (75%), and science (68%) [Walshe et al. (2025)]. This may suggest that the NC is having to be bypassed as it only taught about environmental topics in 'science'. It is also interesting to see that it is being covered in a variety of different lessons, not simply within science, as the NC states.

Sustainability Strategy for Education

The recent change of government may lead to new changes occurring with education, but the last significant attempt to improve the National Curriculum (in terms of sustainable education) was in April 2022; the UK Government published a press release with the title 'UK to lead the way in climate and sustainability education' [HM Government (2022)c] This is a bold and very optimistic statement and when attending the 'DfE Sustainability and Climate Change Strategy Briefing for Schools' soon after the announcement, it was clear that no hard changes or decisions had been made. It was obvious to all teachers present that their own efforts (often outside the normal school scope) in their schools were already beyond that which the government spokesperson was recommending or pushing as groundbreaking. These include schools introducing meat-free Mondays, electing Eco-Champions, planting trees and vegetable patches or reducing plastic usage - all of which the schools involved in this research already have done for several years. There was no mention of key aspirations that the teachers kept mentioning, such as funding, training and assistance in creating real change within their schools. It is important to add that no time frame was discussed apart from an end target of 2030 [HM Government (2022)c].

Looking within the released document at Action Area 1: Climate Education, there is talk of 'empowering future earth citizens', but the first addition to the National Curriculum is a 'Natural History GCSE' to be launched by 2025 [HM Government (2022)c], which does not consider ages between 4-15. This is unfortunate to see from the perspective of this report that it is not targeting the 4-11 primary school age. However, a welcome addition is the 'annual climate literacy survey to benchmark progress in improving the climate knowledge of school leavers'. Although this is for 'school leavers', there can be no remedial changes or improvements for those children. This could inform the need for the topic to be taught differently.

The chapter does go on to discuss training for teachers through CPD-style education; this is an aspect that has been discussed earlier in the report. Teachers are currently not taught how or what to teach regarding climate change and sustainability.

The government said they hoped by 2023 to have 'developed a Primary Science Model Curriculum, which included an emphasis on nature to ensure all children understand the world around them' [HM Government (2022)c]. However this did not occur, and with the recent change of government, it can be expected that a new solution may be proposed.

COP 26: Glasgow

COP 26 saw the world's leaders and over 2000 Non-Governmental Organisations (NGOs) meet in Glasgow to discuss climate targets for the future [Nat Geo (2021)]. COP26 released a 'Schools Pack' aimed to inspire younger generations into action [SVCC (2021)]. These packs were aimed at teachers and included full lesson plans and activities all related to climate change, linking in with the current national curriculum - a very similar idea to the content proposed for the studies within this research. They are also split between Key stages to allow for differences in ability. This is an aspect that will be discussed within each method separately.

Additional environmental education in schools

Separate from the National Curriculum and thus not required, schools can voluntarily sign up to one or more of many charities and groups that promote environmental education. 'Eco-Schools' is the largest of these, operating in 67 countries and engaging with 19.5 million children [Eco Schools (2021)a]. It proposes a framework of 7 steps with children at the centre, these include setting up student committees, reviewing the school and current behaviour and setting up an eco-code of conduct. It also promotes including their '10 Eco Topics' into the existing curriculum. These topics include Biodiversity, Energy, Transport, Waste and more. Schools have to reach certain levels to achieve certification and be able to fly the 'Eco-Schools Green Flag'. It has been praised by UNESCO and the United Nations as 'A major contributor to sustainable development' [Eco Schools (2021)b], yet the government has included very little if any, of the EcoSchools framework into mandatory education.

Other significant organisations such as NASA and OXFAM also have similar systems in place and offer resources for teachers, but this requires teachers to first want to teach such topics, then to go out of their way to find resources that are suitable to also teach what is required of the current National Curriculum. Similarly to legislation playing a significant role in laws and requirements, such as the Building Regulations, the National Curriculum requires a substantial update. This raises four questions about how environmental education should be introduced: (i) should it be a separate subject (potentially taking the place of something else)? (ii) Should it be included within subjects such as PSHCE (Personal, social, health, citizenship and economic education) that have more leeway? (iii) Could it be immersed into every subject in much smaller chunks? (iv) What topics should be included for what ages? Referring back to the Teach The Future research, it was found that framing climate change in terms of 'animals, nature and wildlife' was the most chosen answer, followed by 'health, food and wellbeing'. This can be seen in Figure 7 below. It would make sense to follow this as these are topics that can be aimed at all ages, rather than the lowest performing answer 'politics, economics and foreign policy' which is considerably heavier.

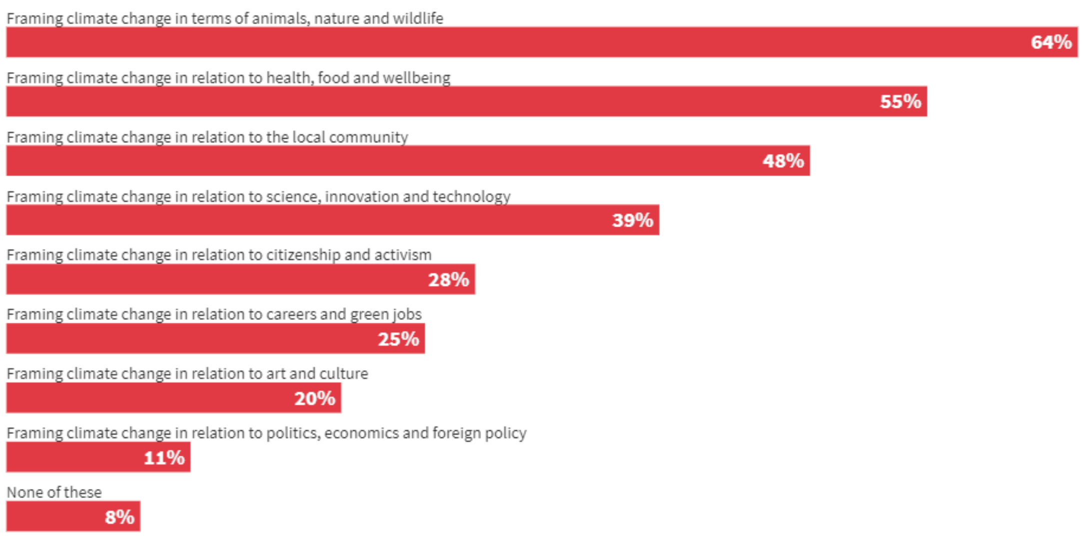


Figure 7: Results from the 'Teach The Future' teacher survey question: Teachers Opinions on the Best Topics to Teach regarding Climate Change

Source: [Teach The Future (2020)].

As recently as May 2021 prominent politicians have been attempting to influence the government concerning environmental education; Lord Knight introduced the 'Environment and Sustainable Citizenship' Bill into the House of Lords, aiming to "make provision in the national curriculum regarding sustainable citizenship and protection of the environment" (Knight, 2021). A similar Bill was introduced in 2019 titled the 'Climate Emergency Education Act', which aimed to achieve a sweeping change to the National Curriculum, including retraining all teachers and funding youth-led climate social action [Teach The Future (2020)]. Both are yet to see any progress, in part due to the COVID-19 pandemic.

It is apparent that the current education system is failing in terms of teaching any aspect of climate change and its associated topics. Yet there is hope in many initiatives and influential people pushing for the change it needs. This research study aims to be another positive example of the difference improved 'energy literacy' can have in the fight against climate change.

Eco-Anxiety amongst children

With higher levels of understanding of topics such as climate change or energy come issues that have not been seen before in children, namely, Eco-Anxiety - which is increasingly recognised as affecting even very young children. A qualitative study of children aged 4–8 found that 96% expressed anxiety about issues such as droughts, forest fires, and endangered species, with concerns often centred around scarcity, loss, and human neglect [Ojala and Chen (2022)] [Hensler et al. (2025)]. Similarly, research conducted in East London showed that around half of primary-school children were both aware of and worried about global warming, with worry levels positively correlated with climate knowledge and willingness to act [Ojala (2022)].

Children's experience of eco-anxiety involves a range of emotional reactions, including fear, sadness, guilt, frustration, and anger, frequently accompanied by a perception that climate change is uncontrollable [Hickman et al. (2021)]. A scoping review identified increased vulnerability in girls, particularly when opportunities for meaningful climate action were lacking or governmental response was perceived as inadequate. Other research highlights that eco-anxiety can extend beyond worry, encompassing trauma, spiritual and existential distress, and even physiological anxiety, particularly among children affected by climate-related disasters [Hickman et al. (2021)].

Coping with Eco-Anxiety is again, a very new area of study that has arisen alongside. Studies in Sweden classify children's coping strategies into three broad categories: problem-focused, emotion-focused, and meaning-focused coping (Ojala, 2022). Problem-focused coping, which involves individual or collective environmental action, may lead to guilt or emotional exhaustion if children feel overburdened [Ojala and Chen (2022)]. Emotion-focused coping, such as avoidance or emotional distancing, can provide short-term relief but does not resolve underlying concerns. By contrast, meaning-focused coping

— which reframes eco-anxiety through values, hope, and engagement — appears to be the most adaptive, supporting resilience and constructive action [Ojala and Chen (2022)]. The following interventions within this research will be designed with these coping strategies in mind, attempting to find the balance between the knowledge children need to know to make substantial change and at what point they may become prone to negative effects, such as eco-anxiety.

If it is not dealt with properly, Eco-anxiety can lead to wider mental health outcomes. Research on young people in regional Australia who were already using mental health services found that eco-anxiety manifested as feelings of helplessness in the present, hopelessness about the future, and acute stress following climate events, all of which increased risk for depressive symptoms and anxiety disorders [Boyd et al. (2024)]. Social support systems were seen as critical for coping, with both clinicians and young people highlighting the role of peer networks and collective action in reducing distress, although formal eco-therapeutic interventions remain underdeveloped [Boyd et al. (2024)]. This paper was, however, focused on children in secondary school and over.

Education is widely recognised as a key arena for addressing eco-anxiety. School counsellors and similar roles, in particular, are seen as crucial in helping children process ecological emotions, yet literature exploring their role remains limited [Köse (2023)]. Eco-anxiety is both widespread and emotionally potent among youth. A pressing sense of worry often arises from perceived societal failures, amplifying stress. But coping strategies matter: while simply trying to act (problem-focused coping) may sometimes increase distress, meaning-focused coping—anchored in hope, trust, and value-driven reframing—supports resilience, well-being, and constructive engagement.

2.7 Pedagogy

Teaching during Covid-19

As aforementioned, 2020 and 2021 saw the outbreak and then the continued pandemic caused by the COVID-19 virus. As of July 2020, approximately half of the world's student population had been affected by the closures of educational institutes [Viner et al. (2020)]. This led to many issues with delivering lessons of the same standard worldwide [Mahmood (2021)]. In the UK context, depending on the school or teacher, teaching during COVID-19 was either through live sessions on programmes such as Zoom or through recorded sessions on YouTube/Google Classroom. Children often had access to a virtual learning environment (VLE) such as Google Classroom, where resources and activities could be accessed. Any intervention that was to be planned would have to fit into this new system for the foreseeable future.

Creating content for the online realm still requires the same basic principles as a classroom-based, face-to-face delivered lesson. For example, according to Taggart et al (2024), blending short, live contact with short tasks gave the best results for primary pupils during/after pandemic teaching [Taggart et al. (2024)]. Teacher presence and social presence are strong predictors of engagement in young learners' online learning. This may be harder to achieve as the requirement for a live teacher online may be outside the limitations of this research; however, lessons and content will be aimed to be designed so that a child feels "seen" [Borup and Archambault (2023)]. Amin et al (2023) suggest that parental/carer support and simple, school-provided devices hugely improve learning outcomes for primary pupils learning from home. This too may be hard to achieve within the remit and budgetary constraints of this research. Having said that, it is important that a wide spectrum of participants is included within the intervention; thus, device ownership may become a theme that can be explored further [Amin et al. (2023)].
Even with outstanding resources, virtual learning may still not be ideal for all students. This could include those with special educational needs that would otherwise need significant differentiation, even when in the classroom environment, and unfortunately, even in the UK, some students will still not have access to the technology needed in the home to take part in online education. This is known as 'Digital Poverty' and some disadvantaged areas see numbers as high as 70% for children who do not have access to a computer outside school [BBC (2020)]. It may be a potentially viable solution to create both classroom-based lessons and online lessons so that as many children as possible can be reached as possible.

Reasons for teaching in the traditional classroom environment:
The classroom environment has many positive attributes that have allowed it to continue being the dominant form of education to this day. A school is a place of learning, it is expected as the main aim by parents and children alike, and the school day is designed to schedule times for specific activities that aim to manage leisure and work time effectively. This structure promotes learning for a certain amount of time and then positively rewards that work with leisure time at several points during the day [Tabvuma et al. (2021)]. This work and reward system mitigates some negative factors that may be detrimental to learning, such as boredom, procrastination or distractions that may occur in other learning environments, such as the home.

The classroom environment also allows horizontal learning to take place – teaching and learning from fellow students in the same classroom during lessons. The concept of 'community of practice' was conceived by Etienne Wenger in 1991, who was the first to recognise that members of a group were learning from each other and developing on 'both a professional and personal level' by sharing common knowledge and experiences [Jiwa et al. (2011)]. The idea is now considered a crucial aspect of early development and has been recognised to improve social interactions and behaviour throughout adult life. This occurs less in smaller groups and is not possible when students are isolated by themselves.

The classroom has also been designed to promote learning and mitigate distractions and bad behaviour. Children's seating can be organised to maximise learning, walls and displays can motivate students, and there are often several members of staff within a class to aid in learning. Panek (2014) found that "when students are unstructured (in the home) they overuse leisure media, such as social media and watching online videos, due to a lack of self-control" [Panek (2014)]. This is an aspect that is hard to improve, as there are no obvious ways of intervening within the home.

The UK's educational system is made up of a vast amount of people, students, buildings and infrastructure amongst a plethora of aspects behind the scenes. Any change ordered from the government, be it for the considered benefit or unexpected detriment of the system as a whole, will take time to take hold and show any results. When changes are forced upon the system, or simply forced too quickly, they often fail to yield positive results - Lamie's categories of educational innovation (2005) breaks down changes into various categories. An 'enforced shift' such as one to online learning during the COVID-19 pandemic, for example, is a 'power-coercive unplanned innovation', a category with one of the lowest likelihoods of being successful [Lamie (2005)]. Letting the education system of the UK evolve slowly with incremental changes may lead to better success in the long term, but unknown and uncontrollable factors such as the COVID-19 pandemic may always be ahead, and the requirement to innovate at a fast pace may follow.

From the student's perspective, Kemp and Greive (2014) showed that the classroom environment is the preferred place to learn, with participants stating that "immediate feedback from peers and teachers" was one of the most important aspects [Kemp and Grieve (2014)]. This would suggest that the lack of contact when distance or online learning may lead to dissatisfied or under-motivated students who may not perform as well as those taught in the classroom. Similarly to this point, an investigation by Tang et al (2020) found that "students are generally dissatisfied with the learning effect of online courses and content", again showing that online does not seem to be the preferred method from the student's perspective. The same study also found that "a sense of isolation among students" was evident when using online methods of teaching [Tang et al. (2020)]. As previously discussed, the social side of a learning environment is very important and is not being experienced when learning online.

Reasons for teaching using the online environment:
There are also many positives to teaching online, the first could be considered the most well-known and that is the flexibility that comes with working from home. Caldwell (2018) found that Japanese students "were happy to learn either way, the inherent convenience offered by online learning means they are more likely to choose this". This 'convenience' is a significant positive for online learning, allowing students to maintain other aspects of their lives; Keengwe and Kidd (2010) also found that there are "various benefits for online learning including flexibility in terms of when the work is undertaken", allowing students to work on different items at different times and compensate when they are unwell for example [Keengwe and Kidd (2010)].

There are numerous additional benefits, for example, not having to travel to and from or experience the social pressures of the school/university environment is often seen as reason enough to move to online learning. In addition, research has indicated that online learning is "pedagogically promising because it encourages deeper learning due to its self-paced and student-centred approach" [Grieve et al. (2017)]. The ability to re-watch, or pause recorded lessons, allows this student-centred approach and is unachievable in the classroom environment.

Online learning also allows for a broader range of students located potentially across the world to gain access to qualifications they may not have been able to previously. This 'international audience' is a huge benefit of online learning that could allow any potential interventions of this research to reach a participant group large enough to provide significantly powerful data for analysis.

Comparing and contrasting the above - In Person Vs Online:
An interesting aspect of this debate is that perceived perceptions may not match real-world results, for example, in a study completed by Vaccani et al (2016), 69% of students agreed with the statement: "I feel that being able to interact with the lecturer in person in a classroom setting is a better learning experience than the online format' - yet the online students performed better than live lecture students within the associated exam. This may mean that their opinion could be based on the lack of social interaction, rather than the level of education they were receiving. The students are likely to put this social side at a higher importance, whereas the teachers would likely put the level of education as the most important aspect.

Deslauriers argues that students are found to often feel that learning online is harder than in person [Deslauriers et al. (2019)], but this is a misconception, and the issue does not come from being online, but from the change in technique – going from in-person classes to online classes. Deslauriers et al (2019) go on to say "This is due to students' inexperience with the new learning format and the increased cognitive challenges they experience within this demanding environment, especially at the beginning of its implementation, as opposed to the perceived "cognitive fluency" of the traditional lecture format. These findings introduce an important aspect of the discussion - time. After the initial change has occurred, students struggle as aforementioned, but after some time the online procedures become ingrained and the quality of learning returns to normal. For example at the start of the COVID-19 pandemic, schools and universities "encountered several serious problems with software and procedures" [Todd (2020)], often leading to wasted lesson time and lack of concentration. These were, however, "largely solved within a few weeks", and the lessons returned to the initial pre-COVID level of performance. There is always a learning curve with anything new, but once this is overcome, the benefits of the new system or procedure can be gained. Children, students and adults alike are now accustomed to working online, and it may have many potential benefits in the future. Similarly, Tabvuma et al (2021) found that when initially transitioning to online learning "there was an increase in time spent on leisure activities", meaning learning was not at the optimum level for at least a short period. The novelty of not being in the classroom also means students and children are not watched by staff and thus behaviour control is not possible [Tabvuma et al. (2021)].

Improving the energy literacy levels of children

A 2023 Vietnamese study by Quy Van Khuc et al found that 83% of participating students wanted to increase their energy-saving knowledge, but around 50% were interested in enrolling in an energy course, suggesting that the want to take action and the act of taking action are still far apart when it comes to environmentally conscious behaviour [Khuc et al. (2023)]. This raises the question, however, whether those who completed the course would then behave better in terms of their energy decisions? This study was also using university age students. Turning attention to younger teenagers and children, Rohmatulloh et al (2022) found programs in middle schools were able to inspire a change in behaviour toward energy saving through habituation in learning activities [Rohmatulloh et al. (2022)].

Bayley et al (2021) carried out a study using game design to improve the energy literacy levels of children. An online game titled 'Power Pets' was used to teach about energy and its connection to the environment. Findings suggested *"Power Pets provided preliminary indications for improvements in children's understanding of energy saving and the link* *between energy saving and the environment"* [Bayley et al. (2020)]. This style of teaching would suit this thesis research very well. Combining gamification with the topics of animals, which was earlier suggested as a key topic for teaching environmental awareness to children. Having said that, a game of this magnitude is outside the scope of this research. If a similar-themed game can make a similar impact, it may produce a good study. Similarly, 'Games for Change' has seen an increase in research in recent years. Ndulue and Orji have found 15 games are now accessible that are purely aimed to teach children about energy and sustainability [Ndulue and Orji (2023)].

2.8 Summary

In summary, it is evident that homes and the people within them are a hugely influential factor in reducing energy consumption in the UK. Occupants in homes have many different reasons and drivers for the way they behave, and environmental awareness or 'energy literacy' has the potential to be one of the most influential.

There appears to be a substantial gap in the national curriculum regarding environmental topics, especially aimed at those younger than GCSE age (for which there are no requirements to learn anything related to the environment from ages 4-15), yet the government has not implemented any environmental content into the national curriculum since 2014. It should not be the case that children do not get to learn what will most likely have the biggest effect on them throughout their lifetime. This also means, however, that there is an untouched population that can be used to pass knowledge on to the main occupants of homes.

This research will target all of the above aspects: teaching children the knowledge they need to act responsibly, creating opportunities for discussion between the generations and finding out if there has been a transfer of knowledge that has led to behavioural change of the occupants.

There have been several aspects discussed in the above literature review that have different viewpoints to achieve the same goal. For example, there appear to be balanced arguments that justify school learning and online learning, therefore this research will have to test both methods to find which is more appropriate.

2.9 Research Questions

To follow the initial research question of this literature review, these will be answered in this thesis to meet the aim and objectives:

1. How do occupants currently behave (in terms of energy) in the home?
2. What are the current levels of inter-generational influences on energy in the home?
3. What are the current energy literacy levels of occupants and children?
4. What topics and knowledge would be best to teach children (and parents)?
5. How should this knowledge be delivered?
6. How should interactions be triggered in the home?
7. What is considered a successful interaction?

3 Methodology

The aims and objectives of this research study are addressed through the four different studies in this research and are based on a multi-part method, referred to as **phases** throughout, which can be seen below. Some studies will cover only one or two phases, whereas others will cover all five. The methods put forward below are not based on interventions from other studies, but have been produced from analysing a wide range of papers and studies.

Phase 1 – Establishing a Parental Energy Behaviour Baseline
Phase 2 – Improving Energy Literacy Levels of Children
Phase 3 – Creating Opportunity for Inter-Generational Interaction
Phase 4 – Reassessing Parental Energy Behaviour Baseline
Phase 5 – Longitudinal Reassessment of Parental Energy Behaviour Baseline

Phase 1 - Creating a baseline of current energy behaviour in the home is a key part of understanding if any changes occurred during the interventions. It is important to gather information and data that is relevant, reliable and measurable during this stage.

Phase 2 – Each method had an intervention that aimed to improve the energy literacy levels of the children taking part (excluding method 1). Methods 2 and 4 took place within the school environment, and method 3 took place within the online environment.

Phase 3 – All three methods that included this aspect attempted it within the home. Methods 2 and 4 employed physical, tactile games to encourage interaction with parents, whilst Method 3 used an online data-gathering activity. The actual recordings or data gathered were secondary to the act of interaction.

Phase 4 – Reassessing the baseline of energy behaviour in the home is a key part of understanding if any changes occurred during interventions. It is important to gather the same information and data at the end of the study, thus allowing for comparisons.

Phase 5 - During Method 4, an additional longitudinal aspect was included to gather data on whether the gained knowledge and improved energy behaviour were retained over a period of time.

Figure 8 below summarises how the four studies correspond with the five phases within the research.

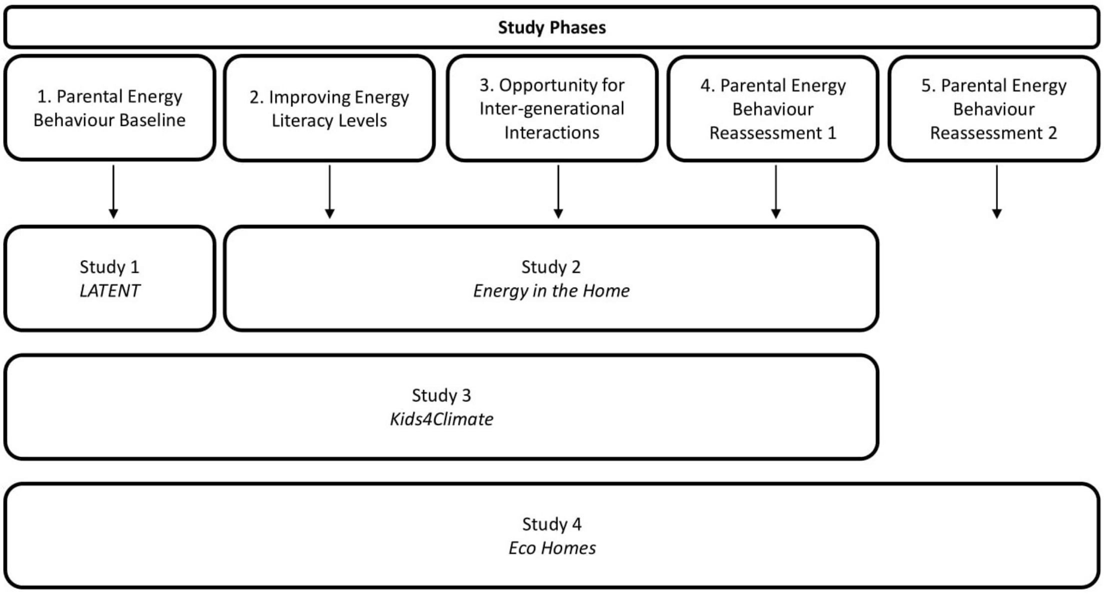


Figure 8: Graphic showing the four studies in relation to the phases covered

Figure 9 summarises the four studies and can be seen below, stating the intervention at each stage and the final number of participants. Phase 5 is not included within this and will be discussed later in the research.

	Phase 1 Pre-Intervention 'Current' Energy Behaviour Baseline	**Phase 2** Intervention Part A: *Improving Knowledge*	**Phase 3** Intervention Part B: *Transferring Knowledge*	**Phase 4** Post-Intervention 'New' Energy Behaviour Baseline
Study 1 **LATENT**	Survey Final N = 5000	NA	NA	NA
Study 2 **In Person**	NA	4 'Eco' Lessons at Woodcot Primary. Final N = 150	'Energy Detective Game' take home activity. Final N = 34	Short Survey similar to LATENT Questions Final N = 34
Study 3 **Online**	Initial 15 Question Survey Final N = 63	Kids4Climate Website Videos Final N = 33	Kids4Climate Energy Detective Game Final N = 33	Exit Survey Final N = 17
Study 4 **In Person**	Initial 13 Question Survey Final N = 66	The Eco Lesson Games Final N = 186	Eco Home Games Final N = 38	Exit Survey Final N = 38

3.1 Sampling Strategy Description

There are many advantages and disadvantages to using children in a study, but initially, the correct age must be chosen. The 0-4 age group was dismissed because they were inaccessible and could not complete an intervention. Secondary age was dismissed as they are already undertaking (although incredibly limited) lessons focused on the environment at school. The National Curriculum includes learning the 'pros and cons' of climate change during GCSE studies [Department for Education (2014)]. There are also an abundance of external influences aimed toward this age, such as the 'Fridays for Future' initiative [Fridays for Future.org (2022)]. Thus, the primary age was chosen (4-11).

3.2 Measuring success of the research

Determining how to measure the outcomes is reviewed in the following section. Initially, quantitative data was collected, particularly participant gas and electricity meter readings. When combined with a control group, a successful study would produce data that would ideally show the intervention group reducing their energy consumption when compared to that of the control group.

However, to maintain larger groups of participants for more powerful data during analysis, a similar idea was to negate the control group and ask the participants for additional meter readings, taking readings from a time before the study took place. This would, once normalised with Heating Degree Days (HDD), show a normal daily consumption, then this would be compared with a similar normalised consumption using the final meter reading after the intervention, also normalised for HHD. A pre- and post-summer meter reading was also considered; this would allow the removal of Domestic Hot Water (DHW) from the overall consumption, leaving only space heating.

It has been discussed earlier in this report how geopolitical factors have affected the study. The invasion of Ukraine by Russian forces, which in turn caused energy prices around the world to increase, coincided with Study 3 - Kids4Climate.co.uk. An increase in the energy price cap meant the higher unit and daily charges led to occupants around the country reducing their heating usage. It was therefore not possible to state that any reductions in utility consumption would be an effect of economic issues or the positive effect of the intervention.

A successful study would now show improvements between phases 1 and 4 (described below). It would also show a difference between control group survey responses and intervention group survey responses, with the latter ideally showing behaviours towards energy demand reduction in the home when compared to the control group or the initial survey responses. A relationship between responses that show an inter-generational interaction and an improvement in energy behaviours in the home will show the highest levels of success. Respondents who show an interaction has taken place, but has not led to improved energy behaviours in the home, would still show success, but at a lower level.

3.3 Statistical Analysis of and between the Studies

It is discussed above that the studies can be analysed internally, namely between phase one and phase four, which are directly comparable before and after intervention results. It is the intention that cross-analysis between the studies will also take place, aiming to compare and contrast not just the results, but the methods themselves, to understand if there is an ideal solution to take this research forward in the future. Initially, basic descriptive analyses will be carried out before more in-depth regression analyses are completed. These may vary based on data and results available from each phase and study. Each phase is tested three times over the four studies, with the exception that study four also includes the fifth phase.

Analysis of Phase 1 intends to further understand the reasons behind the current energy behaviour of adults in the home, specifically, whether children currently play a role in affecting the decision-making of their parents. This phase maintains a similar method, process and format throughout the three studies.

The analysis of Phase 2 intends to compare the three different methods that are used to improve the energy literacy levels of children. This phase sees significant change between the three studies and thus may require analysis that also changes. This phase is a key part of the study; without a successful phase 2, the following phases are almost nullified, thus the analysis must be of high quality.

Phase 3, creating opportunity for inter-generational interactions, also varies from study to study. The pros and cons of each study's method to do this will be analysed here. The main distinction will be between online and in-person opportunities, both of which have many merits.

Phase 4 is intended to be very similar to Phase 1. This is to allow direct comparisons between the two - one before and one after the main intervention (phases 2+3). Comparing this phase between the various studies may show which methods worked more effectively.

Phase 5 cannot be compared directly between studies as it only occurred within study 4. However, it is inherently comparable to phase 4 of the studies as it is gathering the same data. The only difference is the time between the intervention and the data gathering within this phase.

3.4 Study Populations

Several different populations of participants were utilised within this research. The LATENT population were initially utilised within Study 1 and then used again for Study 3. Woodcot Primary School was used for Study 2 and Study 4, with Walhampton Preparatory School also providing participants for Study 4. Figure 10 illustrates how the four different studies encompassed different populations.

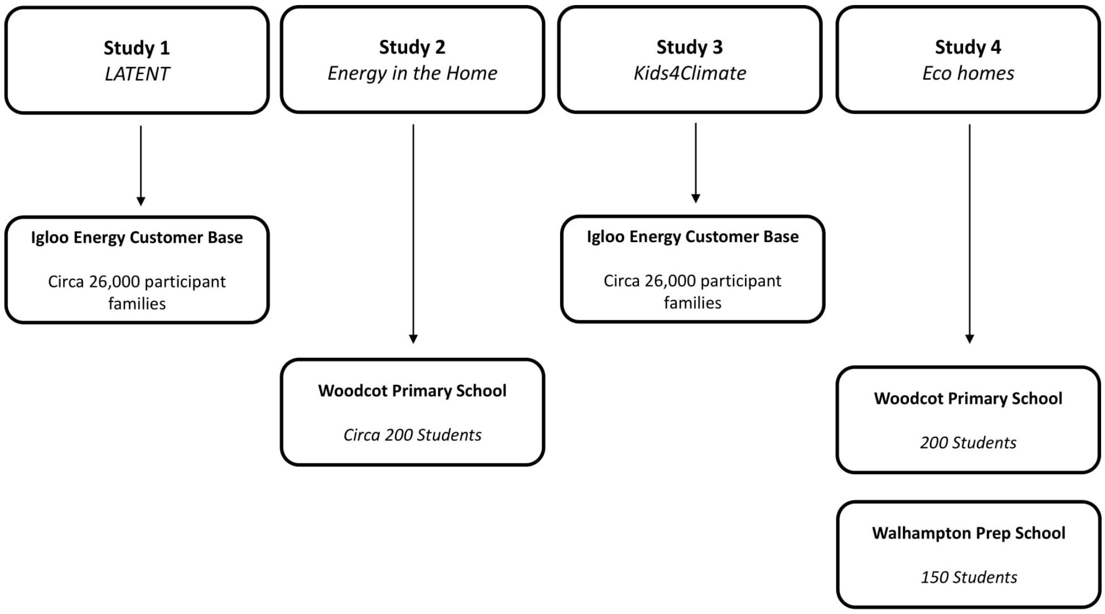


Figure 10: Graphic demonstrating the participant pools and potential number of participants

Concerning this research, the LATENT study provided a combination of primary and secondary data. An existing survey was to be sent to the entire customer base of Igloo Energy, an energy company that has since fallen into administration as the Ukraine-Russia conflict escalated and energy prices increased. This research was granted access to the survey before it was released, and four questions were added that would aid in collecting data for Phase 1 - establishing current energy behaviours in the home. The existing survey already contained fifty questions regarding an array of topics; further details can be seen in later sections.

Woodcot Primary School had pre-existing connections with researchers at the University of Southampton and was open to research taking place within the school environment, as well as encouraging the uptake of home activities with their students' families.
Transitioning the study online required a participant pool that was families with children of the correct age and who had reliable access to devices and the internet at home. Returned to the LATENT Studies, participants met these requirements. The participant pool had also already worked with the university, and thus, the uptake may have been higher than approaching those who had not already built a relationship with a research institute.

Returning to the school environment was required for Study 4. Adding a second school not only improved potential numbers of participants, and, in turn, the potential reliability of collected data but also provided an opportunity to test a different social demographic. Walhampton Prep is an independent school in an area that scores far higher in terms of indices of deprivation when compared to Woodcot Primary. This may allow for interesting comparisons to be made.

Summary In summary, the four studies within this thesis will each use a four-phase methodology. Initially, a baseline for current energy behaviour and inter-generational influences in the home is established. Secondly, an intervention takes place aimed at improving the energy literacy levels of children. Thirdly, an opportunity is provided for children and adults to interact within the home. Lastly, a re-assessment of the energy behaviour and inter-generational influences in the home is completed. Changes between phases one and four will be the main comparisons for each study's measure of success. Ideally, an improvement on the initial baselines would show a high level of success. By designing each method around these four Phases, the data produced at each stage would be comparable for a range of analyses.

3.5 Study 1 - The LATENT Study

Study 1 can work in synchronicity with Study 2; the first looking at Phase 1 - Parental Energy Behaviour Baseline exclusively, and Study 2 undertaking Phases 2-4. Together, they can act as one larger intervention covering all 4 phases of the overarching method. However, they utilise a different participant pool and thus comparisons must be understood to have this caveat. Study 1 could be more effectively described as an attempt to gather a large-scale baseline of current energy behaviour in the home. The participant pool is not 100% accurate or representative of the UK population, but the participant numbers do suggest a better reliability than that of Study 2.

3.5.1 Study 1 Background

The aim of Study 1 was to assess the context of inter-generational influences on energy in the home and establish a baseline of key performance indicators. It specifically looked at influences on energy behaviour originating from inter-generational sources other than the occupant, in this case, children and the elderly. It is also intended to ascertain potential future opportunities in the home for inter-generational influence to occur. The data collected in the study were used to create a reference baseline that future studies would aim to outperform.

This study would not be possible without a pre-existing research project currently being undertaken at Southampton University; these have been carried out in partnership with Igloo Energy, a Solent-based energy company that aims 'to make homes smarter, more efficient and cost less' [Igloo Energy (2021)]. LATENT, the study being discussed, is a multi-year study that has produced significant home energy surveys of data for university research studies. The research undertaken during this thesis took relevant aspects of the LATENT datasets and explored them in depth.

LATENT (ERGO 62684) continues to run until October 2025. This is the study that will be utilised for Study 1. LATENT aims to analyse the thermal preference and acceptance of automated, direct (3rd party) control of residential heating systems in the home [University of Southampton (2021)]. An initial survey has been sent to all Igloo customers, with more interventions to follow in the future. This initial survey was sent in January 2021, allowing time for additional questions relevant to this research to be added, and thus, data could be gathered on any existing inter-generational influences within the home. Participant numbers are approximately n=5000.

Me + My Home (M+MH) was a survey filled out by customers when they first signed up for Igloo Energy. The survey was used to tailor an individual tariff to the customer, allowing for the most efficient and cost-effective strategy. Customers had the opportunity to describe in great detail how they used their appliances and home, for example, stating what type of oven they had and how often (on average) they used it.

Figure 11 summarises the data that is used within Study 1. The vast majority of data will be secondary data from the LATENT Study's main survey. Several questions were added to this survey to provide results aimed at answering key questions within this research. Further parts are discussed below.

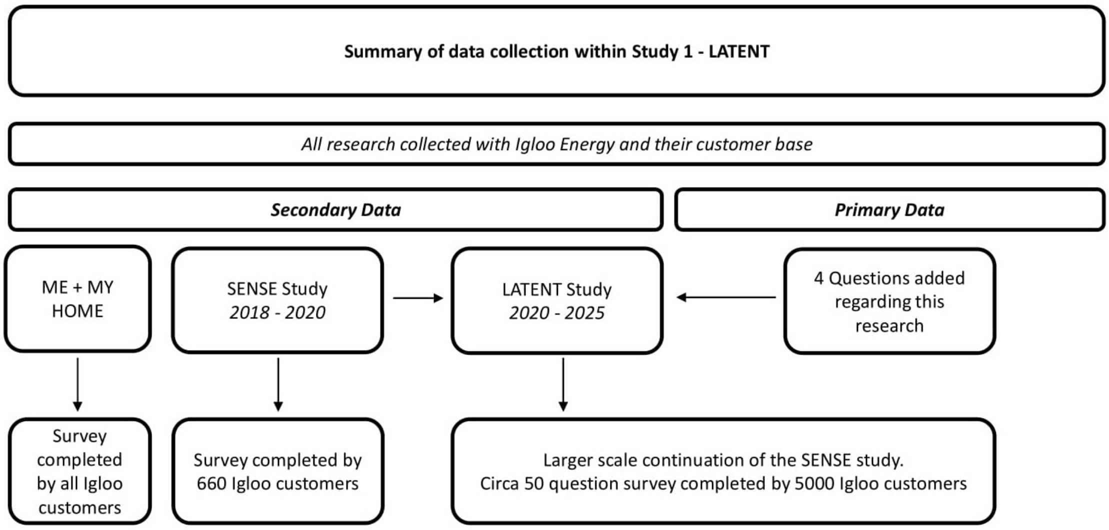


Figure 11: Graphic demonstrating the data accessed using the Igloo Energy customer base

Estimating Participant Numbers

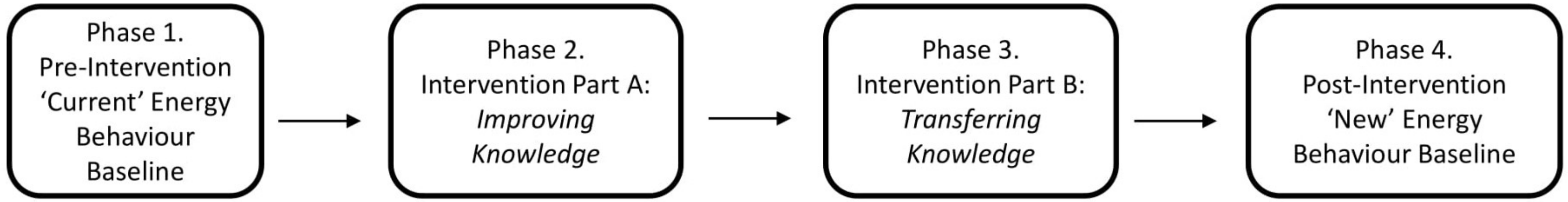
When this research commenced, LATENT had yet to be started, but access to the existing SENSE and M+MH databases was granted. SENSE (ERGO 47164) was the preceding joint study between Igloo Energy and Southampton before LATENT (ERGO 62684). It uses the same participant base, and a very similar survey was completed. An initial scoping analysis was carried out on the SENSE data to ascertain the general distributions expected to be seen in the future LATENT survey. It is important to note that SENSE response rates were around 10%, with just over 6000 surveys being sent out and 660 responding. Subsetting the data through various groupings shows the following:

- All participants, n=660
- Adults with Children, n=116 (17.6%)

- Adults with Children in Education (4-18), n=46 (7%)

3.5.2 Study 1 Methodology

Figure 12 shows the overall process of Study 1. It is important to note that the LATENT study is only phase 1 - it is not attempting to alter or improve energy behaviour in the home, simply measuring the current status of intergenerational influence on energy behaviours and decisions in the home. As it can work in tandem with Study 2, which does not include Phase 1, no comparative analysis can take place between the two studies. However, with studies 1 and 2 combined, comparative analysis will be able to occur with studies 3 and 4.



Output:	Qualtrics Survey Data	NA	NA	NA
Potential Participant Numbers:	26 000	NA	NA	NA
Study Information	Large online survey with 4 additional questions regarding inter-generational influences	NA	NA	NA
Final Participant Numbers:*	5500	NA	NA	NA
Participant	Adults	NA	NA	NA

1 Aim of intervention is to create a baseline for 'occupant energy behaviour' and inter-generational influences in the home

Figure 12: Study 1 Process Diagram

Study 1 Phase 1 Methodology – Parental Energy Behaviour Baseline

The LATENT survey allowed access to a large participant group. Joining with an existing study does mean, however, that this research was not the main route of enquiry. There was a limited number of additions that could be made to the survey for the specific research proposed here. Similarly, when it came to overarching design and decisions, this research was not the main focus of the LATENT survey. The full LATENT Survey can be found in the appendices; the following sections will focus only on the questions added for this research.

Fortunately, the survey gathered a large amount of information, which included data on the occupant number of children and their ages. This was however as far as the questions explored about inter-generational influences. Study 1 intended to add several questions following the existing survey to ascertain the interaction/influence between the generations. In addition to this, the survey also asked 'if there is an elderly (75+) person in the household'. As this already existed, the opportunity to ask similar questions regarding the interaction/influence between this second generation and the main occupants was also taken. This older generation is currently not a major part of the research, but could be added in future.

The survey was completed online and thus had the positives associated with it that were discussed in Chapter 3. Additionally, the ability for questions to open or close routes to other questions depending on the initial answer was applied. Therefore, only 'families' had to answer questions added about inter-generational interaction. To this end, this research used questions already proposed within LATENT as a starting point. Even with this in mind, it was important to keep questions as short and simple as possible; the final survey went through several iterations as it was progressively streamlined to shorter versions.

Building on the aims and objectives, some key questions were formulated that should form the basis of the final survey, including:

- What is the current level of Energy Literacy of the main occupant(s)?
- What is the current level of Energy Literacy of other generations within the home?
- What currently influences the energy decisions within the home?
- Do other generations influence (or request) heating changes in the home?
- Do discussions happen between generations about energy/environment?
- Would adults allow other generations to influence their behaviour?

- What do occupants currently do when they are thermally uncomfortable?
- Would they like to change their behaviour? What are the incentives?

LATENT was not intended to be used for an analysis of intergenerational influences in the home. Initially, there were no questions about this route of inquiry. Family size was only ascertained to further understand the energy requirements of differing family types and sizes. The questions discussed below, which were added for this research, provide a distinction from LATENT in that they directly ask the working-age occupants about their opinions on any energy influences in the home from other generations. The participants were unaware of any of these questions and would not have prepared any answers or recorded any intergenerational influences before completing the survey. The addition of these questions created a baseline of current intergenerational energy influences in the home in an effective way - an utcome that would not have been achieved without these additional questions.
After several discussions with other researchers within the LATENT Project, as well as Directors from Igloo Energy, the questions evolved to the final version, see below. Some of the initially proposed questions were absorbed into other parts of the existing survey, some were removed as they were repetitions of existing questions, and some needed to be refined so they could gather more information. As aforementioned, the following 'Part A Questions' will only have been seen if the participants have stated previously in the survey that i) they have dependant(s) living with them and ii) those dependant(s) are below the age of 18. If they specify at the second stage that the dependant(s) are over 75, then they will be directed to the Part B Questions. If the participants have both younger and older generations in the home, they will have to answer both sets of questions, and if the participants have stated no to either of these, they will simply be taken to the next set of questions within the survey. The style of the questions (Likert Scales) was chosen to maintain a cohesive study, as the vast majority of questions were already in this style.

Part A Question 1
Do you have discussions with your child about energy issues and the environment?
Almost every day / Frequently / Occasionally / Infrequently / Almost never

Part A Question 2
Who starts the conversations about energy issues and the environment?
Adults / Child or Children / Equal likelihood between the two

Part A Question 3
Do you think your children influence your energy usage decision making in the home?

Almost every day / Frequently / Occasionally / Infrequently / Almost never

Part A Question 4
Does your child /Do your children ask you to turn the heating up or down?
Turn the heating up / Turn the heating down / Both up and down / Never

Part B Question 1
Do your elderly relative(s) ask to turn the heating up or down?
Turn the heating up / Turn the heating down / Both up and down / Never

Part B Question 2
Do you think your elderly relative influences the heating strategy of your home?
Almost every day / Frequently / Occasionally / Infrequently / Almost never

Part B Question 3
If possible, please could you briefly explain the reason that your elderly relative/relatives influence your household heating strategy?
Space provided for written answer

Any question that was regarding duration or occurrence uses the same 5 answers on the same scale; thus, this should allow ease of completion for the participants and mitigate any confusion that may arise.

Collected data
The survey collected simple scale answers for the most part (only Part B Question 3 was an open-written answer), these could easily be manipulated into numerical quantitative data ready for analysis. R-Code was used to clean and collate the answers into a numeric-based CSV file for data analysis.

Analysis of collected data
Initially, the data was collated, made digital and cleaned of any missing data and errors. Basic descriptive analysis then took place, looking for patterns and distributions. Exploratory data analysis then took place, looking for correlations and using some simple visualisation techniques to show these.

Information on data gathered. Quantitative (Numerical Values from the survey) and a single written answer. Quantitative data was electronically gathered as per the LATENT Procedures and kept on secure University OneDrive Cloud Servers. Data was split between three documents: LATENT, M+MH and EPC Data files. These were kept separately as each independently holds information that, together, can be used to identify participants. Data had important DPA aspects removed before access was granted as another layer of security. Full details can be found at ERGO 62684.

3.6 Study 2 - 'Energy In The Home' School Study

3.6.1 Study 2 Background

This study aimed to develop and test an 'in-person, classroom' based intervention intended to promote energy interactions between generations in the home. It has been shown from Study 1 that around 40% of homes with family occupants have environmental discussions between adults and children at least 'frequently'. This study will be considered a success if the same number is reached when the exit survey is completed by the parents at the end of the study. In February 2021, A request for participation was sent to Woodcot Primary School in Gosport. The head teacher agreed to allow any research or interventions proposed for this study to take place within the school.

The school was relatively small, with one class of around 30 children for each school year (Reception to Year 6), totalling approximately 200 students. The Indices of Deprivation showed the neighbourhood (Gosport 001A) to be in the bottom 40% (ranked 12,217th out of 32,844) of most deprived areas in England [Gov UK (2019)]. Shockingly, in terms of education, the location ranks 2,306th and thus is in the bottom 10% of the country when it comes to 'education, skills and training' [Gov UK (2019)]. This is a stark contrast to the Part 1 LATENT participants.

At the time the school was approached, the UK was in full Lockdown with only children of key workers attending each day in person. All other children were remaining at home and were taught online. This would have put constraints on how any participants could engage with the study, as well as how resources could be delivered to said participants. This would be especially difficult if a class was split between online and in-person.

During the lockdown, Woodcot Primary School used Google Classroom, which is an online platform that consists of many features. These include, but are not limited to, having lessons be held live, watching recorded sessions, interactions between teachers and students, uploading homework and accessibility to downloadable work. Any lessons, resources or take-home activities produced for the intervention would have to meet the requirements of this platform.

All content was prepared to work for both online and in-person lessons; however, fortunately, normal school days had resumed by the time the intervention took place. Unfortunately, the ideal winter period had also passed. This would have allowed more emphasis on heating use in the home. The Eco Day was carried out in May, which may have seen some heating use still continuing, but far less than during the winter months. Although the most significant energy consumer in the home, heating, was not the only aspect of energy that this study looked at, the study continued at this time.

Before any intervention could take place, an ethics application had to be completed and registered with the university ERGO II scheme (ERGO 63806.A1). This included creating a Participant Information Sheet, a Data Management Plan, a Risk Assessment and a Data Protection Plan, among others. The application stated that this was to be a longitudinal study, lasting the entire duration of this PhD research. This was agreed with the head teacher before the ethics application and will allow the future study of the children as they progress through the school.

The study was split into three distinct phases in line with the methodology laid out in Chapter 3: In-class teaching for the children, a take-home activity for the children, and lastly, a feedback survey for the parents. Together, these three aspects, along with the phase 1 results from Method 1, should answer the proposed aims of the study, exploring and testing inter-generational interaction on energy in the home.

All lessons were carried out by members of staff at the school, and all results, observations and encouragement to complete the work were down to the individual teachers. The original intention was to be present within the school, but due to COVID-19 restrictions that were still in place, this was not allowed.

3.6.2 Study 2 Methodology

The graphic on the following page shows the overall process of Study 2. It is again important to note that Study 1 (LATENT) did not include Phases 2-4. Therefore, it works in tandem with this study, which does not include Phase 1.

It can be seen in the figure below, specifically the arrows at the bottom of the graphic, that the main pieces of data for this study are the pre-intervention and post-intervention surveys. The comparison between these two sets of data will be able to show if the school and home interventions have been successful in promoting inter-generational interactions and potentially any energy behavioural change in the adults.

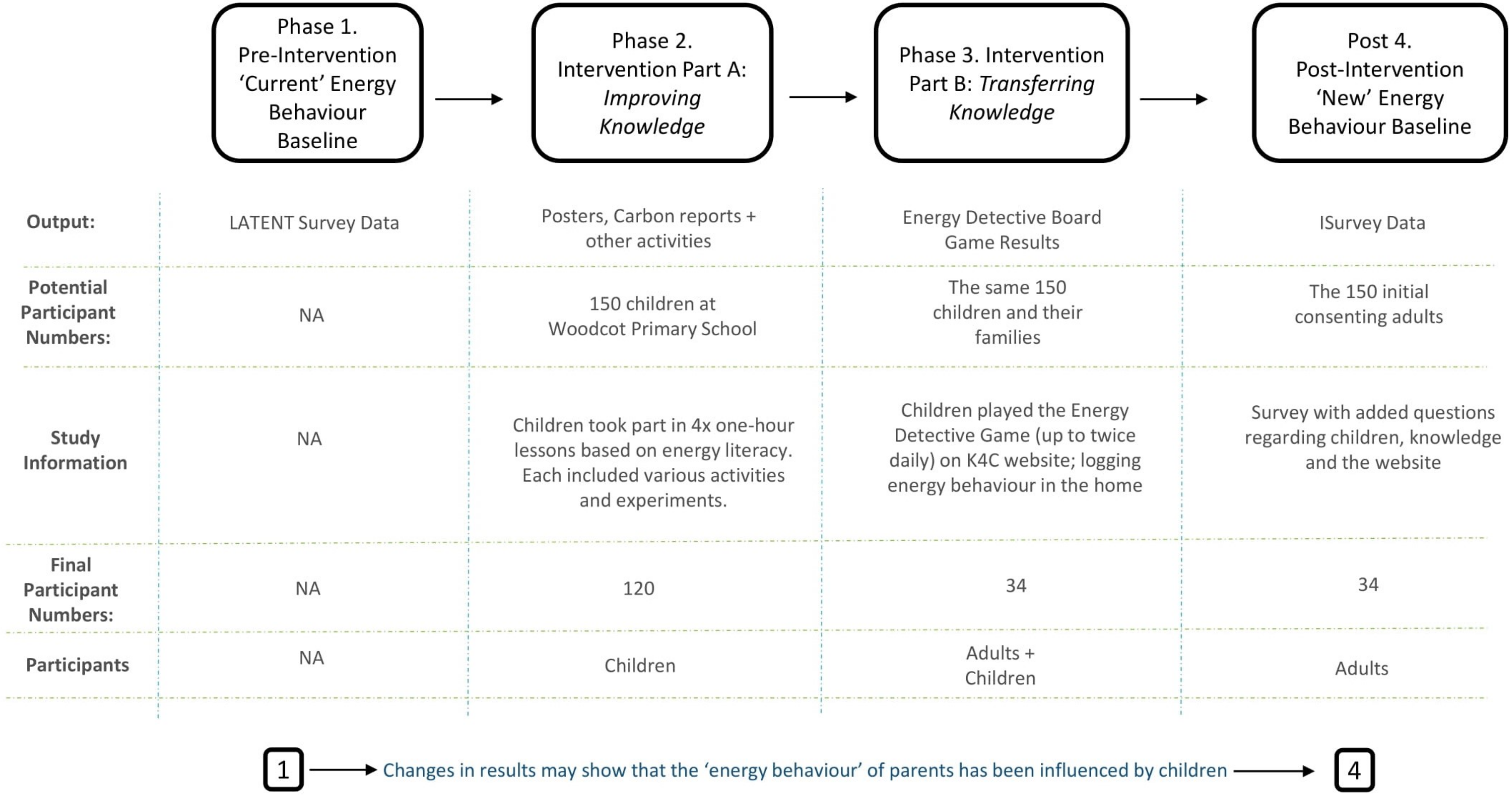


Figure 13: Study 2 Process Diagram

Study 2 Phase 2 Methodology – Improving Energy Literacy Levels of Children

- 4x 1-hour lessons were created with the input of the teaching staff at Woodcot Primary School, Gosport, for an Eco Day in May 2021.
- In order, these lessons were about the following:
  - An Introduction to Sustainability and Climate Change (geography)
  - Power and Energy (science)
  - Carbon Footprints and Food (maths)
  - Energy in the Home (design + technology)
- The input of staff from the outset has meant lessons do not deviate from the national curriculum, but also include the new knowledge that the study will be investigating. It has also meant that presentations and activities during these lessons have been appropriately targeted to the correct ages and abilities of the children.
  - There are several iterations of the presentations and resources, depending on the age
    - Reception up to Year 2
    - Year 3 + 4
    - Years 5 + 6
- Within the last lesson, the children were given a worksheet allowing them to draw their own home in a board game style. This was then the main sheet to work from for the second part of the study.

The below figures (14, 15, 16, 17)show some of the content created. A full day of lesson plans with learning objectives, links to the curriculum and notes for the teachers were provided to the school. These also differentiated between Key Stages for each class and year group. Following the PowerPoint below, several other figures are shown providing examples of the activities in the lessons. These were sourced from several established teacher resource websites such as Twinkl and then amended, or created bespoke for this intervention.

Figure 14: Example of a presentation. In this case, years 1-4 Introduction.

Use the table and graph below to record your results.

Time	Temperature – No jar	Temperature – Glass jar

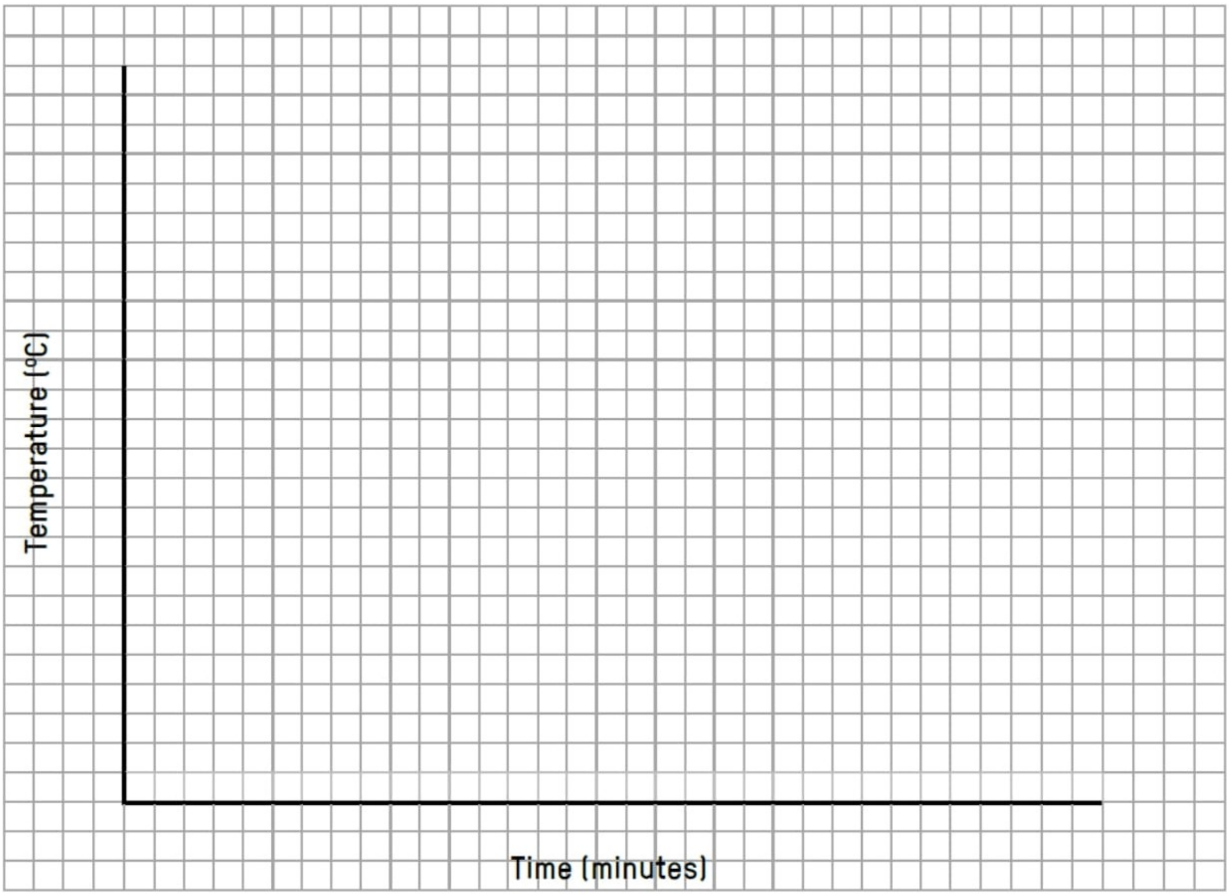


Figure 15: Worksheet for the greenhouse effect experiment that all children undertook

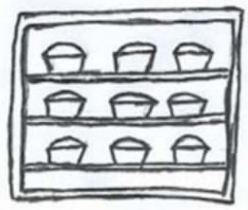
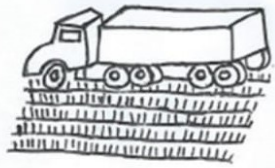
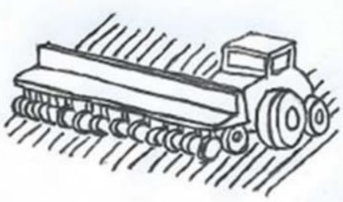
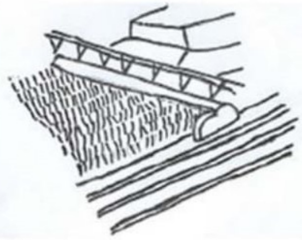
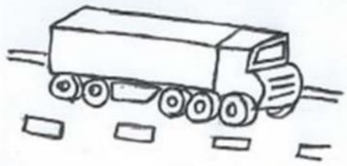
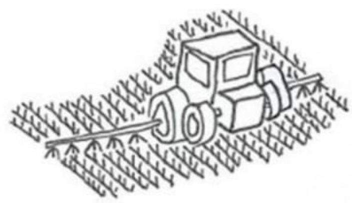
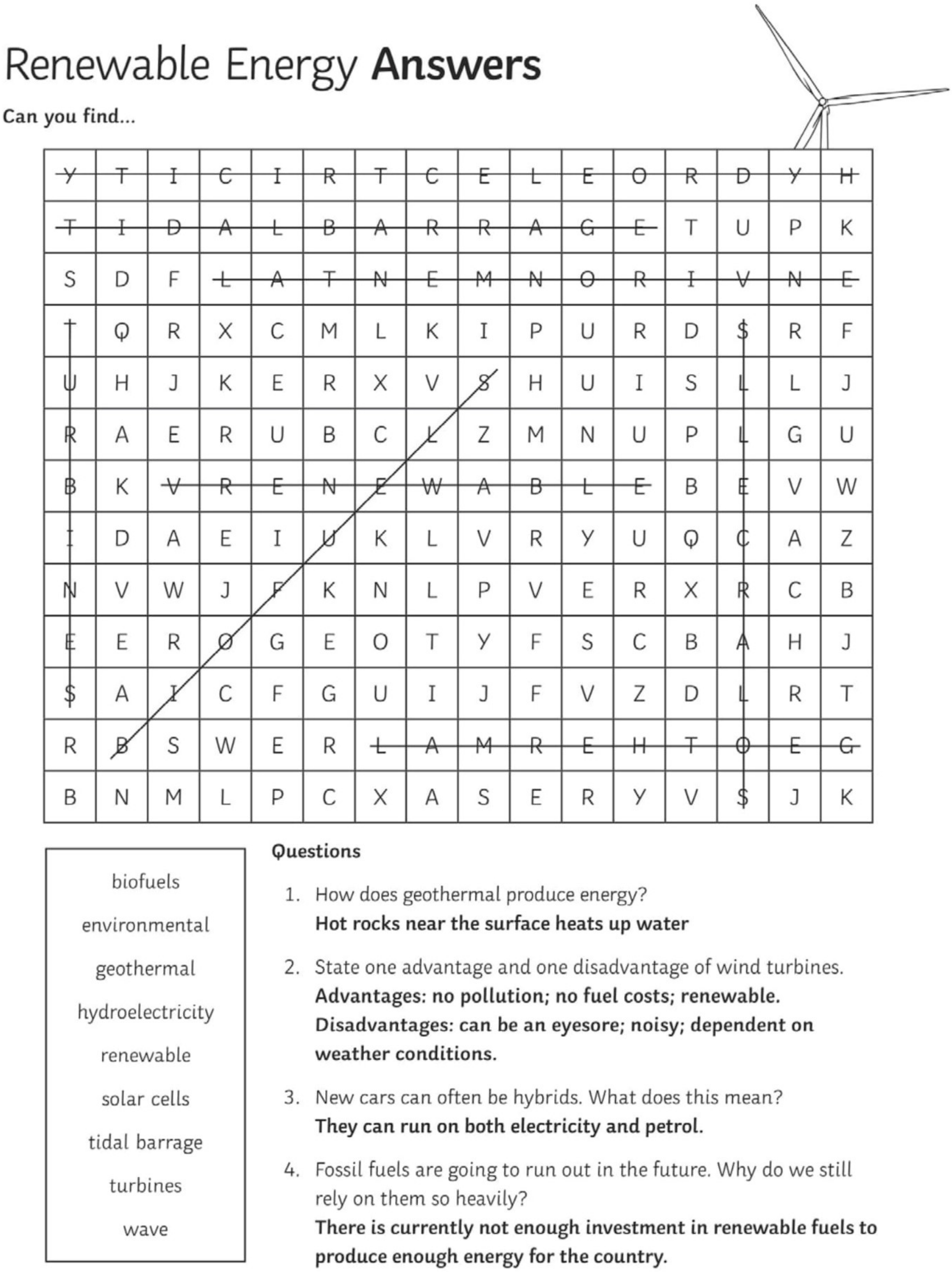
 Customer driving to and from the shop.	 Milling the flour.	 Baking the loaf of bread.
 Packing the loaf of bread into its plastic packaging.	 Irrigating (watering) the wheat.	 Transporting the wheat to the mill.
 Mixing the ingredients together by machine.	 Planting the wheat.	 Transporting the flour to the bread factory.
 Harvesting the wheat.	 Transporting the loaf of bread to the supermarket.	 Spraying the wheat with pesticides.

Figure 16: Embodied carbon exercise - energy in a loaf of bread



Renewable Energy **Answers**

Can you find...

Y	T	I	C	I	R	T	C	E	L	E	O	R	D	Y	H
T	I	D	A	L	B	A	R	R	A	G	E	T	U	P	K
S	D	F	L	A	T	N	E	M	N	O	R	I	V	N	E
T	Q	R	X	C	M	L	K	I	P	U	R	D	S	R	F
U	H	J	K	E	R	X	V	S	H	U	I	S	L	L	J
R	A	E	R	U	B	C	L	Z	M	N	U	P	L	G	U
B	K	V	R	E	N	E	W	A	B	L	E	B	E	V	W
I	D	A	E	I	U	K	L	V	R	Y	U	Q	C	A	Z
N	V	W	J	F	K	N	L	P	V	E	R	X	R	C	B
E	E	R	O	G	E	O	T	Y	F	S	C	B	A	H	J
S	A	I	C	F	G	U	I	J	F	V	Z	D	L	R	T
R	B	S	W	E	R	L	A	M	R	E	H	T	O	E	G
B	N	M	L	P	C	X	A	S	E	R	Y	V	S	J	K

biofuels
environmental
geothermal
hydroelectricity
renewable
solar cells
tidal barrage
turbines
wave

Questions

1. How does geothermal produce energy?
   Hot rocks near the surface heats up water
2. State one advantage and one disadvantage of wind turbines.
   Advantages: no pollution; no fuel costs; renewable.
   Disadvantages: can be an eyesore; noisy; dependent on weather conditions.
3. New cars can often be hybrids. What does this mean?
   They can run on both electricity and petrol.
4. Fossil fuels are going to run out in the future. Why do we still rely on them so heavily?
   There is currently not enough investment in renewable fuels to produce enough energy for the country.

Figure 17: Renewable Energy Wordsearch activity - completed by the younger children

Study 2 Phase 3 Methodology – Opportunity for Inter-Generational Interaction

Take Home Activity:-

- Having completed a simple 2D cross-section of their own home in school and cut out the rest of the game's parts (tokens, dice nets, etc..), this will create the basis of the 'Energy Detective Boardgame' that was then completed at home. A simple board game (Snakes and Ladders) was chosen because of its simplicity and familiarity. The sheet allowed for two play-throughs, and the children had access to fresh sheets on Google Classroom if they wanted to play more times than this. The children investigated different areas of the home, looking into aspects of energy and trying to mitigate any unnecessary energy wastage.

- The children added their findings to a table provided with the game that was returned to the teacher after a week. This was the main output from this phase of the study.

- The game encouraged interaction with the home and adults within it, discussing common themes such as plastics, recycling, heating and travel.

- The results also provided a 'snapshot' into an evening in a family home, similar (although less detailed) to that of the LATENT Study.

- The four worksheets can be seen in the figures below.

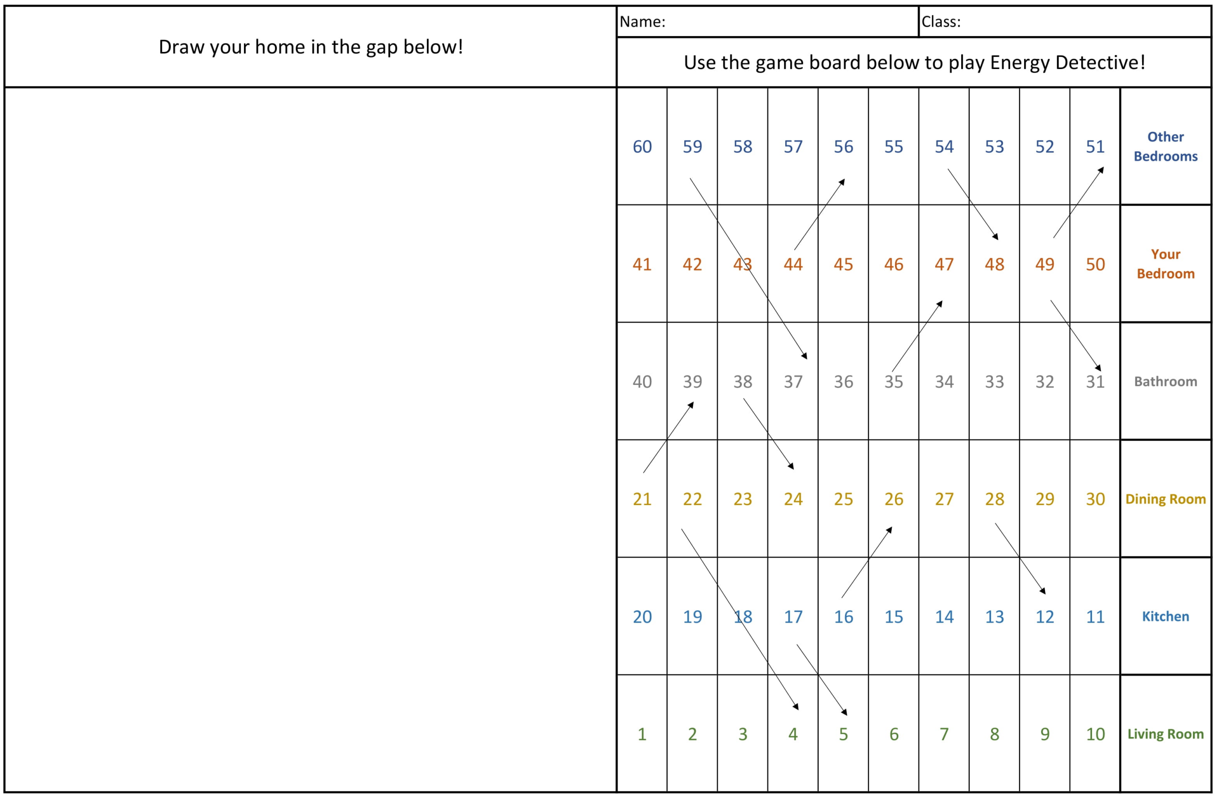
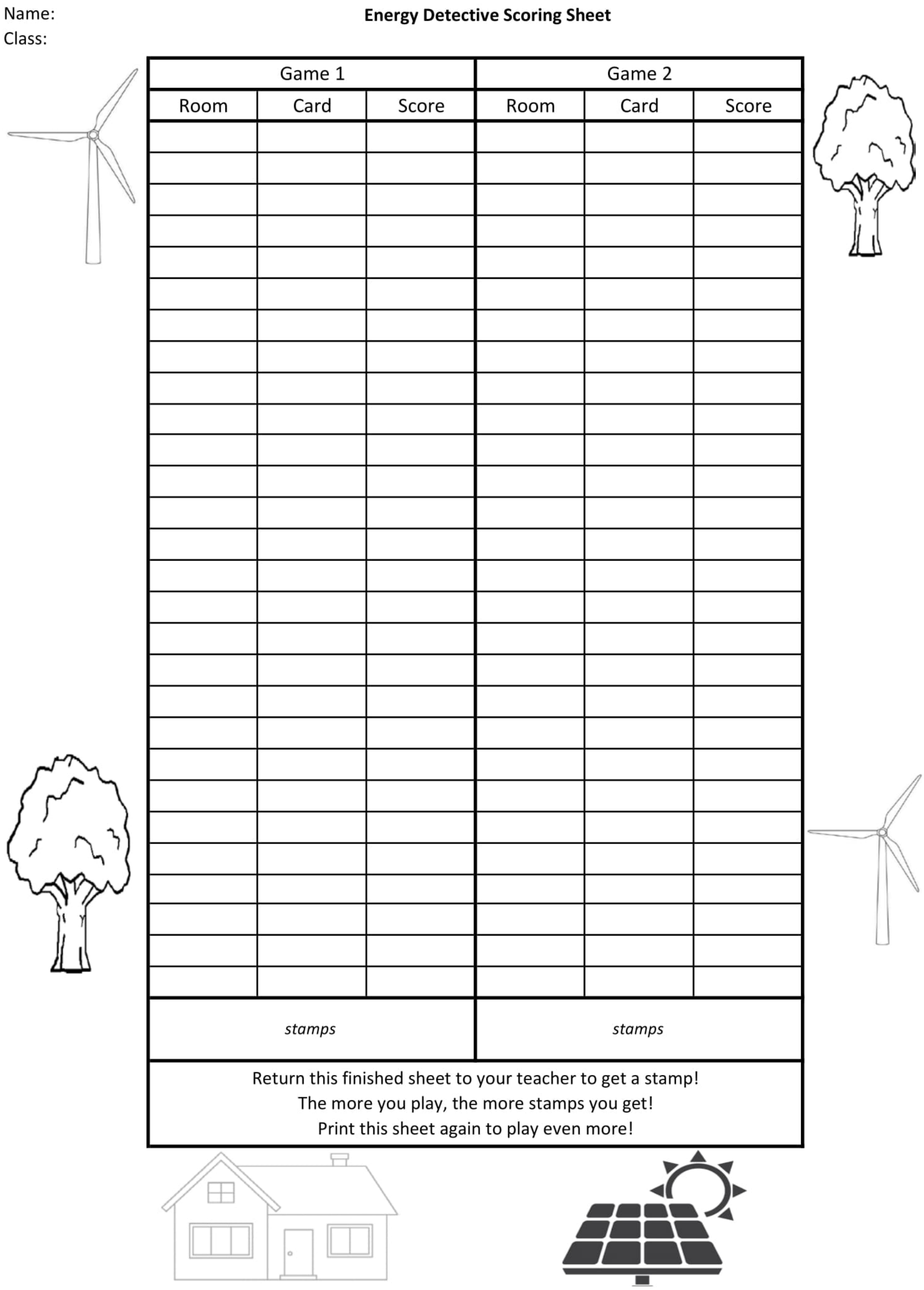


Figure 18: Study 2 Phase 3 intervention - main A3 game sheet. The left side is for the children to draw a cross-section of their home



Name:
Class:

Energy Detective Scoring Sheet

Game 1			Game 2		
Room	Card	Score	Room	Card	Score
stamps			*stamps*		

Return this finished sheet to your teacher to get a stamp!
The more you play, the more stamps you get!
Print this sheet again to play even more!

Figure 19: Study 2 Phase 3 intervention - scoring sheet

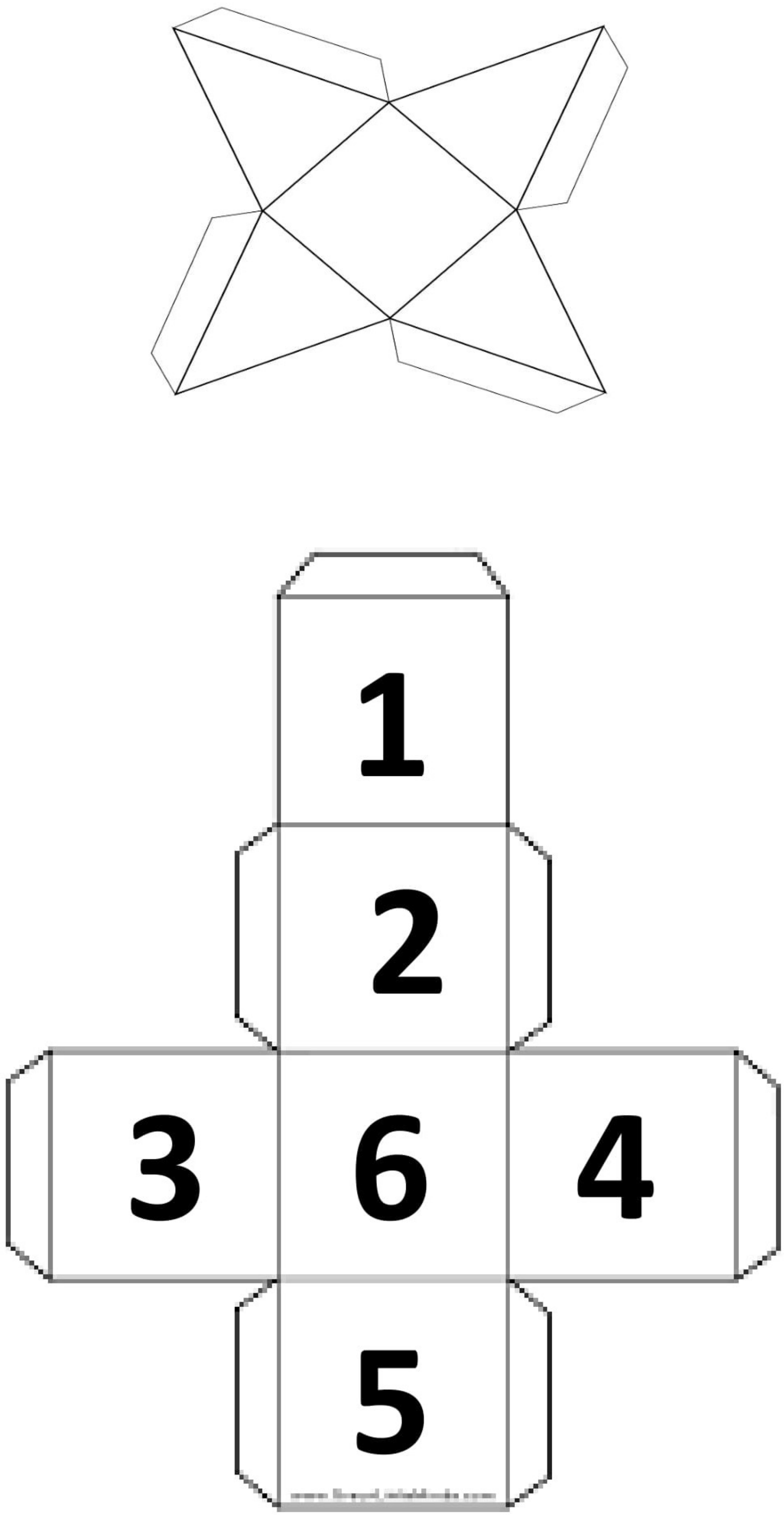


Figure 20: Study 2 Phase 3 intervention - Dice net

Energy Detective Tasks

1. How many draughts can you feel?	11. How many electric items are there?	21. Does this room feel warm?
2. How many lights can you turn off?	12. How many lights are in here?	22. Turn off half the lights in here
3. How many plugs are in here?	13. How mnay plugs are on?	23. Turn off any plug not being used right now
4. How many electric items are in here?	14. How many electric items are turned on?	24. Turn off anything electric not being used
5. How many windows are open?	15. How many windows are open?	25. Close the window if it open
6. How many people are wearing jumpers?	16. How many people in here are cold?	26. How many people in here are hot?
7. How many cars do you have?	17. How many meals contained meat today?	27. How many fruit and veg have you eaten today?
8. How many things are in the bin?	18. Is there a recycling bin in here?	28. How many things in the bin should be recycled?
9. How many radiators are in here?	19. How many clothes are on the radiator?	29. What number is the radiator set to?
10. What's the temperture on the thermostat?	20. How many radiators are cold?	30. How many radiators are warm?

Rules to the game: -

Start Investigating! As you play through the game, add any items to your House Drawing that you have missed so that it is even more realistic!

Firstly, you will need to cut out the boxes above and shuffle them. Then lay them face down beside your main sheet. You'll also need a token to represent you and a dice to play game! It is just like snake and ladders! Roll a dice and make your way up the numbers!

Starting at 1, roll the dice and see where you end up! Remember to follow the arrows up or down!! You will see as you go, each row of numbers is a different room in your house. When you land on a number, pick a card and do what it says in the room stated! Write down the room, the card number and the score in the Results Sheet. You win when you get to the end or when you have filled every result square! There is space for two games, so you can play with a friend!

If you want to play again, then just print the scoring sheet again!

Figure 21: Study 2 Phase 3 intervention - Question and rules sheet

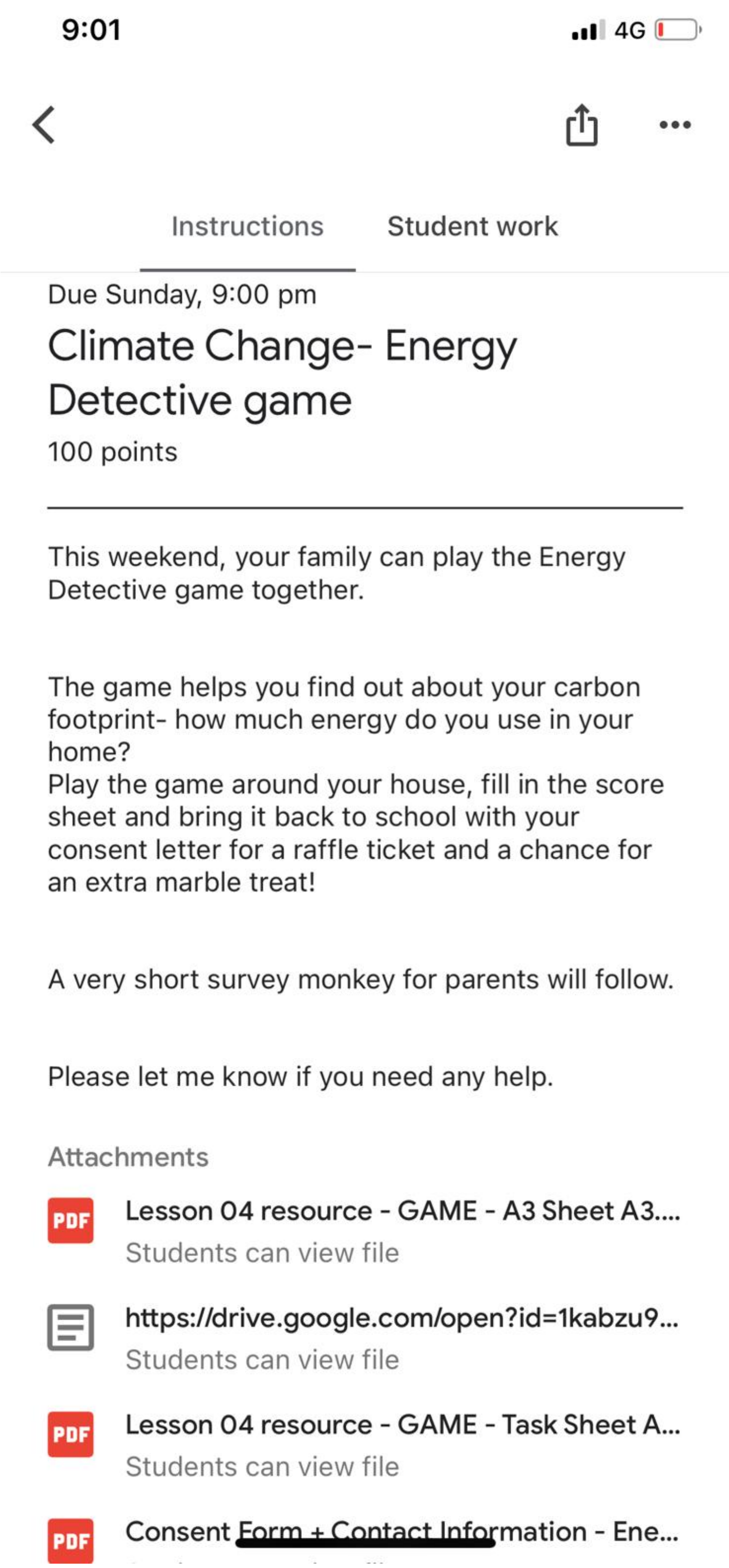


Figure 22: Example of take-home activity available on Google Classroom on IOS - Accessible by parents on any device

Study 2 Phase 4 Methodology – Reassessing Opportunity for Inter-Generational Interaction

Collecting parental feedback was completed using a survey.

- This was automatically sent to the parents/carers/guardians of the children after completion of the board game. This was done using the online ISurvey survey system provided by the university. The school had a system in place containing parental contact details and regularly used such surveys to gather feedback. The survey link was passed on to the teaching staff for them to send out, thus stopping protected data from changing hands and leaving school systems.

- The survey was divided into 5 parts; exact details can be seen in ethics application ERGO Number 63806.A1. It is made of simple yes/no questions and should take less than 5 minutes to complete by an adult.

- The parental view of the work and any of their thoughts were considered vital to the success of the study. Their input provided information on the frequency of interactions that have taken place and potential behaviours that are easy to change and even maintain in the future. Any aspects such as these could be more emphasised in future studies of teaching content.

The choice was made to move away from the substantial size of the survey in the LATENT study to a far smaller, more concise and simple yes-no style survey for the parents to complete. This was done for several reasons, which are described in the paragraph below:

Firstly, they 'substantially reduce respondent cognitive burden and speed up completion'. Several empirical studies show that dichotomous items take less time and are easier for respondents to process than multi-point scales or open text, which improves completion and reduces fatigue for long questionnaires [Rivera-Garrido et al. (2022), Dolnicar et al. (2011)]. Secondly, they simplify coding, analysis and reporting. Dichotomous data are trivial to code, summarise, and model, reducing effort and risk of miscoding [DeCastellarnau (2018), West et al. (2023)]. Knowing the background of the participant population, speed and ease of completion will likely be a necessity to maintain respondent rates.

Study 2 Survey Questions

<u>Consent</u>

- Do you agree to take part in this feedback survey? By confirming and continuing, you are agreeing to allow this data to be used as research at the University of Southampton.

Content

- Has your child talked about what they learnt during the lessons?
- Have they mentioned the phrase Climate Change to you?
- Have they talked to you about their Carbon Footprint?
- Have they spoken to you about how they think they can help?

Engagement

- Did your child play the energy detective board game?
- Did they seem to enjoy playing it?
- Did you play the game with them?
- Did you help them complete the tasks?
- Did your child ask you questions about your home + energy behaviour?

Behavioural Aspect

- Have they asked you if things in the house can be done differently? Heating, driving..
- Have they asked you if they/you can eat different foods?
- Have they asked you to lower or change the heating?

Parents

- Have you learnt anything new from your child about the environment?
- Have you changed how you use your heating because of their comments?
- Do you think you will continue this or any other changes?
- Would you like to know more about the environment?

Collected data
The take-home activity collected basic quantitative data on aspects such as the number of items in the home (e.g. light fittings) and then how many are turned off to save energy. The activity contained numerous categories of items and systems within a typical house to explore. The feedback survey was completed by the parent/carer/guardian of the child after the take-home activity had finished. It was a simple 5-part survey with 16 yes/no questions to be answered. The parts were consent, content, engagement, behaviour, and summary of final thoughts.

Analysis of collected data
Initially, the data for both the take-home activity and the feedback survey was collated, made digital and cleaned of any missing data and errors. Basic descriptive analysis, looking for patterns and distributions of interactions between generations, was undertaken. Exploratory data analysis will then take place after this, looking for relationships between variables and using visualisation techniques to show these. Teachers were also able to verbally provide feedback gathered in the classroom post lessons and activities.

Pilot Study A small pilot study was carried out on several children before the roll-out of the entire intervention. This was used to gauge whether children of different ages could achieve the proposed goals in the different presentations and games. This pilot study led to the take-home activity game being made simpler on two occasions before it was released. The game has to be easy to play for a 6-year-old, but still maintain the interest of an 11-year-old.

3.7 Study 3 - Kids4Climate Online Study

3.7.1 Study 3 Background

This study aimed to develop and test an ‘online, web-based intervention’ to promote energy interactions between generations in the home. It has been shown from Study 2 that an ’in-school’ based intervention with a physical home activity did create positive results in promoting interactions in the home, but it also had its limitations. This study takes the content of the school lessons. It makes them available to the same participant pool used for the LATENT study, thus increasing potential numbers from 100 children in the school to several thousand families with primary-age children.

Study 2 allowed the children to play the home activity twice before they had to print off more sheets. It was also reported back to the teacher that the scoring system was complicated, thus for this study the game aimed to be more engaging to allow repeated play through (potentially promoting interaction on more than one instance), whilst also being simple enough that children can see scores and progression, potentially adding a competitive aspect.

This study, by using the post-Igloo customer base, had the potential to gather utility readings such as gas and electricity. This added another layer to the study that provided quantitative data. How this is completed is discussed further in the following sections.

Estimating the size of the participant group was based on how many were required to give the study statistical power. Also setting aside budget as the intervention is essentially budget-free once the website is created, the only other crucial aspect to ensure is good study design practice [Anderson et al. (2020)]. The ideal study participant number would be n=400, this number should be would deliver an adequate confidence level and a small margin of error. This was calculated using the Qualtrics Sample Size Calculator [Qualtrics (2024)]. Although the LATENT participant pool respondents were very high for the LATENT study, (20%), it is unlikely that the same number would take part in this study. This is especially true as after filtering suitable participants, only around 750 were considered for the study. To this end, it is hoped that a number greater than 50 participant families will take part in the study (7%) This is discussed further below.

3.7.2 Study 3 Methodology

The graphic on the following page shows the overall process of Study 3. For important analysis, please note the comparison outputs labelled at the bottom of the page.

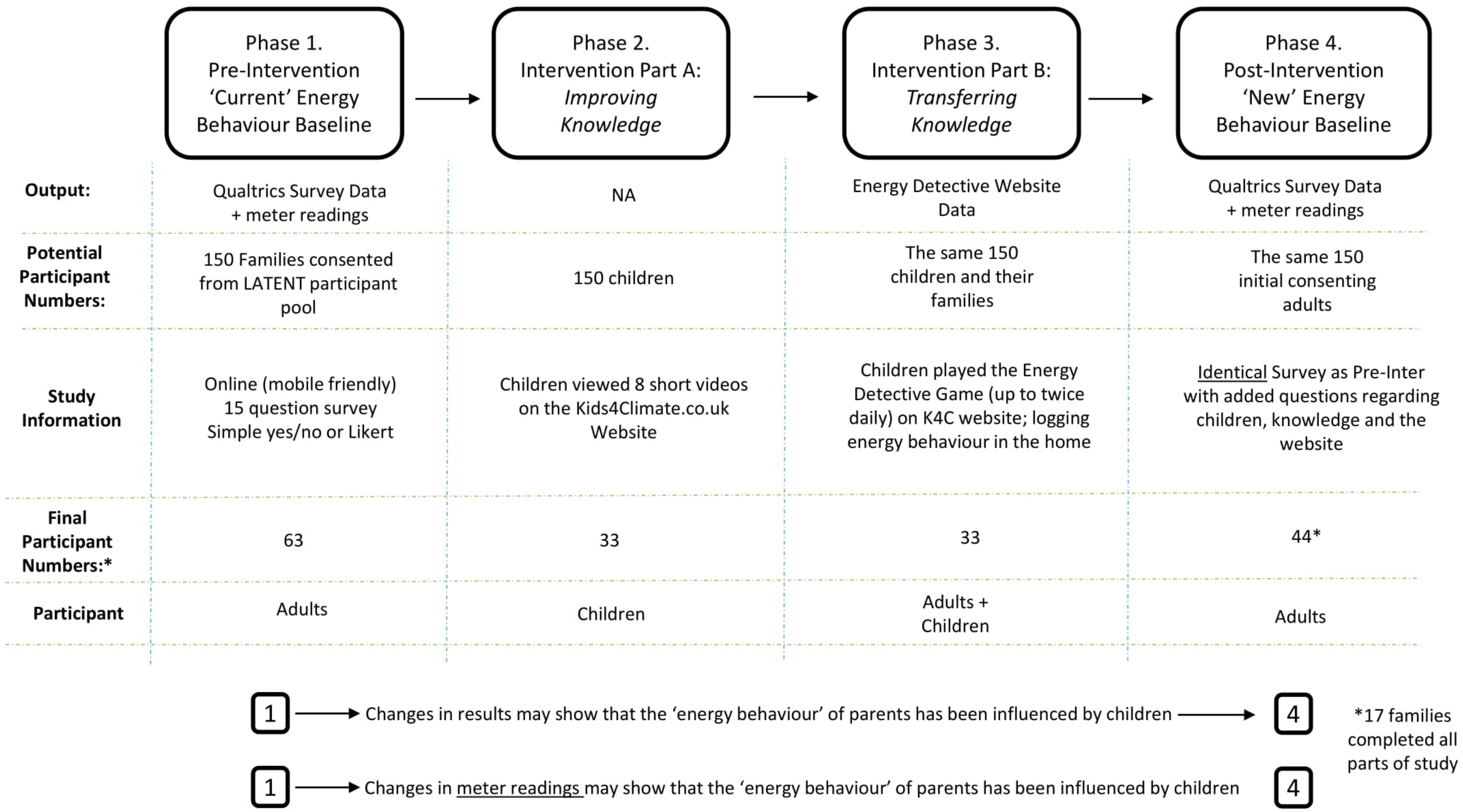


Figure 23: Study 3 Process Diagram

As per the overarching methodology, the study was split into four distinct phases: (1) an initial survey for parents, (2 and 3) website activities for the children (taking place continually through the winter), and on completion; (4) a second parental survey. Together, these four phases should answer the aim of this study to test different methods of initiating intergenerational interactions on energy in the home.

All participants were taken from the same initial pool that LATENT used, from Igloo Energy. Although the company has ceased trading, a significant amount of its customers had chosen to remain in contact with the university. After filtering the initial pool of people to show only those that met the below conditions, there were 750 families that met all the criteria.

- Confirmed interest in future studies
- Not included within other ongoing heat pump studies (LATENT)
- House uses a gas boiler
- Have child(ren) within the age range required

Creation of the website

The Kids4climate Study took place within the home only, rather than as a home activity after an intervention in school. This was the progression taken as it would allow the research to reach a broader audience; the Igloo customer base (and potentially even larger pools of people in the future). The school guaranteed participation but limited it to the immediate local area. Moving the same information taught in the lessons to an online platform took a considerable amount of time in planning how to deliver this information to various ages in a concise, simple and importantly fun way.

The theme of the Home Detective game was carried forward from Study 2 - the house section that the children originally drew themselves as part of the in-school lessons was replaced with an interactive version, within which the children could go to different rooms or areas to learn different aspects of sustainability (through a video) and then record some readings from that room in real life. The Snakes and Ladders style game-play has been removed, with the children simply clicking on the area they would like to investigate. Many of the original investigations remained, such as logging the thermostat temperature or counting open windows.

The website is available at the following domains (to mitigate any incorrect attempts to visit). Entering the username 'Admin' and password 'Admin' should allow access to the website.

www.kids4climate.co.uk
www.kids4climate.net
www.kids4climate.com

Stages of the study:

- Email requests to join were sent to the 750 potential participants from the LATENT customer base.
- Those who confirmed participation received login details and the parents completed the short Initial Survey - this included recording of 2 gas meter readings and the dates collected of these.
- The participating children (and parents) could complete the Kids4climate website in their own time as often as they see fit during the intervention period.
- At the end of the study, the parents completed the Final Survey and recorded a third gas meter reading and took note of the date. The entire study was reviewed by the university ethics committee (and granted approval - ERGO 69173)

Phase 1 Methodology – Parental Energy Behaviour Baseline
This collected several key pieces of data; how the family use their home currently, energy behaviour and interactions (about climate change) between the generations, but also initial gas meter readings that formed the base level:

- Gas reading from 29/09/22 – The day Igloo Energy ceased trading. This was sent to all participants by Igloo in their final bills.
- Gas reading from the day the survey was complete (circa mid-Feb 2023). The exact date the meter reading was taken was also recorded.

These two readings created a baseline average consumption for the households taking part in the study. Data showed overall consumption in the 5 months leading to the date the study started when the second reading was taken. By correcting these numbers using localised Heating Degree Day data, a baseline value was created for each participant family - gas consumed per HDD (kWh/HDD). This baseline was then recalculated using the gas reading taken after the study intervention to ascertain any difference in energy consumption.

Although initially a worrying prospect for this research, the closure of Igloo Energy meant that all users were regularly checking their meters and logging their recordings, thus data that is normally inconvenient for participants to gather was already collected. Adding to this is a concern for the lack of uptake for survey-style investigations. Having several historic meter readings allowed the participant group to be fully utilised instead of split in half between the Intervention and Control groups as would be the traditional method. The control group could be seen as the 5 months of energy consumption before the intervention period. Then the 3 months of study was the intervention group, but both utilised the same participants, maintaining numbers.

The Initial Survey Questions were divided into three sections and are very similar to the additional LATENT questions produced for this research in year one. Bar the final feedback question, all of these questions were answerable using a 3 or 5-point scale from positive to negative (yes to no, often to not often etc..):

- Adult Opinions
  - How concerned are you about climate change?
  - Do you consider environmental impacts when you make decisions in your daily life?
  - Do you think about the environmental impacts when using your heating?
  - Do you think about the financial cost impacts when using your heating?
- About the Children
  - Do you think your children are concerned about climate change?
  - Do you have discussions with your child(ren) about climate change?
  - Who starts the conversation about climate change / the environment?
  - Do you think your child(ren) influences your energy usage decisions in the home?
  - Does your child ever ask you to turn the heating up or down?
- Feedback
  - Please comment with any issues or concerns about the survey

Study 3 Phase 2 Methodology – Improving Energy Literacy Levels of Children

Study 3 Phase 3 Methodology – Opportunity for Inter-Generational Interaction

Phases 2 and 3 were combined within this study to the single website Kids4Climate.co.uk. The following chapter discusses the methodology for both teaching children and creating the opportunity for inter-generational interaction.

The link directly to the website was sent along with login details to each participating family. Login details were both a username and password that can be saved using cookies, this allowed quick access repeatedly whilst maintaining security and safeguarding precautions. The usernames were all endangered animals in the hopes it may encourage more interaction, whilst the passwords were randomly generated nouns accompanied by numbers and special characters, they needed to be usable by the age range of the children whilst maintaining security. These were sent directly in an email to the parents/carers. Participants were never told who else was taking part and there was no way for one participant to contact another. The leaderboard showed only the username of other participants (and their scores), no personal details were shared anywhere on the site, or between users. Once logged on to the website, the children were initially directed to a cross-section of a cartoon house, this page was called Home Detective; in each room, there was a lesson about energy/climate change to do with that room's activities, for example, food (production and waste) in the kitchen or device/electricity use in the lounge. Figures 24 and 25 show screenshots taken from the website.

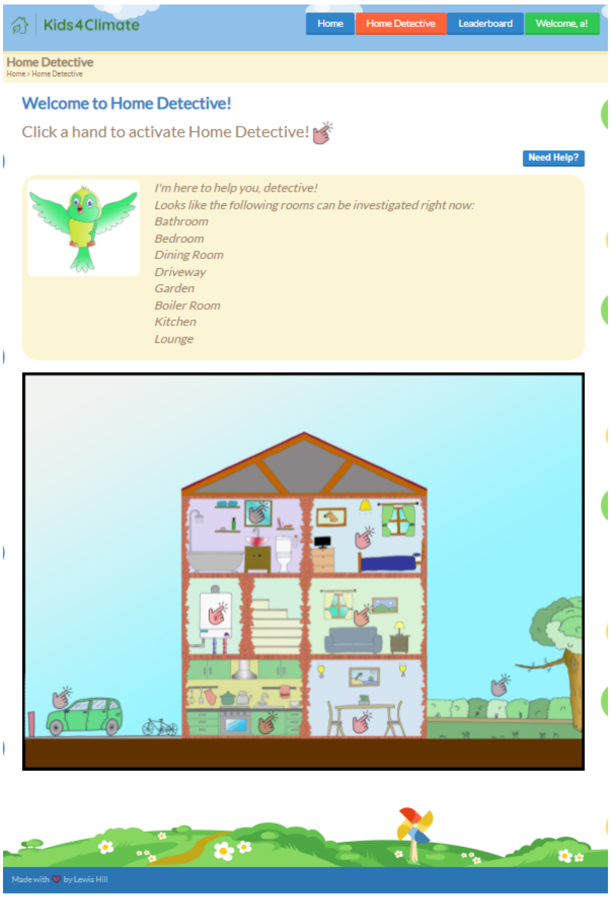


Figure 24: Study 3 Kids4climate.co.uk Home Page

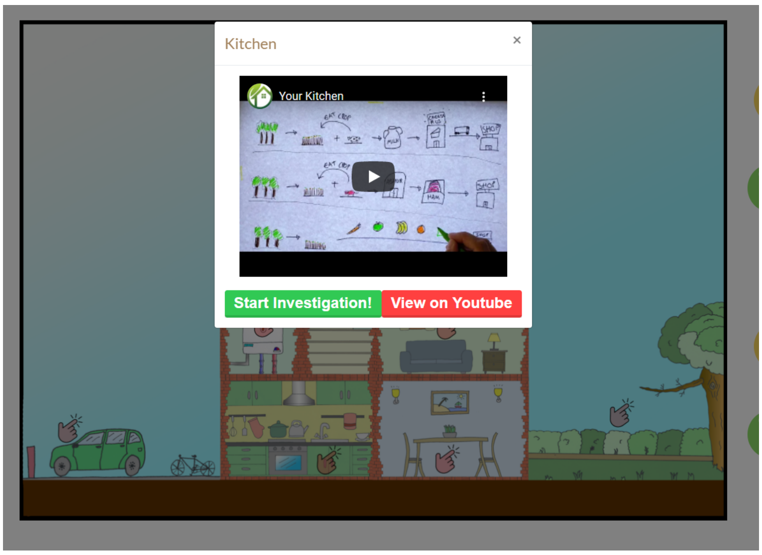


Figure 25: Study 3 Kids4climate.co.uk Kitchen Video

The content of these videos was extracted from in-class lessons produced for Study 2. Based on the feedback from children, parents and teachers, certain aspects were removed, kept or added. Where some activities were not possible online, they were also omitted. The videos were short and maintained a fun humorous style throughout. They can be viewed using the below link:

https://youtube.com/playlist?list=PLw0L84proYyBeZ0wsu32pqVYjCrnEbA3a

The production of these videos took a considerable amount of time. The stop motion style was chosen as it allowed the production to be completed in time for the study to take place and still appealed to children in the primary age range. The videos were all produced and edited at home with minimal equipment. If the website were to become successful, it would be sensible to outsource this type of work to a professional company.

The website then asked the children to take measurements of specific aspects of energy in that room and around the house. For example, when looking at heating, the thermostat temperature is recorded and the number of radiators in use is noted, or when in the kitchen, plastic items in the fridge are counted. Some of the more complicated questions, or those that required word answers had a drop-down option added so the children could easily choose and spelling errors were mitigated. Figure 26 shows the input page for the kitchen.

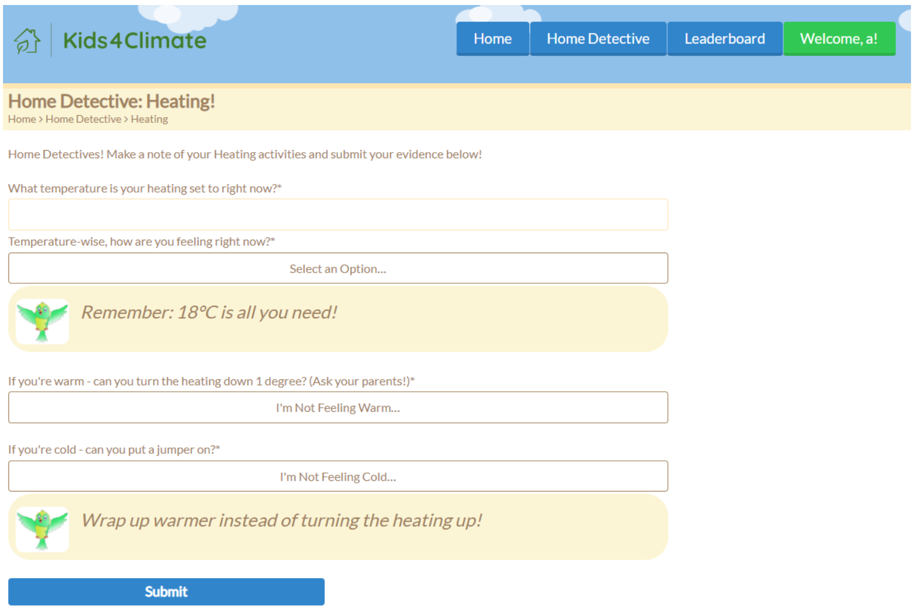


Figure 26: Study 3 Kids4climate website Screenshot - Kitchen Data Recording page of the Home Detective Activity

The exact data collected can be seen listed below; there are 8 different sections (rooms/areas of the home). Each section has a different set of queries that need to be filled in; the boiler has a separate section to emphasise its importance. The frequency at which these can be recorded changed depending on the area; for example, the kitchen could only be ticked off weekly (weekly shop), whereas the heating section could be repeated every 12 hours (morning and evening).

- The drive:
  - How many times have you walked somewhere today?
  - Have you used public transport today instead of your car?
  - Have you ridden your bike today instead of using your car?
- The Garden:
  - How many plants trees are in your garden?
  - How many animals and bugs can you find in your garden?
- The Kitchen:
  - How many plastic items are in your fridge?
  - How many meat items are in your fridge?
  - How many dairy items are in your fridge?
- The dining room:
  - How many lights are on in the whole house?
  - How many of these can you turn off right now?
  - How many radiators are there in your whole house?
  - How many radiators are turned on right now, in your whole house?
- The lounge:
  - How many electronic devices are on standby in your house?
  - How many wall sockets can you turn off right now around your house (remember only for devices that aren't being used!)?
  - How many windows are open (or draughts can you feel) in your house?
  - How many of these windows can you close right now?
- Heating:
  - What temperature is your heating set to right now?

- Temperature-wise, how are you feeling right now?
  - If you are warm, can you turn the heating down 1 degree? Maybe ask your parents!
  - If you are cold, are you wearing a jumper?

- Bedroom:
  - How many electric devices and electric toys do you have in here?
  - How many of these are on right now?
  - How many can you turn off?

- Bathroom:
  - Did you have a bath or shower today?
  - If it was a shower, how long was it?
  - Did you open a window, or use the extractor fan to let the steam out?
  - Did you use the small flush today?

The children continued recording over the period of the study, from early March 2022 until mid-April 2022 (or as long as they wanted within this study period), receiving feedback from the website if they were doing well, or if they could change some things to improve their energy behaviour to save more carbon. As the participant children recorded readings, they earned 'carbon points'. Within the website, these were recorded on a shared leaderboard between all users, along with their ranking and any medals they have earned. Leaderboards and rewards can increase short-term engagement, participation and effort by providing clear performance feedback and satisfying competence and achievement needs [Khoshnoodifar et al. (2023)]. The leaderboard, the number of points awarded for different rooms and tasks, has all been designed around creating a competitive and rewarding leaderboard has the end effect is 'context and design-dependent' - a leaderboard scope, direction (who you compare to), anonymity, and reward type strongly shape whether the element helps or hurts motivation [Park and Kim (2021)].

Figure 27: Study 3 Kids4climate website screenshot - The Leaderboard - showing rank, badges and the leaderboard

Rewards + Incentives

To encourage take-up of participants, a reward system was put in place. Five (5) random participants were chosen at the end of the study and received a monetary prize. This will be a £20 Amazon voucher sent online to participants (only chosen from those who have fully completed the study).

Collected data

The website activity consisted of basic numerical quantitative data on aspects such as the number of items in the home (e.g. lights, and then how many are turned off to save energy). The activity contained numerous different categories of items and systems within a typical house to explore. Full details of the ERGO Ethics application can be found using the following identifier:- ERGO 69173.

The two surveys (initial + final feedback) were completed by the parent/carer/guardian of the child before and after the website activity had finished (respectively). It was a simple survey with mainly yes/no questions (quantitative).

Analysis of collected data

Initially, the data from both the surveys and website activity was collated, relocated to the university servers (from their respective domain and Qualtrics server) and cleaned of any missing data and errors. Descriptive analysis, looking for patterns and distributions of behavioural change within homes, took place. Exploratory data analysis utilising R-

Studio, looking for relationships between variables.

Pilot Study After the success of feedback from the Study 2 Pilot Study, a small pilot study was also carried out for this study. Several children of differing ages were given access to the website before the roll-out of the entire intervention. This was again used to gauge whether children of different ages would engage with the various aspects online. It was reported that some aspects required the parents' help to record, but others were too easy. This small requirement for parental input was exactly what the study was aiming to achieve and not enough parental involvement to create tedium during the prolonged activities.

3.8 Study 4 - 'Eco Homes' School Study

3.8.1 Study 4 Background

This study aimed to develop and test a 'larger scale school-based intervention' intended to promote energy interactions between generations in the home. It has been shown from Study 2 that an 'in-school' based teaching intervention worked very well for several reasons. A significant aspect of success seems to be that children are so versed in learning within that environment that there are strict rules, schedules, and rewards that promote learning. This is in stark contrast to Study 3, which saw children in the home not be as successful in the learning aspect of the intervention; likely because they did not want to take part as they saw it as taking their free time, for example. For these reasons and others discussed in the previous studies, Study 4 returned to the classroom environment for the teaching part of the intervention.

Initially, estimating the participant group size for this study was done in the same way as study 3. The sample size calculator suggested again at least 385 participants must be involved to create statistically powerful data [Qualtrics (2024)]. This would require around 5 primary schools located in Hampshire, UK - this would then require significant financial support to create the intervention, simply out of reach for the scale of this study. Thus the study was proposed for two schools, totalling around 300 pupils. This would allow almost the entirety to be utlised for lessons within the classroom and it is expected that there would be lower rates of participation for the home activity and then the final survey. These schools significantly varied in location, catchment area and academic performance; Woodcot Primary School, Gosport, used in Study 2 (within the bottom 10% of the UK for "education, skills and training" [Gov UK (2019)]), and Walhampton Preparatory School in Lymington (within the top 6% of the UK for "education, skills and training" [Gov UK (2019)]). Such contrasting participant groups were purposely chosen to review possible influences between such groups. For the second part of the intervention, the home intervention encouragement, the children were given a physical take-home activity that can be kept, repeated and used in other ways.

3.8.2 Study 4 Methodology

Figure 28 on the following page shows the overall process of Study 4. An additional longitudinal aspect was added to this study to test whether changes in behaviour are sustained. Further analysis was undertaken as other added aspects within the phases, such as testing child energy literacy levels and introducing a control group throughout.

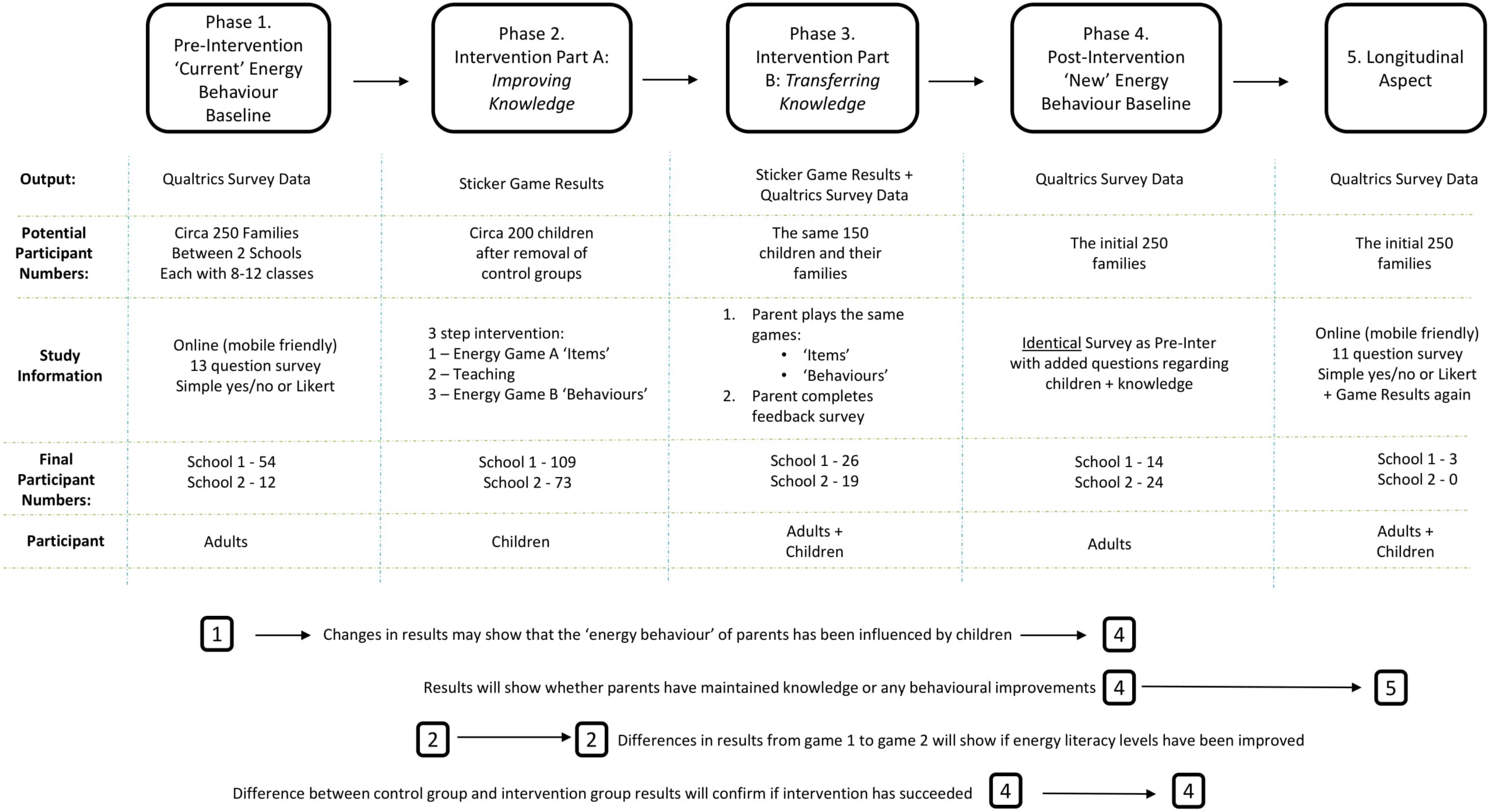


Figure 28: Study 4 Process Diagram

Study 4 Phase 1 – Parental Energy Behaviour Baseline
An initial survey was sent to the parents/carers/guardians of the children at the start of the study (unless the parents have opted out). This was via the Qualtrics survey system. The schools had a system in place containing parental contact details and regularly used such questionnaires to gather feedback. The survey link was sent out to all parents of years 1-6 at Woodcot and 3-6 at Walhampton. More details can be found using the ethics code ERGO 82313.

The questions within the survey were either yes/no, a drop-down of options/numbers, a 5-step positive-negative scale (very often, often, sometimes, not often, never, for example), or finally open-ended with a text box available to write in. The initial survey questions were as follows:

Initial Parental Survey

- Ethics:
  - Consent to take part in the survey (yes/no)
- Initial Information:
  - Please enter your child's class name (Drop Down Box)
  - Do you have another child at the same school (no/yes 1/yes 2/yes 3)
  - REDIRECTED ONLY FOR PARTICIPANTS WITH MULTIPLE CHILDREN
  - Please enter second your child's class name (Drop Down Box)
- Initial Questions:
  - How concerned are you about climate change? (5 categories)
  - Do you consider environmental impacts when you make decisions in your daily life? Diet, Driving, Lights etc... (5 categories)
  - Do you think about the environmental impacts when using your heating? (5 categories)
  - Do you think about the financial cost impacts when using your heating? (5 categories)
- Children Questions:
  - Do you think your child or children are concerned about climate change? (5 categories)
  - Do you have discussions with your child or children about climate change or the environment? (5 categories)

  - Who starts the conversations about energy issues or the environment? (3 categories - Adult/Child/Equal)
  - Do you think your child or children influence your energy usage decision-making in the home? (5 categories)
  - Does your child ever ask you to turn the heating up or down? (4 categories - Up/Down/Neither/Both)

- Survey Feedback:
  - Thank you for completing this survey, please comment below if you had any issues/concerns about the survey (i.e specific questions that were difficult to understand) (Text Entry)

Rather than having participants select the school and class within the survey, two identical surveys were created; one for each school. Participants then simply had to identify their child's class. They then stated whether they had any other children at the school. This was done in this way to meet the needs of the ethics ERGO application (ERGO 82313). This stated that parents would be identifiable if information were made available that showed how many children they had and in which classes. It would also affect the reliability of the data if one child were part of the control group and one child were not. Therefore the information collected here was used to determine which classes would be intervention or control.

The requirement for utility readings was removed from this study. Not only was quantitative data such as this unreliable in the (quarterly shifting) current economic climate of the UK, but feedback from participants within the Kids4Climate Study would suggest that this data was not easily accessible, even with modern smart metering and app-based dashboard-style widgets available.

Study 4 Phase 2 – Improving Energy Literacy Levels of Children

The school intervention was very similar to the Study 2 version. Lessons and activities were updated to be in line with any feedback received during Study 2, and data/facts and figures were updated to match Study 3. The most important feedback gathered from teachers was that losing four timetable lessons to this study was too much. Therefore, only the most important aspects were retained, and a single 1-hour lesson was produced. If the teachers wanted to extend the single lesson to more, additional activities were offered. Initially, a single presentation, lesson plan and accompanying activities were provided to teachers.

The presentation consists of the following topics in order:-

1. What is Energy?
2. Creating Energy + Emissions
3. What does this mean?
4. How do buildings use Energy
5. Energy in homes
6. The Eco Game 1
7. Energy behaviour in the home
8. The Eco Game 2

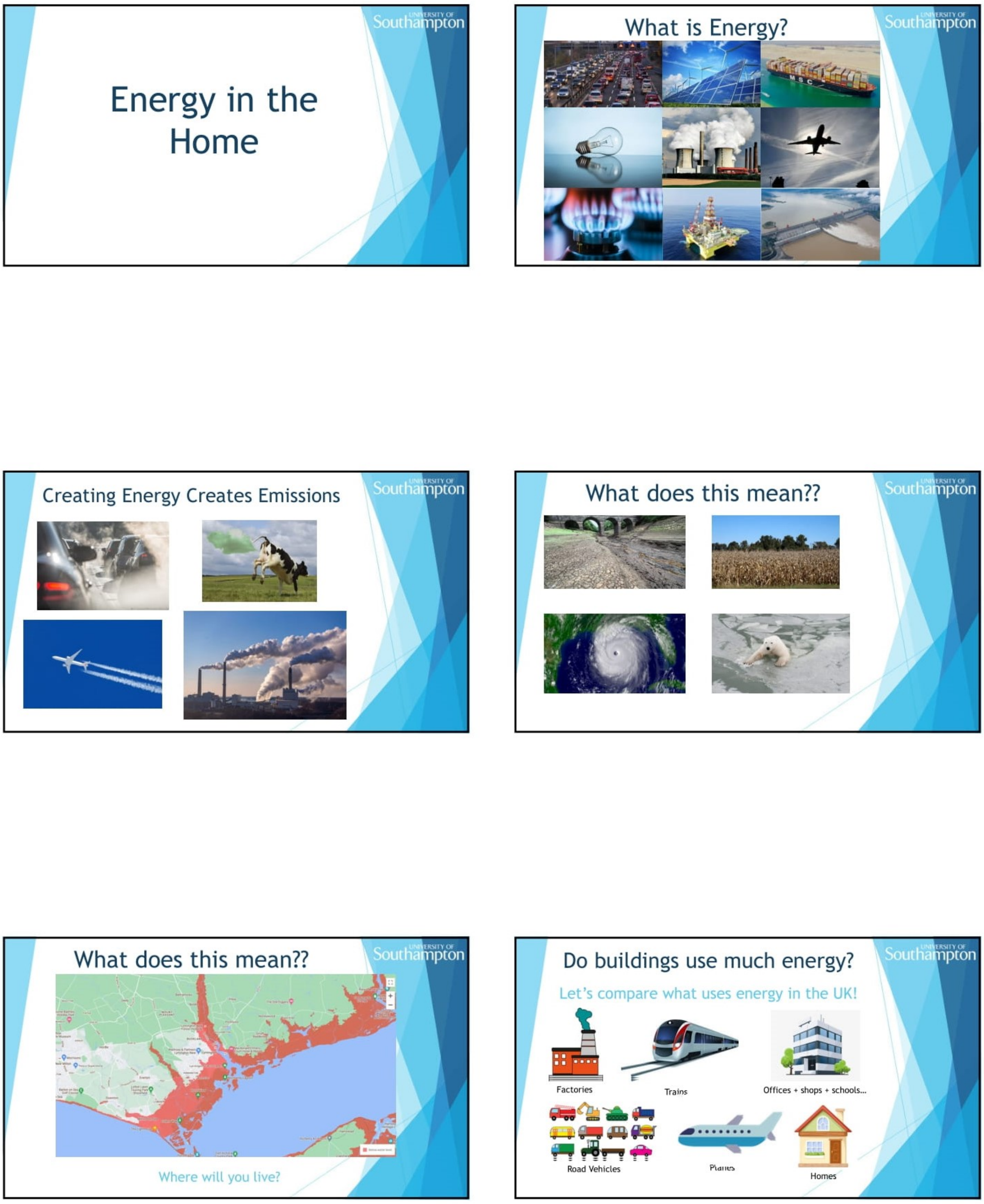


Figure 29: Study 4 Eco Homes - School Lesson Presentation - first 6 slides

The two games were played on either side of a short presentation about energy behaviour within the home. The aim was to improve the energy literacy levels of the children, and the game at the start and end of the presentation tested whether this had happened. The games vary slightly, the first is regarding items in the home and the second regarding behaviours in the home. Both games covered the same areas of energy use, for example, lights are looked at in the first game and then leaving lights on is looked at in the second game.

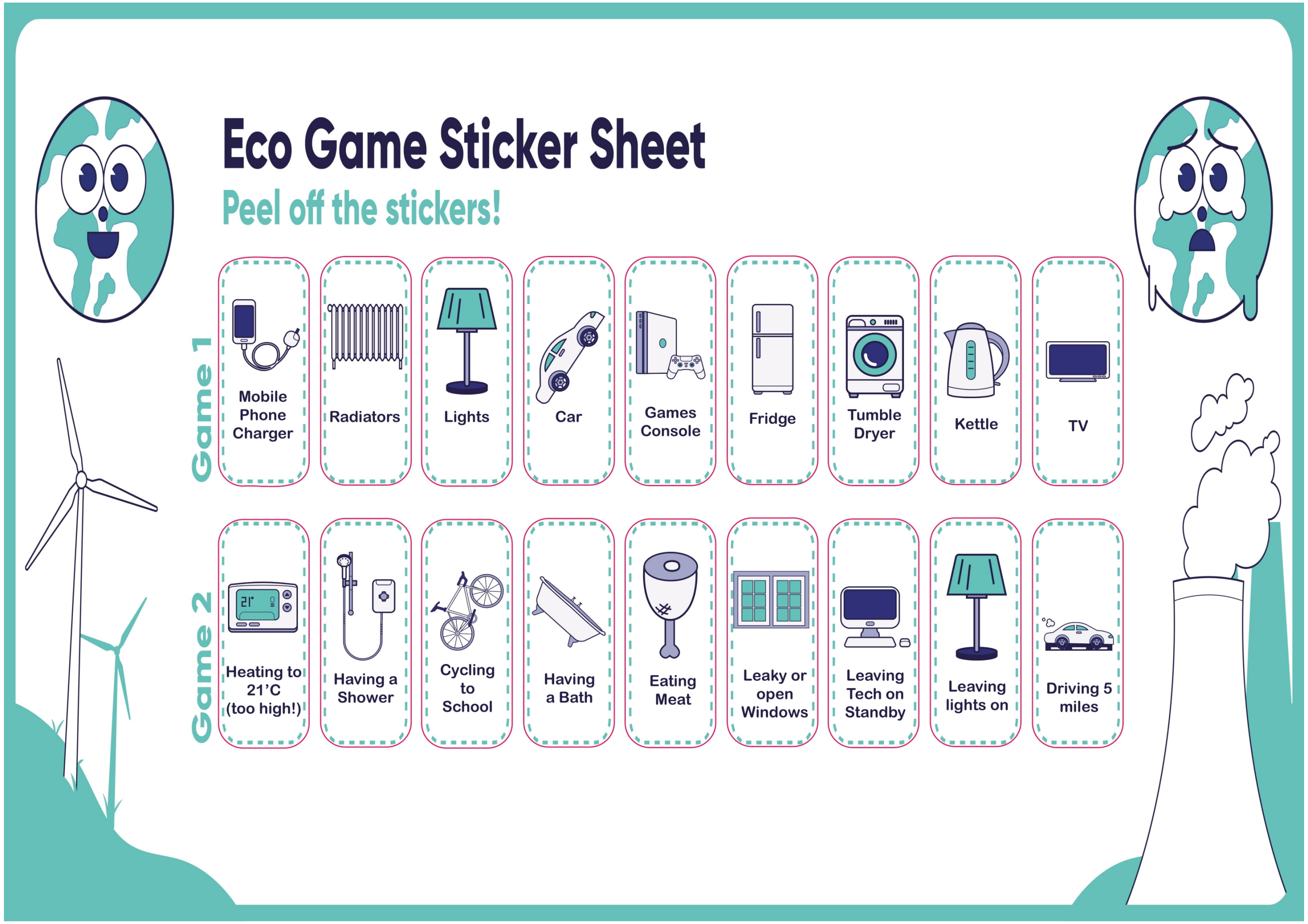


Figure 30: Study 4 Eco Homes - School Lesson Sticker Sheet

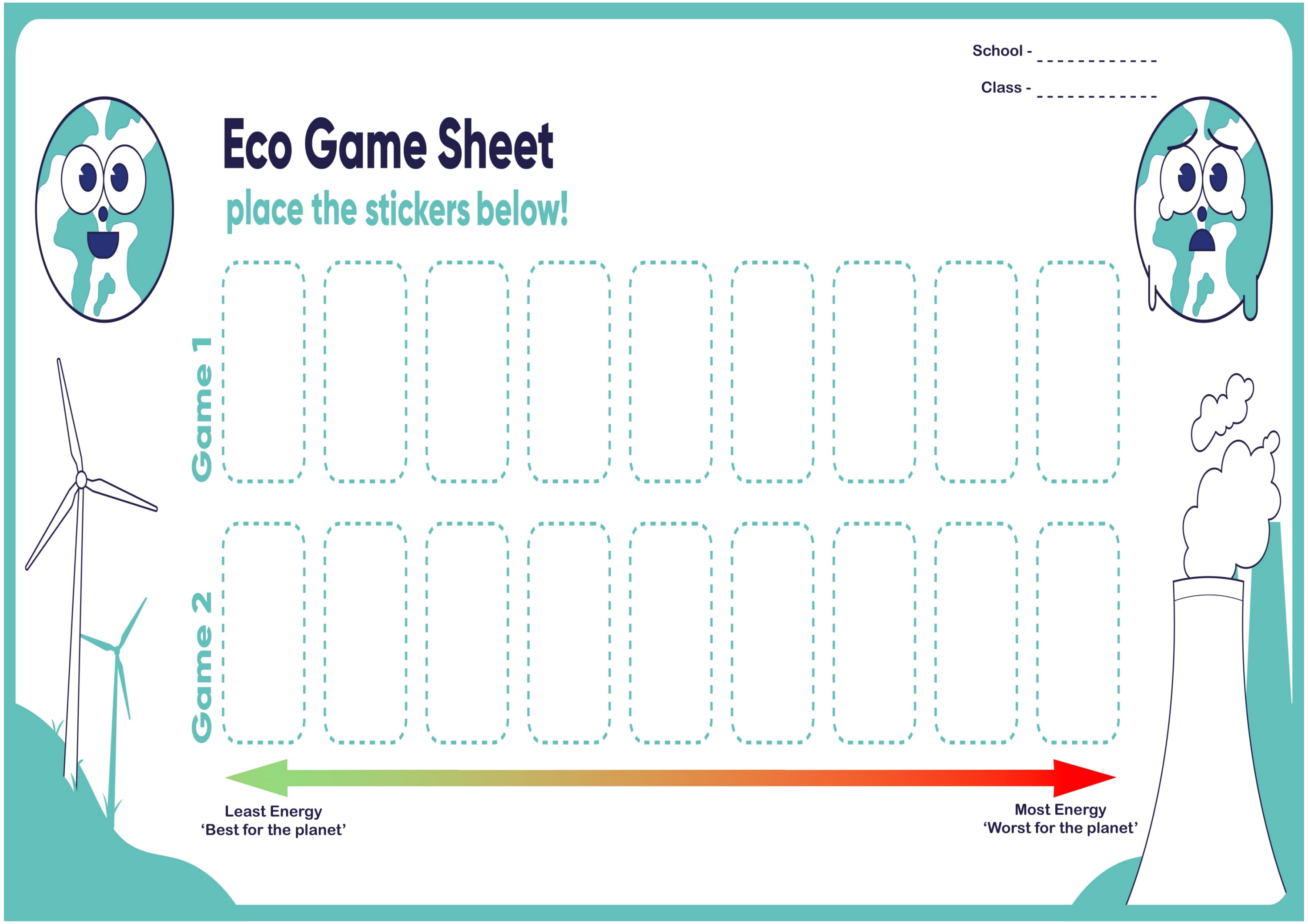


Figure 31: Study 4 Eco Homes - School Lesson Sticker Answer Sheet

The energy game is a simple sticker game that requires the player to guess the order, from lowest to highest, of energy-consuming items (or behaviours) in the home. Professional graphic designers were consulted in the creation of the game to create a child-friendly theme. The correct number of stickers and answer sheets were given to teachers at each school for each child to play the game in the class. The data on energy consumption for all aspects of the game can be found in the appendix.

Around 20% of the children from the two schools (circa 50 students) were not asked to complete the lesson or take-home activity. These formed the control group classes. The parents from the intervention and control groups were also asked to complete the initial and exit surveys.

Study 4 Phase 3 – Opportunity for Inter-Generational Interaction

The children within the intervention group classes were given a second game pack to take home. This included the sticker sheet, an empty answer sheet, an instructions sheet and a correct answer sheet (sealed shut) - all of these can be seen below. The teachers told the children to go home and challenge their parents to the game. This game was changed from the previous two methods' games in that it is no longer an investigative style game aimed at allowing children to explore their home but rather aimed at testing parent's energy literacy in the hope that the act of playing the game together would encourage the child and parent to discuss the items and behaviours in front of them.

Hello!

Thank you for taking part in this study!

Please play the 'Eco Homes Sticker Game' with your child!

The first row is made up of <u>items</u> in your home.

The second row is made up of <u>behaviours</u> in your home.

<u>How much energy do they use each day?</u>

- Peel off the stickers in the first row and place them on the answer sheet in the order you think they should go.
- Left to right – least energy consuming, to most energy consuming!
- Discuss with your child the reasons why you chose your order.
- Think about what it takes to make, use or power the item.
- Now do the second row!

Once you're finished, please scan the QR code below to complete the 2-minute survey.

https://tinyurl.com/Walhampton-Sticker-Game

That's all! Thanks!

Figure 32: Study 4 Eco Homes - School Take home activity instructions

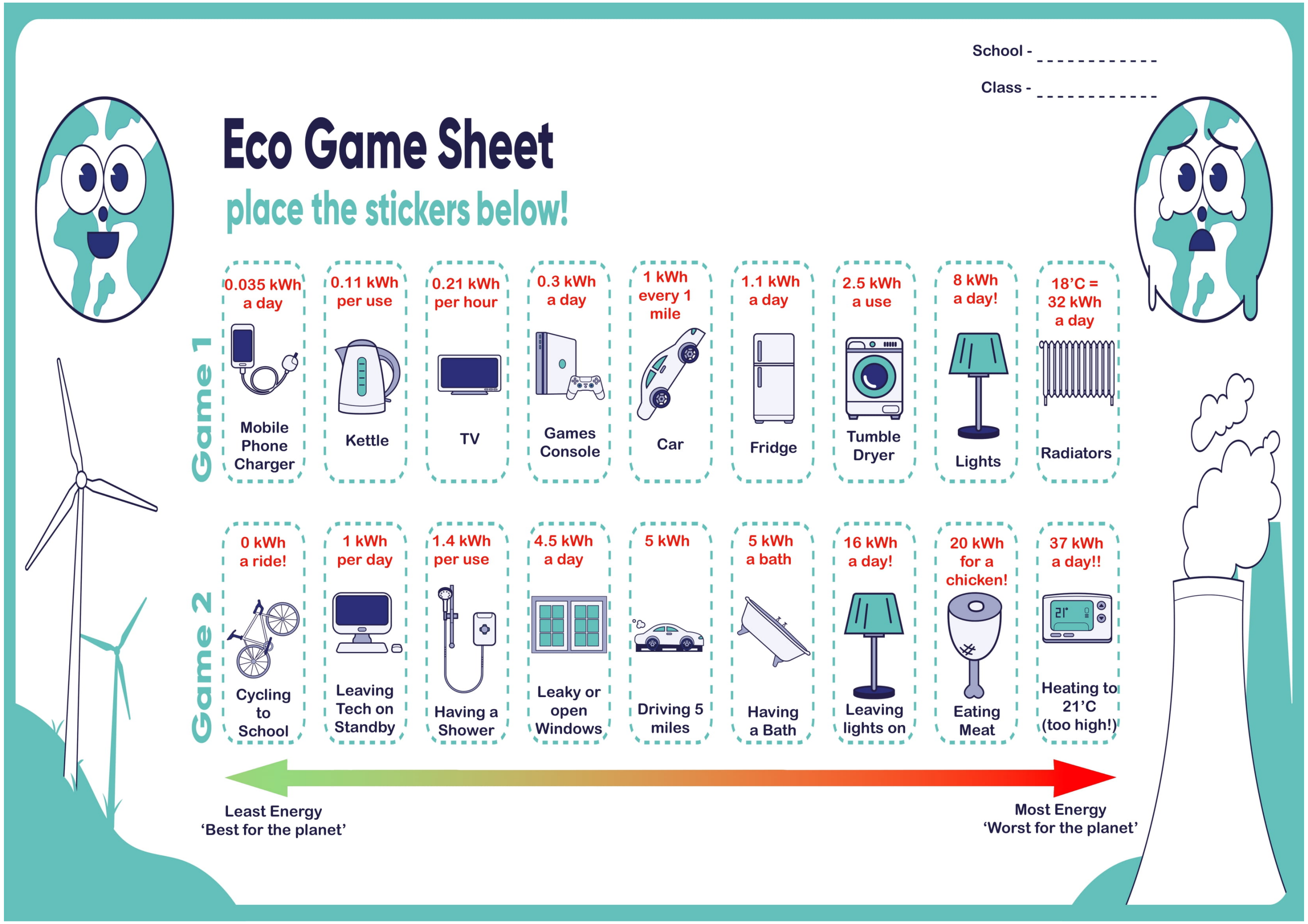


Figure 33: Study 4 Eco Homes - School Lesson Correctly finished Sticker Sheet

Revealing the correct answers at the end of the game will inform the parent of their current energy literacy levels. They may find they are not as well informed as initially thought, potentially prompting further discussions with the child. As the final step on the instructions, a QR code (and website address) will direct the parents to a short survey to be completed.

The survey asked the following questions:-

- Ethics:
  - Consent to take part in the survey (yes/no)
- Information:
  - Please enter your child's class name (Drop Down Box)
- Questions (Items):
  - Please drag and drop the options to match your sticker answers - from best (1) to worst (9)
  - Did any Items surprise you in how HIGH they were? If so, which ones? (Tick Box)
  - Did any Items surprise you in how LOW they were? If so, which ones? (Tick Box)
  - Did your child discuss energy issues related to any items whilst you played? (Tick Box)
  - If so, what was discussed? (Text Box)
- Questions (Behaviours):
  - Please drag and drop the options to match your sticker answers - from best (1) to worst (9)
  - Did any Behaviours surprise you in how HIGH they were? If so, which ones? (Tick Box)
  - Did any Behaviours surprise you in how LOW they were? If so, which ones? (Tick Box)
  - Did your child discuss energy issues related to any items whilst you played? (Tick Box)
  - If so, what was discussed? (Text Box)
- Survey Feedback:

- Thank you for completing this survey, please comment below if you had any issues/concerns about the survey (i.e specific questions that were difficult to understand) (Text Entry)

Initially, the survey was intended to ask users to take a photograph of the answer sheet to streamline the experience of the survey even more, but unfortunately, due to national university regulations on surveys, this ability on Qualtrics is banned for all UK universities. The 'drag and drop' system to show their answers was selected as the next most effective way to record parental scores without requesting the sheets back.

Phase 4 – Reassessing Parental Energy Behaviour Baseline All parents from the control and intervention groups within both schools were asked to complete the surveys. The exit survey started with an identical set of questions from the entry survey but continued to discuss the take-home activity and then any interactions and behaviour changes that may have occurred since. Below are the additional questions only, please see above to read the initial questions:-

- Take-Home Activity Feedback:
  - Did you play the Sticker Game with your child? (yes/no/unsure)
  - Has your child spoken to you about anything they have learnt? (yes/no/unsure)
  - Did your child seem to enjoy the lessons and game? (yes/no/unsure)
  - Has your child asked you questions about your home + behaviour? (yes/no/unsure)
  - Has your child asked if anything else in the home can be done differently? Ventilation, Driving etc... (yes/no/unsure)
  - If so, can you give an example of a change you have made in the box below? (Text Box)
  - Do you think you will continue this or any other changes? (yes/no/unsure)
- Parental Feedback:
  - Have you learnt anything new from your child? (yes/no/unsure)
  - If so, can you give an example of something you have learnt in the box below? (Text Box)
  - Do you feel you are now more aware of your energy behaviour in the home? (yes/no/unsure)
  - Would you like to learn more about climate change and the environment? (yes/no/unsure)

- Survey Feedback:
  - Thank you for completing this survey, please comment below if you had any issues/concerns about the survey (i.e specific questions that were difficult to understand) (Text Entry)

Study 4 Phase 5 – Additional Longitudinal Interaction and Assessment
Study 4 also included an additional longitudinal aspect. This consisted of the same Eco Game but was designed within a normal deck of playing cards. These used the same graphic and have a similar survey accessed from a QR code. Details of the game can be seen below:-

- Hearts - showed cartoon-style images of 13 items/systems in the house, ranging from a phone charger to heating.
- Diamonds - showed the same items with the order printed (from lowest to highest) and the total energy consumed per day (kWh).
- Spades - showed cartoon-style images of 13 more items/systems in the house, ranging from a phone charger to heating.
- Clubs - showed the same items with the order printed (from lowest to highest) and the total energy consumed per day (kWh).
- Jokers - showed a QR code leading to a short feedback survey for the parents.

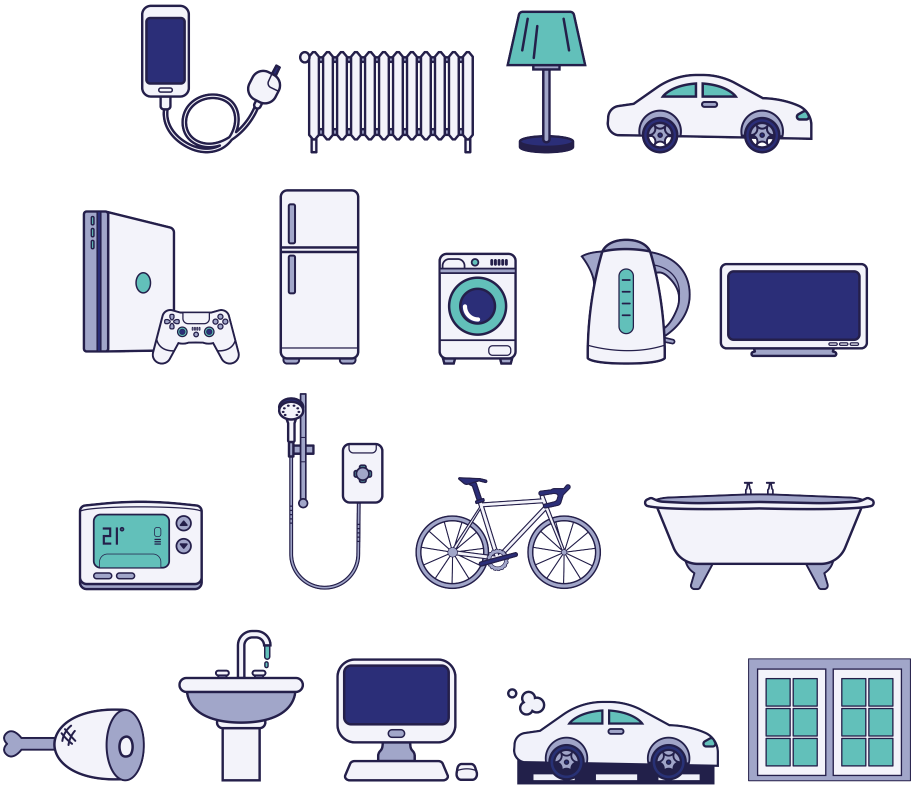


Figure 34: Study 4 Eco Homes - Longitudinal School Take home activity Artwork

Figure 35: Study 4 Eco Homes - Longitudinal School Take home activity Deck box

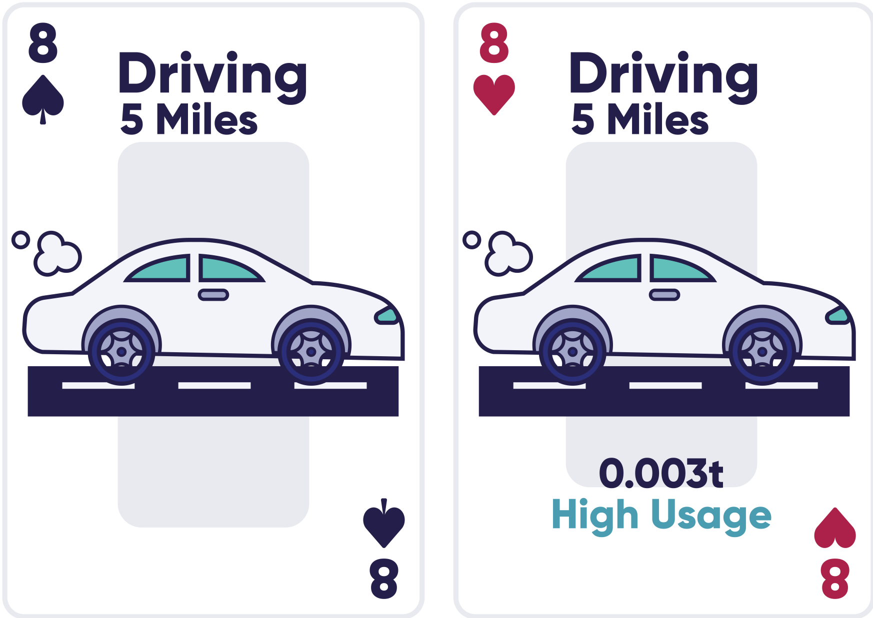


Figure 36: Study 4 Eco Homes - Longitudinal School Take home activity Card examples

This configuration allowed the children/adults to play the game with as many people or on as many occasions as they so wished. The same method was followed; the children gave their parents the data-free cards and asked them to guess the order and leave them laid out. The children then revealed the correct order to their parents and potentially discussed any queries or ideas together. The parents could then fill out the survey. Instructions were printed on a sheet and also written on the cards for repeated play.

As aforementioned, QR codes were used for easy access to feedback surveys. The same questions from the take-home activity survey. This enabled comparisons over time and to understand if behaviour changes were sustained.

Pilot Study A small pilot study was carried out on a class within Walhampton School prior to the release of the entire intervention. The class was an after-school enrichment club called the 'Green Class'. An early version of the Eco Sticker game involving cutting and sticking was used, which took a lot of the available time. The class students were a mixture of year 5 and 6. The items and behaviours in this game have remained the same throughout the real study. It was very interesting to hear the thoughts of the children first-hand, as well as input from the class teacher on what could be improved. Below are the sticker sheet and answer sheet that were used in this early edition.

Figure 37: Study 4 Eco Homes Pilot Study Sticker Sheet

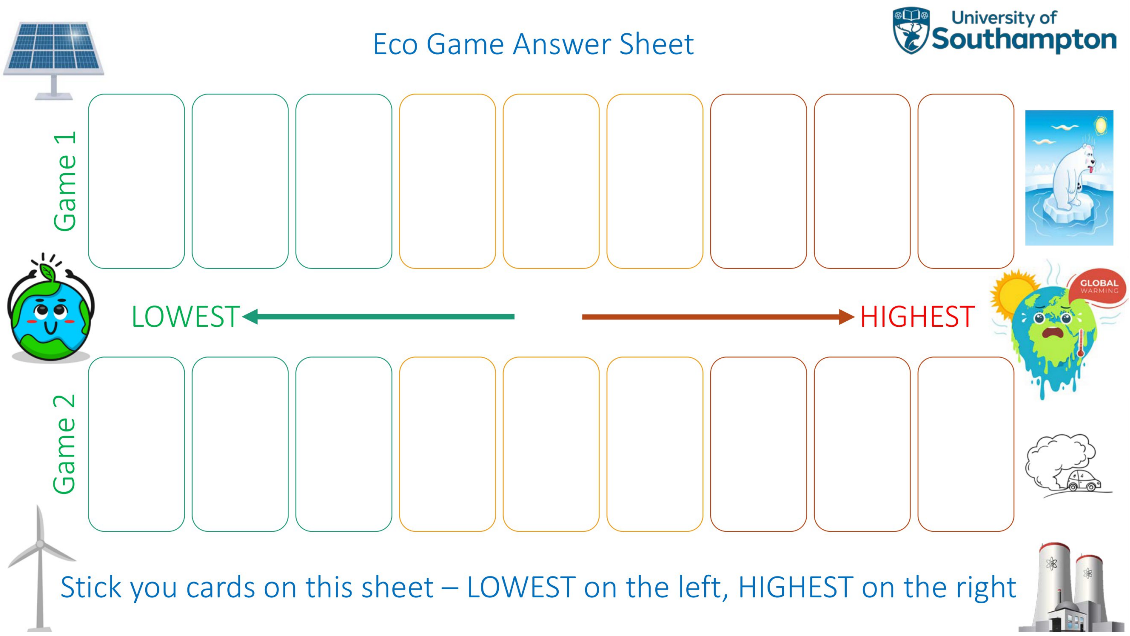


Figure 38: Study 4 Eco Homes Pilot Study Answer Sheet

4 Results

4.1 Study 1 Results

Phase 1 Results – Parental Energy Behaviour Baseline

The LATENT survey saw 4954 respondents complete and return the survey out of the approximate 26,000-strong customer base that were asked (19% return rate). Although the sample size was large, it was not representative of the UK population, see Table 1. Most participants were between 50 and 64 years old, male, in full-time employment, had a degree or higher and were part of a household earning more than £60,000 per year.

Table 1: LATENT survey participants' characteristics.

Characteristic	Range	UK %	Survey %
Age	<18 years	21.3	0
	18-29	16.2	5.3
	30-49	27.8	35.3
	50-64	18.1	42
	>65	16.4	17.2
Gender	Male	49	65.2
	Female	51	34.8
Household annual income	<£20,000	24.3	8.7
	£20,000-£39,999	51.3	25.3
	£40,000-£59,999	18.6	20.2
	>£60,000	5.8	34.3
	Rather not say		11.5
Heating Decision Maker	Myself		40.4
	My partner		6.6
	Shared equally		52.3
	Other		0.7
Main Occupation	Full-time	38.5	54.8
	Part-time	13.7	11.7
	Self-employed	9.5	4.5
	Retired	13.9	26.1
	Unemployed	4.4	1.4
	Full-time education	9.3	0.7
	Other	10.8	0.8
Highest level of qualification	No qualification	23.2	2.8
	O levels/ GCSEs (any grade)	14.1	9.4
	5+ O levels/ GCSEs (A*-C)	12.1	9.3
	2+ A-levels/ 4+ As levels	3.3	10.8
	Apprenticeship	27	5.7
	Degree or higher degree	5.1	56.5
	Other		5.4
Homeowner	Yes	64	88.7
	No	36	11.3

After cleaning of data, the total number of participants was n=4907. Of these participants, n=2012 respondents stated that they 'have dependant children' or live in a 'multi-person household' (41%). These are the households that will be analysed further in this section.

A distribution of these specific households can be seen in the histogram below:

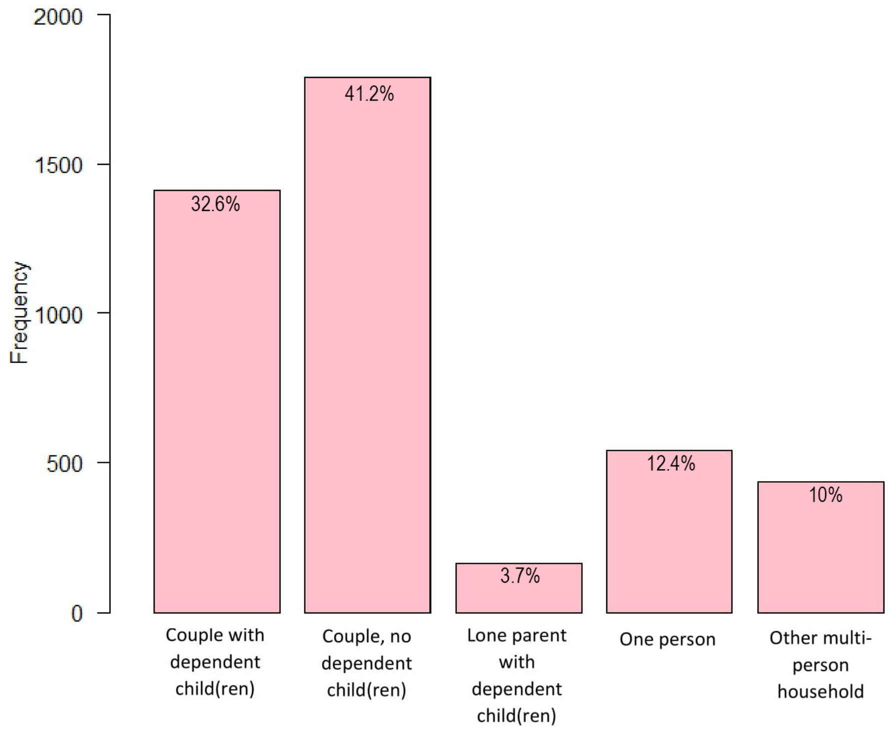


Figure 39: Distribution of Households in the LATENT study

Respondents that specified ‘Other multi-person households’ could include houses with both younger and older generations of the same family, but also those households that may include adult ‘housemates’ or children of the main occupants that are no longer dependent. This section required further sub-setting to include only the target participants required for this research. Figure 40 shows the final distribution of the LATENT respondents.

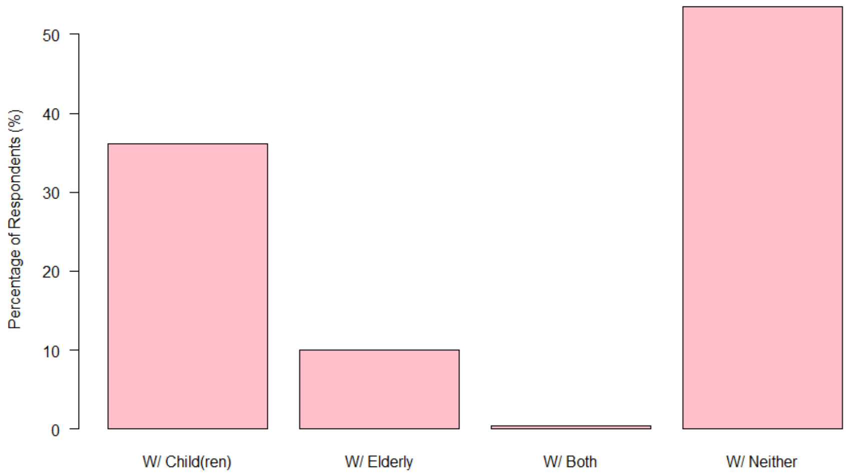


Figure 40: Final Distribution of Households analysed in the LATENT study

These four households formed the basis of the following analysis and will be referred to as Groups 1 – 4 respectively:

- Group 1 = Households with Child(ren) – totalling 1576 (36%)
- Group 2 = Households with 1+ Elderly – totalling 436 (10%)
- Group 3 = Households with Child(ren) and 1+ Elderly – totalling 16 (0.5%)
- Group 4 = Households with Neither – totalling 2330 (53.5%)

For comparison, below are England numbers of the same family groups [ONS (2021)a, ONS (2021)d]:

- Group 1 = Households with Child(ren) – 6 940 000 (29.5%)
- Group 2 = Households with 1+ Elderly – 248 000* (1%)
- Group 3 = Households with Child(ren) and 1+ Elderly – 248 000* (1%)
- Group 4 = Households with Neither – 6 846 000 (29%)
- *Government data does not specify to enough level. (% of total homes - 23,487,000)

The sub-setting of this data will allow for the additional questions within LATENT to be analysed. Comparisons between the four groups and other variables will also be made in later inferential analysis.

Group 3 - Households with children and elderly - has a participant number so low that it will be excluded from any thorough analysis. Data will still be shown on graphs and discussed, but no conclusions will be drawn on this group.

Question 1 - Do you have discussions with your child about energy issues and the environment?

Question 1 can only be analysed for groups 1 and 3 as it is directly about the interaction between children and adults (groups 2 + 4 not having children in the home). It can be seen from Figures 41 and 42 that discussions between main occupants (presumed to be parents in most cases) and children occur 'almost every day' only 4% of the time. 'Frequently' makes up 32% of responses, 'Occasionally' the most with 46% and 'infrequently' at 18%. Both Groups 1 and 3 had 0 results in the 'Almost Never' answer, with group 3 also having zero results in the 'Infrequently' answer.

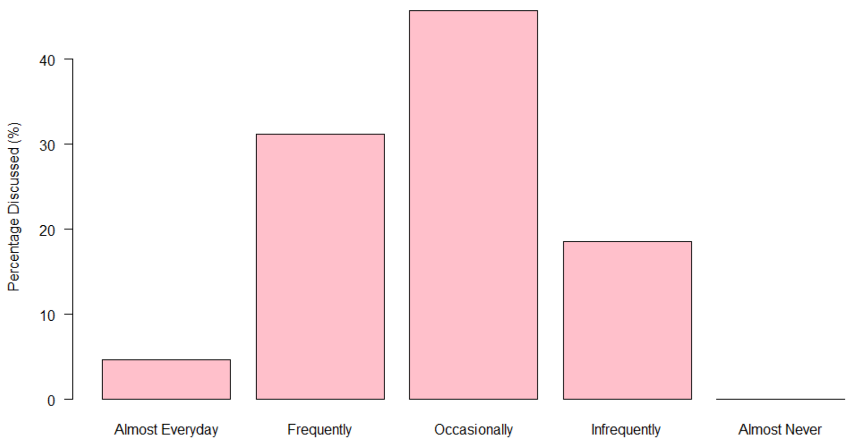


Figure 41: LATENT survey Frequency of Discussions with Children - Group 1 Households with children (n=626)

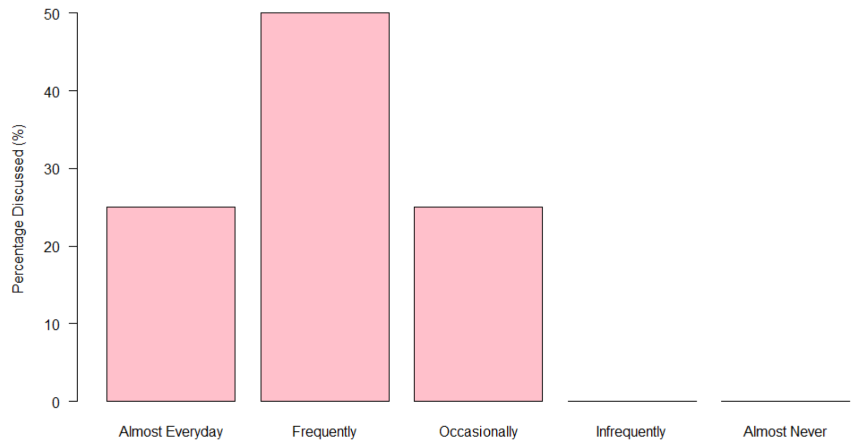


Figure 42: LATENT survey Frequency of Discussions with Children - Group 3 Households with children and elderly (n=8)

These results appear to show that interactions already take place, be it at most commonly only 'occasionally' for group 1 and 'frequently' for group 3. This level of interaction could be taken as the baseline level for future studies. It is important to note firstly, the LATENT participant base is not the UK average and secondly, that these results, as all of the LATENT survey, are the opinion of the resident completing the survey - this is an aspect that will be analysed later in the section.

Question 2 - Who starts the conversations about energy issues and the environment?

Within both groups, the child is the least likely to initiate conversations regarding climate change, this is apparent from Figures 43 and 44. The chi-square statistic was 3.1367. The p-value was .208393 therefore the result is not significant at $p < .05$. Group 1 however, does see an equal split of answers between 'Adult' and 'Both adult and child equal', suggesting that children in 'two-generation households' are indeed starting the conversation at least some of the time. Group 3 (with both older and younger) results suggest that adults are almost always initiating the conversation, with 'Child' actually receiving no responses and 'Both adult and child equal' only receiving two. This would suggest that having elderly relatives in the home affects the dynamic of conversation in some way, or it may be the case that children are discussing such topics directly with their grandparents, thus the parents are unaware.

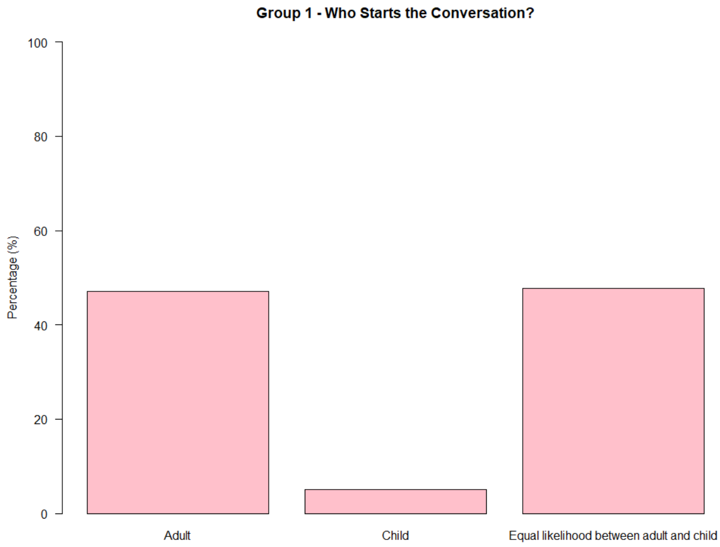


Figure 43: LATENT survey Frequency of Who Starts Discussions - Group 1 Households with children (n=683)

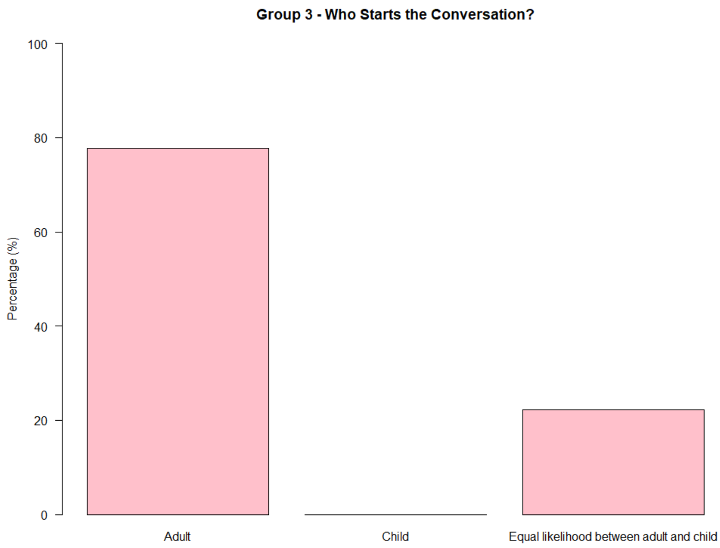


Figure 44: LATENT survey Frequency of Who Starts Discussions - Group 3 Households with children and elderly (n=9)

Question 3 [+6] - Do you think your children [and elderly relatives] influence your energy usage decision-making in the home?

Groups 1, 2 and 3 could all respond to this question, and the results show that there is a perceived difference between the influence of the younger generation compared to the older. Daily influence from children is less than 5%, whereas from elderly it is over 40%. In group 3, with both young and older, daily influence is also over 40% and steps down to 0% for 'Never'. Group 2 is also 0% for 'never influenced', whereas Group 1 (children only) results suggest that 30% of children never influence energy decisions in the home. These graphs can be seen below:

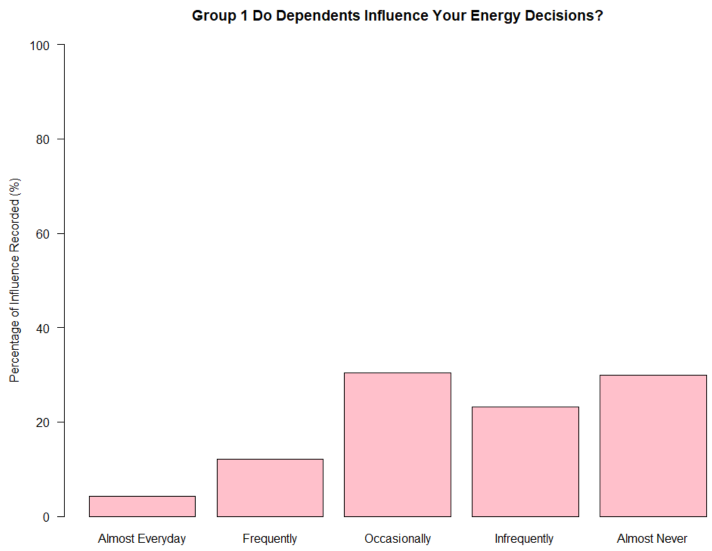


Figure 45: LATENT survey Frequency of Dependants Influencing Energy Decisions - Group 1 Households with children(n=705)

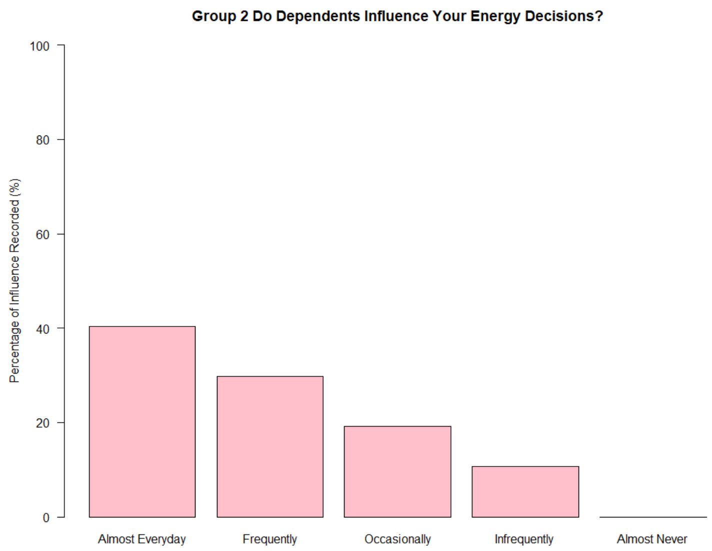


Figure 46: LATENT survey Frequency of Dependants Influencing Energy Decisions - Group 2 Households with elderly(n=47)

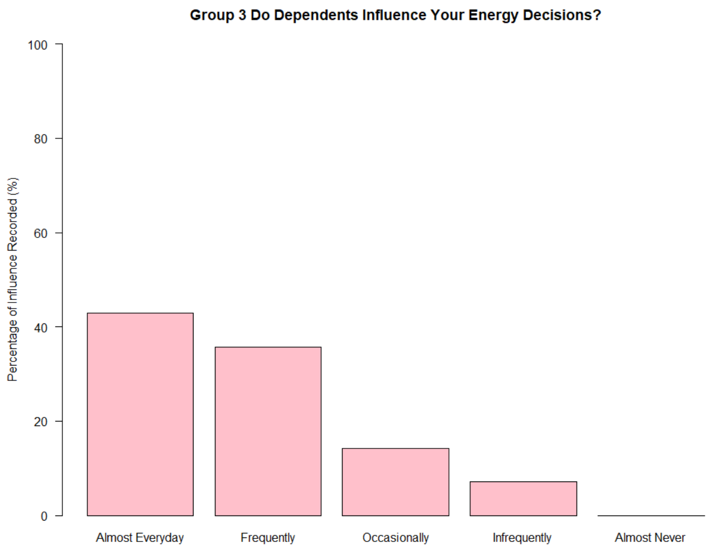


Figure 47: LATENT survey Frequency of Dependants Influencing Energy Decisions - Group 3 Households with children and elderly(n=14)

It is apparent that elderly generations within the home significantly affect energy decisions when they are made, whereas children rarely do. This is more likely to do with the health and comfort of elderly relatives within the home, rather than for environmental concerns.

Question 4 [+5] - Do your children [and elderly relatives] ask you to turn the heating up or down?

The three Figures below (Figures 48, 49 50)represent Groups 1, 2 and 3 results from Question 4. Respondents were given four options: up, down, both or neither. Similarly to question 3, it would seem that the younger generation rarely requests a change to the heating, with >60% of group 1 choosing 'neither'. Group 3, with both children and elderly, is slightly more complicated. The most chosen answer is 'increase' (35%), with 'neither' the second largest (30%) – these could be considered opposites. This may be because this group has elderly in the home and the children may have adapted to a warmer temperature, thus when it is cooler than their normal comfort level, they ask for an increase.

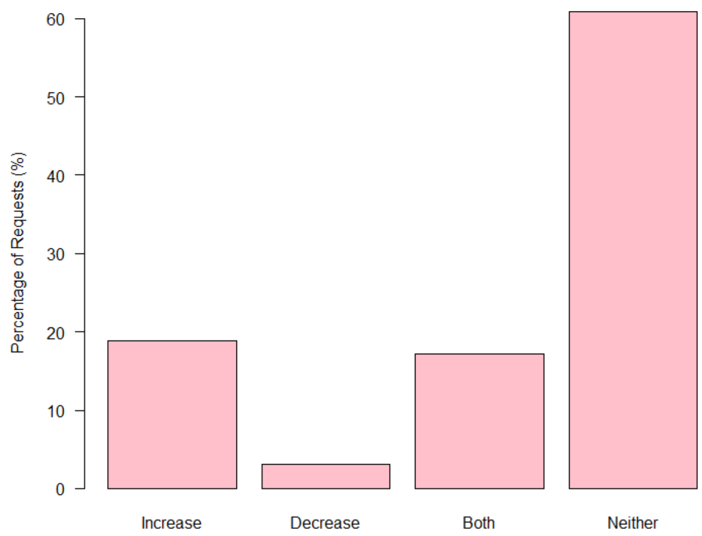


Figure 48: LATENT survey Requests From Dependants to Change Thermostat Temperatures - Group 1 Households with children(n=705)

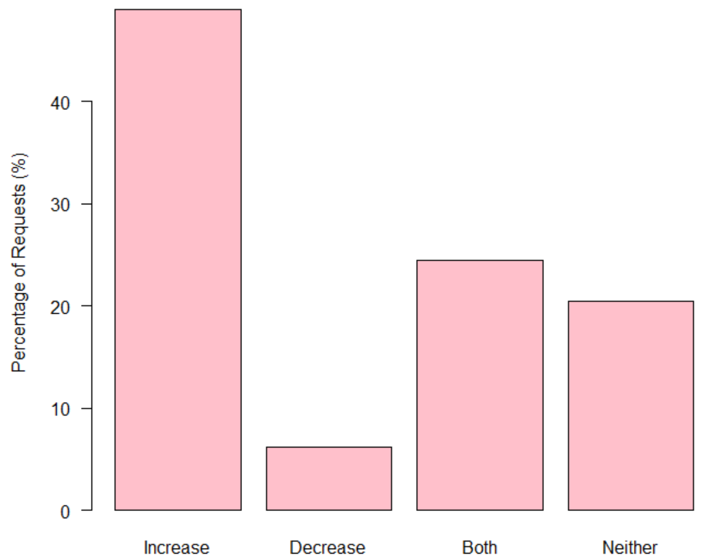


Figure 49: LATENT survey Requests From Dependants to Change Thermostat Temperature - Group 2 Households with elderly(n=49)

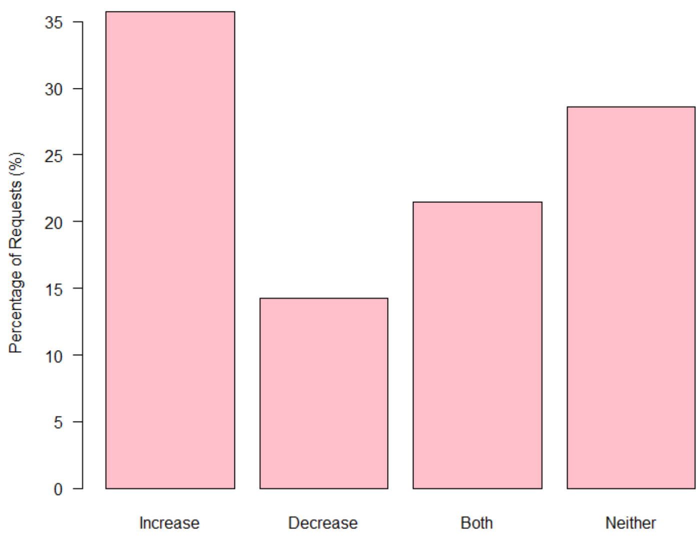


Figure 50: Requests From Dependants to Change Thermostat Temperature - Group 3 Households with children and elderly(n=14)

In contrast to group 1, group 2 sees most respondents choose 'increase' (50%). Both groups 2 and 3 see around 25% of responses vote for 'both up and down' and all three groups' lowest response is 'decrease' (see Figure 50).

Question 7 - If possible, please could you briefly explain the reason your elderly relative(s) influence your household heating strategy?

A total of 42 participants responded to this question. When reading through the answers, 21 participants (50%) said that they have to increase the heating because of health and comfort reasons, and another 6 (14%) also said that health and comfort are the main drivers, but did not specify an increase or decrease in temperature. 4 (10%) stated that the elderly relative(s) live in their own annexe and thus have their own control temperature. Interestingly, 1 (2.5%) answer directly mentioned 'environmental consciousness' playing a role, but did not specify what this entailed. The full list of answers can be seen in the Appendix.

4.2 Study 2 Results

Phase 2 Results – Improving Energy Literacy Levels of Children

Several differing methods were used to assess the initial and continually improving energy literacy levels of the children. These would not be considered formal grading of knowledge levels, but more casual discussions and checking of lesson content as teachers often do. The method depended on the ages of the children. The youngest (years 1-2) were graded by verbally asking the class questions with the teacher creating a mind map on the smart board or a large poster sheet of paper. The middle ages (years 3-4) completed A2-sized mind maps in smaller groups, with sheets pre-prepared by the teachers. The older children (years 5-8) completed the verbal questions on individual sheets or their workbooks, or in some classes, simply discussed the outcomes verbally as a class.

As topics progressed through the lesson and throughout the day, initial questions were asked and feedback gathered, then this was repeated at the end of the lessons to confirm knowledge had been passed on. Below are two of the posters that were created at the start of the first lesson on introducing basic themes of energy and the environment.

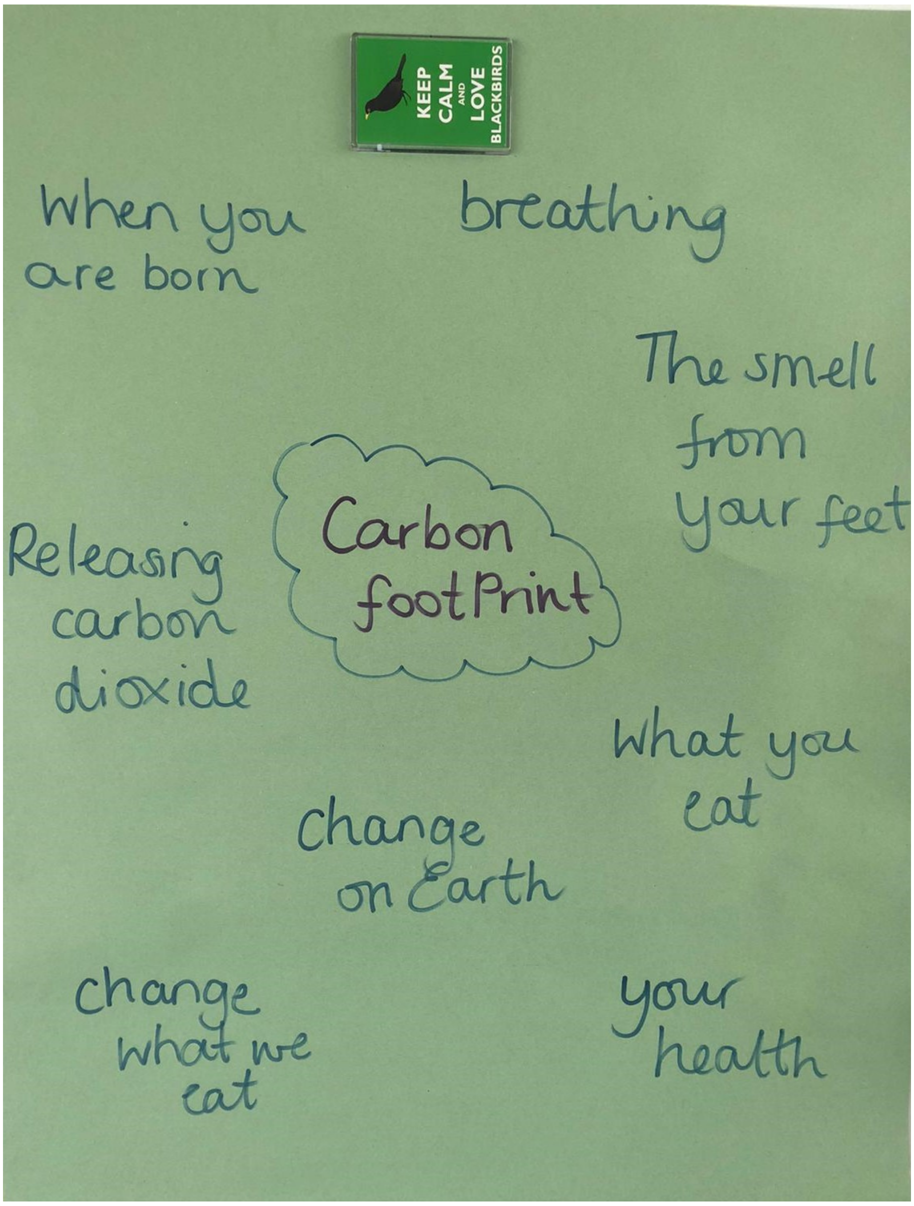


Figure 51: Example of a poster produced by Year 1 Teacher during school intervention of Method 2 asking the children what they think a carbon footprint is.

Phase 3 Results – Opportunity for Inter-Generational Interaction

As mentioned in the research methods section, the end scores and results from this game are almost second in importance to the inter-generational interaction, discussion and activity that playing the game brings. Unlike the air pollution tests carried out by children in Diana Varaden's research, whereby children simply carried electronic sensing devices that did the data collecting [Varaden et al. (2018)], the children in this research activity are physically measuring aspects of their home and then recording their own results. This has almost certainly led to a high level of human error and inaccuracies during the process, which is clear from some of the scores recorded. Having said that, some results can be seen below from the take-home activity.

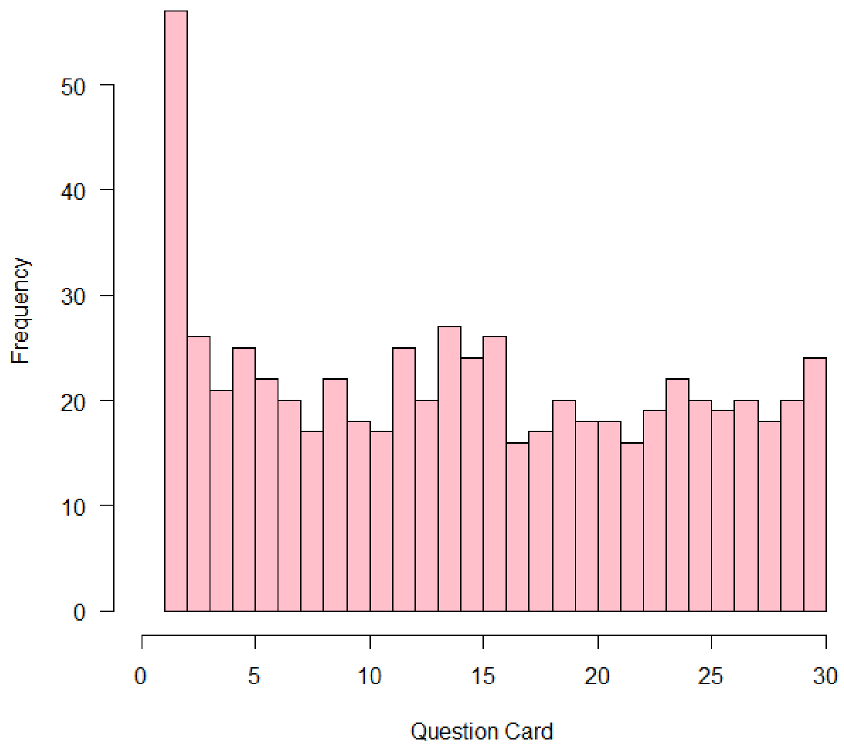


Figure 52: Study 2 Phase 3 Results: Take Home Activity - Distribution of Question Cards Chosen

First, the type of card chosen within the board game was reviewed, Figure 52 shows these results. It can be seen that with the exceptions of card number 1, which is missing entirely and card number 2 which was chosen twice as many times, the nature of a shuffled deck of cards has led to a mostly equal distribution in selection. The full set of Question Cards can be found above in Figure 21. Each card had a different question on it regarding energy and sustainability in the home. Four of the questions are explored in more detail below (Figures 53, 54, 55, 56 .

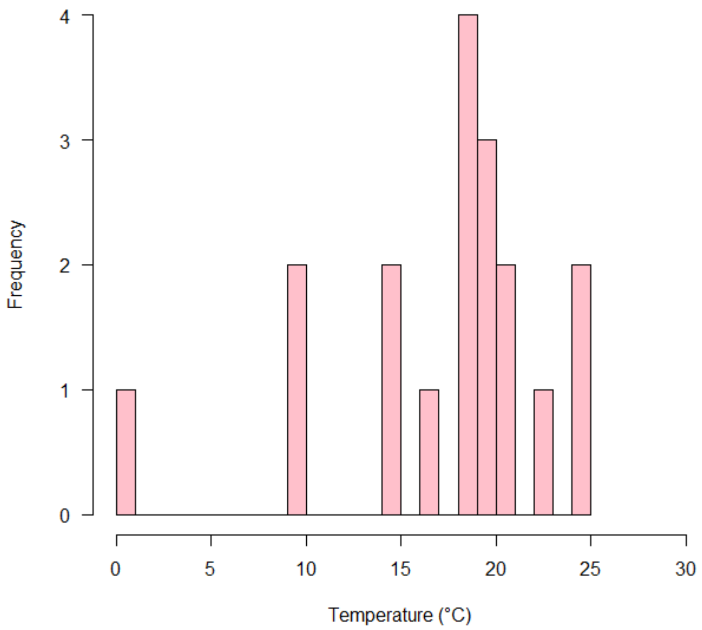


Figure 53: Study 2 Phase 3 Results: Take Home Activity - Responses to Question 10 Self-reported Thermostat Temperature in the home

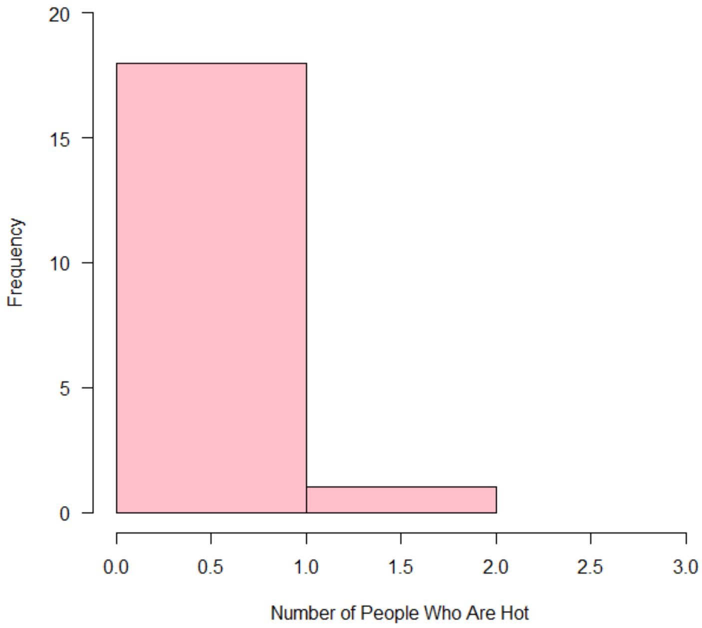


Figure 54: Study 2 Phase 3 Results: Take Home Activity - Responses to Question 26 Self-reported distribution of People stating they feel hot in the home

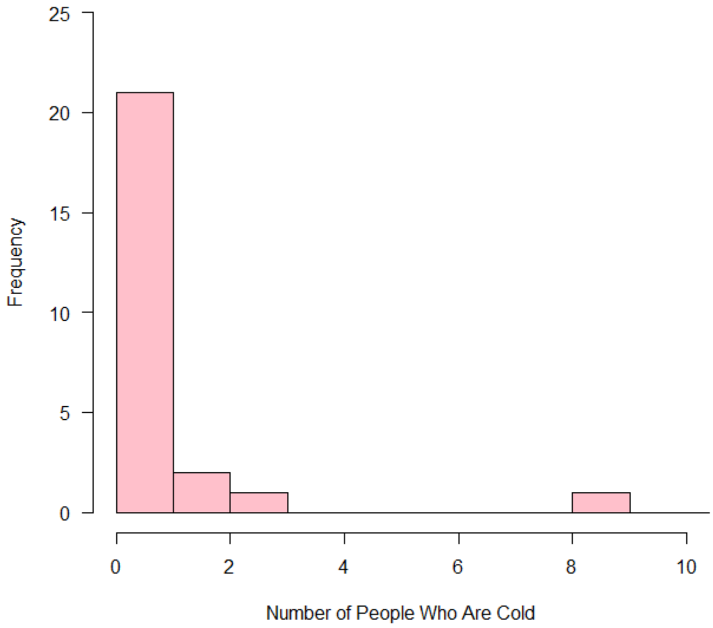


Figure 55: Study 2 Phase 3 Results: Take Home Activity - Responses to Question 16 Self-reported distribution of People stating they feel cold in the home

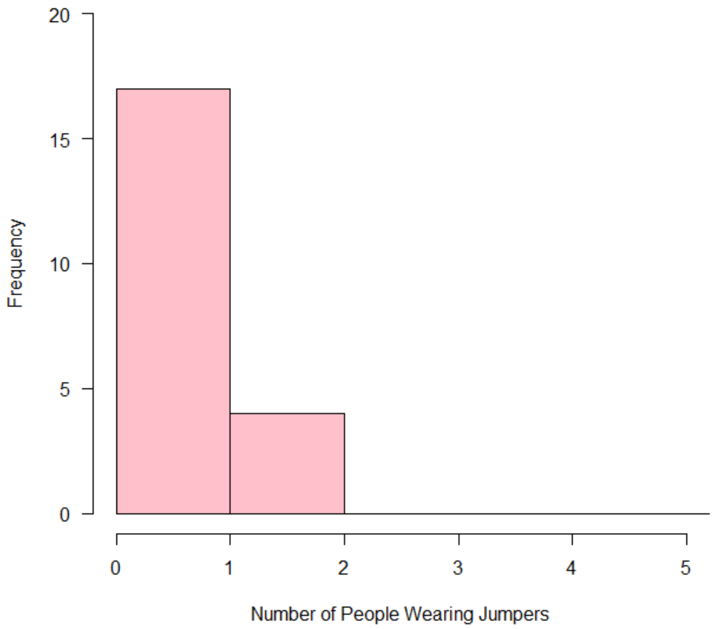


Figure 56: Study 2 Phase 3 Results: Take Home Activity - Responses to Question 06 Self-reported distribution of People stating they are wearing a jumper in the home

The above graphs are specifically about thermal comfort and heating in the home (other questions were more general, about cars or recycling etc..). These are important as heating is the main driver of energy demand and consumption in the home. They show that the numbers of people feeling hot and cold are similar (18/31 (58%) respondents saying one person was hot and 21/31 (67%) respondents saying people were cold). The self-reported indoor ambient temperature of respondent thermostats is generally as one would expect (at a range between 17-25°C) recommended in CIBSE Guide A Table 1.5. Some of the lower temperatures (0°C) are likely from heating systems that are not switched on. Six participants reported indoor temperatures below the recommended range. People wearing jumpers see 17 respondents saying one person and four respondents saying two people. This could be seen as quite high, especially as the thermostat temperature was generally at comfortable levels; maybe to do with the aforementioned low income of the participant group or habits.

Phase 4 Results – Reassessing Opportunity for Inter-Generational Interaction

The parental feedback was completed by 9 of the 55 parents in years 3 and 4, and equally 9 of the circa 60 parents in years 5 and 6 for a total of n=18 (16% response rate). Table 57 on the following page shows the results of the questionnaire.

CONTENT + LESSONS	YES (Y3+4)	YES (Y5+6)	Yes (combined)
Has your child talked about what they learnt during the 'Energy in the Home' lessons?	89%	40%	61%
Have they mentioned the phrase Climate Change to you?	100%	50%	72%
Have they talked to you about their Carbon Footprint?	78%	40%	56%
Have they spoken to you about how they think they can help the planet?	100%	50%	72%
PARENTS + CARERS			
Have you learnt anything new from your child about the environment?	56%	11%	40%
Have you changed how you do anything in the home because of their comments?	56%	11%	35%
Have you changed how you use your heating because of their comments?	44%	0%	24%
Do you think you will continue with this change or any other changes they have mentioned?	89%	44%	65%
Would you like to know more about the environment?	67%	78%	71%
ENGAGEMENT			
Did your child play the 'Energy in the Home' board game?	78%	50%	67%
Did they seem to enjoy playing it?	44%	50%	40%
Did you play the game with them, or help them complete the tasks?	67%	38%	60%
Did your child ask you questions about your home and/or behaviour?	44%	38%	40%
BEHAVIOUR + HABITS			
Has your child asked if things in the home can be done differently? eg. What you eat or recycle..	89%	33%	59%
Have they asked you to change the heating temperature?	33%	0%	20%

Figure 57: Study 2 Final Survey: Parental Feedback Scores (n=18)

Looking at years 3 and 4 first, it can be seen that of the participants who responded, almost every child (89%) has spoken to their parent about the day's activities, and every child (100%) has talked about how they can help the planet. Not only does this suggest that children are indeed concerned about the future, but it also suggests that discussions can happen between generations about environmental topics. If the information discussed was helpful to reduce energy in the home, this may suggest that the younger generations are currently being under-utilised as a positive influence on occupant behaviour in the home.

Interestingly, over half of the parents (that completed the survey) reported that they had learnt something new from their child, this may suggest that almost half of participating adults had initially very low levels of energy literacy, this falls in line with the local levels of deprivation in terms of education and may mean that they are using their heating systems less appropriately than expected. An unexpected heating behaviour may also be due to having to choose priorities financially, as discussed in the literature study [Beatty et al. (2014)].

The main negative result from the younger feedback is that only 44% of parents thought their child enjoyed the take-home activity. This would suggest that it needs to be redesigned before a future research study takes place. A significant 89% of parents reported that their child has asked them to change their behaviour in the home, with the same 89% then saying they would likely maintain this change. This is easily the stand-out result from the feedback and shows that as mentioned above, there is an influential change being self-reported.

The year 5 and 6 responses were not as positive as the younger ages: only 40% spoke to their parent about the day's activities, and half of the children (50%) talked about how they can help the planet; this is a large difference from the younger children. Low levels of parents recorded that they learnt anything new or changed anything in the home because of the children's comments (11% for both).

Only half the children are recorded to have played the game, but all of those seemed to enjoy it from the parents' perspective, an increase from the younger children. Far fewer parents played the game with their children, perhaps because the older children required less help, although this is a subjective answer. It may also have to do with less time available for the parent, or simply because the child or parent did not want to take part.

Overall, it is important to reiterate that these families may not have the opportunity to improve their behaviours to the same degree as the LATENT participant pool would. For example, heating use may already be at a low level due to financial constraints, whereas the LATENT participants may be able to reduce their likely over-consumption. This is the 'pre-bound effect' and it may be considered inappropriate to look for savings in these participant groups [Malik et al. (2020)].

Oral Feedback from Teachers and Children

Having produced 4x lessons with all resources, activities and presentations, as well as differentiating between ages/abilities throughout the school, delivery was now in the teacher's hands. Years 3 and 4 were taught all four lessons in a single day, but years 5 and 6 had to split it over two days due to attempted catching up with lessons missed (due to COVID-19). This may be one of the reasons the intervention did not seem to be so successful with the older children. It was initially asked that the teachers ask several open questions to the classes once they had finished the day's work:

- Did the children have fun today? If so, why?
- Were there any boring parts?
- Were there any parts that were your favourite?
- Did you learn lots?
- Did you like playing the game? - Asked the next week when all had played.

According to the teacher who passed the information on, all feedback from the children was resoundingly positive, stating 'almost all the children were taking every aspect on board and appreciating the consequences that may happen if we don't change things'. She reported that all children enjoyed playing the game and have since repeatedly asked to learn more about climate change. They appeared to enjoy all parts equally, even the heavier sections such as 'power stations' which were deemed as unsuitable within the 'Teach The Future' survey (found in the literature review), which suggested children be taught fewer science aspects and more animal/wildlife aspects.

The lessons and their content were then discussed from a teacher's perspective, including length, any tedium, differentiation etc... The teachers reported that the lessons were very well planned, with all activities being achievable in the 1-hour time frame. The teachers of Y3+4 reported enjoying teaching the subjects, but the Y5+6 teachers were more concerned that time was taken from other parts of the curriculum that they deemed more important.

Interestingly, the younger children chose to continue the climate change theme through other subjects, with the teacher running an English Learning Journey Unit completely about Climate Change. This included using their 'words of the day' to describe climate change, and baking earth cookies, during which they discussed how the ratio of blue and green icing will change in the future. This topic culminated in writing their own Climate Change Poems. Examples can be seen in the Appendix (Figure 118).

When discussing the game with the teacher, it became apparent that even the snakes and ladders-based game was too complicated for some children of y3+4. Although the mechanism was simple, the gathering of information, particularly the scoring side was too complicated, even for some parents. This feedback enabled the game to be altered and improved before the next intervention.

Finally, some additional and unexpected feedback can be seen below:

- One class Teaching Assistant said that she had learnt vast amounts of new knowledge and will be attempting to change her daily decisions.
- After learning about (and calculating) the embodied carbon in their lunches, one boy was so disappointed with his high score (meat and dairy heavy lunch) that he returned the next day with a far better scoring lunch after calculating the total with his parent that morning.
- The children continued the theme of climate change and energy throughout the next weeks in other classes such as cookery, English and maths.

4.3 Study 3 Results

The Kids4climate study took a considerable amount of time to (i) be produced and (ii) to secure ethical approval to study children online. This included designing and creating the website and its content/videos. For these reasons, the initial target timeline of November 21 - January 22 had to be pushed back to February 22 - April 22. The final timeline can be seen below, figure 58

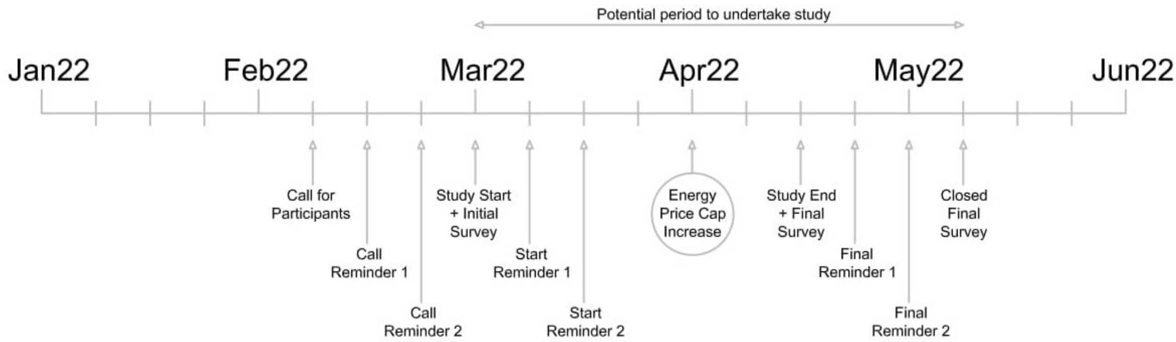


Figure 58: Study 3 Kids4climate.co.uk Study Timeline

The final uptake of the study can be seen below. Unfortunately, the uptake was only 2% - a total of n=19 completed all aspects of the study, out of a possible 750 from the filtered Igloo customer pool.

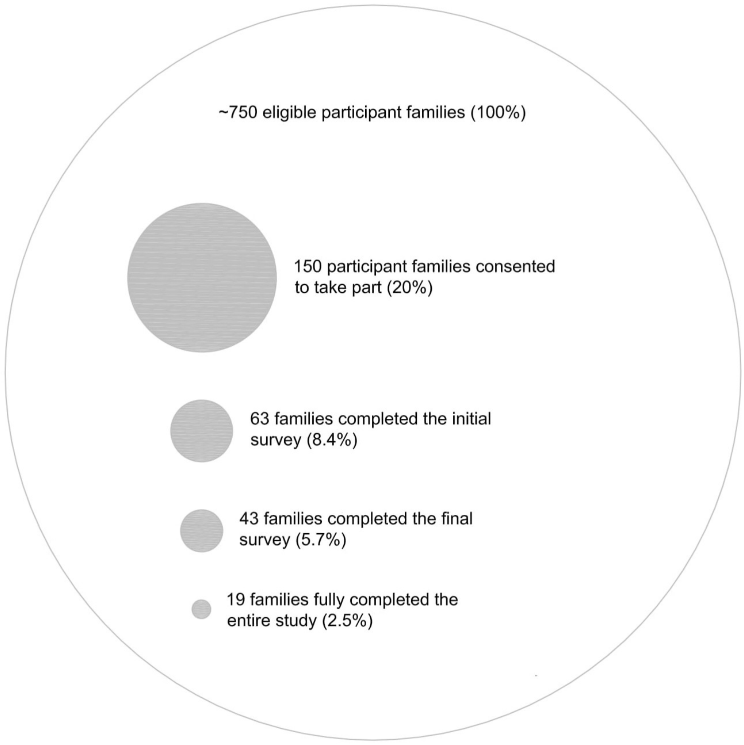


Figure 59: Study 3 Kids4climate.co.uk Participant Breakdown

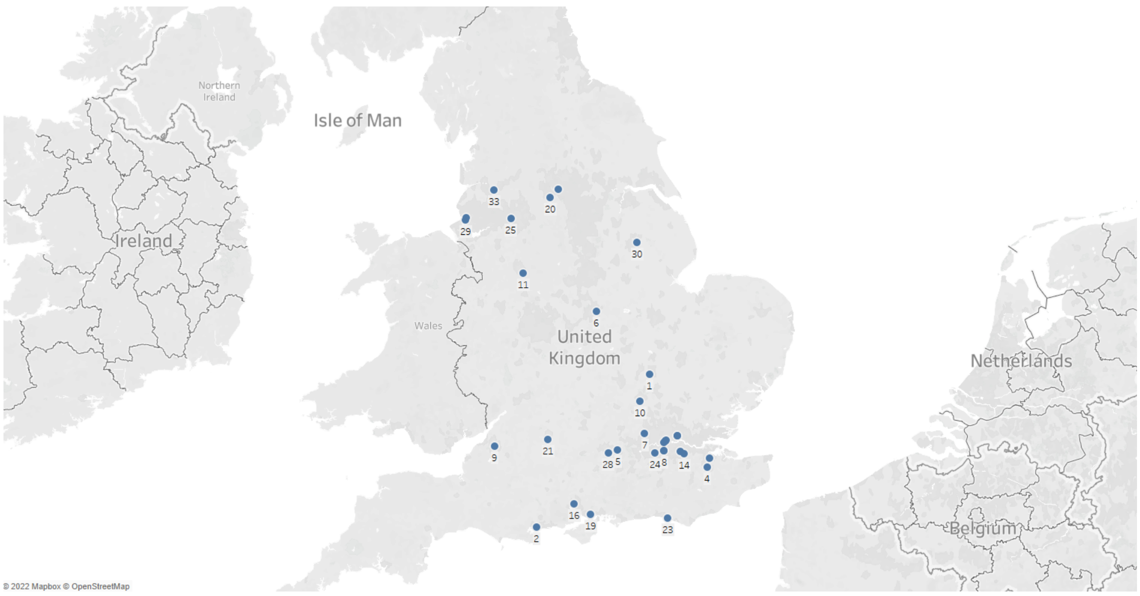


Figure 60: Study 3 Kids4climate.co.uk Location of Participants

The above Figure 60 shows the distribution of the 63 participants who completed the initial survey. It can be seen that they vary widely in location throughout the UK and will likely live in differing types of homes in varying micro-climates.

Phase 1 Results – Parental Energy Behaviour Baseline

The initial survey was undertaken by a total of 63 participants, 19 of whom entered a gas meter reading for their final Igloo reading, an up-to-date reading for the day of the survey and then the final reading post-intervention. These can be seen in the table below (Figure 2).

Specific dates have been omitted from this table, and total days have been used for ease of viewing, but the participants took both readings recorded with a date. Within the survey, written directions led them to where/when they could find the final Igloo readings within their emails on the online dashboard system used by Igloo before it ceased trading. The normalised results for this can be found in the following chapter in Table 13.

Table 2: Study 3 Kids4climate - Results of Gas consumption.

	Prior to Study			**Kids4climate Study Duration**		
Participant Families	**Gas consumed (m^3)**	**Number of days**	**Number of HDDs**	**Gas consumed (m^3)**	**Number of days**	**Number of HDDs**
A	556	138	1092.9	213	72	541.2
B	812	144	1087	259	65	491.9
C	873	139	1140.1	238	59	459.1
D	1019	149	1046	297	59	403
E	767	150	1056.4	212	52	370.1
F	1433	153	1040.6	295	49	336.4
G	1882	153	1374.8	4245	63	420
H	709	153	1077.8	217	63	410
I	749	153	1374.8	181	48	416.4
J	519.6	153	1374.8	151	54	456.8
K	672	153	1097.8	187	50	362.3
L	1516	153	1056.6	563	48	348.5
M	302	154	1081.2	72	54	359.4
N	880	155	1091.6	121	59	400
O	2025	164	1158.2	1348	37	183.3
P	1092	164	1305.9	222	52	450
Q	384	167	1182.8	62	44	279.3
R	814	183	1289.2	46	18	133.4
S	1251	205	1355.7	52	15	94

Figure 61 below represents the baseline for method 2. Results from the final exit survey were compared with those to ascertain if there was a significant difference or improvement. Of the 63 initial surveys undertaken, only 42 were fully completed within the question section. The results of each question can be seen in Figure 61.

Figure 61: Study 3 Kids4climate Initial Survey answers from participants (as percentages) (n=42)

Concern for climate change shows that all participant adults who filled in the survey are concerned to some level, with over 60% being at least ‘very concerned’. The two questions regarding financial or environmental influences on heating show that finance is far more powerful, with over half of participants stating ‘almost always’ compared to less than a quarter stating the same level for environmental influence. Around two-thirds of participants stated they ‘frequently’ consider the environment when making daily decisions.

Regarding their children, the majority of parents ‘somewhat agree’ that their child is concerned about climate change (25/41 or 49%), while 10 parents stated ‘neither agree nor disagree’ or ‘somewhat disagree’. Less than 10% of parents have discussions about the environment with their children daily, with the majority of parents stating discussions are ‘infrequent’. This is an important baseline for comparison and shows a lot of potential for improvement. Having said that, it would have been more beneficial to state specific numbers, as people’s ideas of frequent or infrequent may change and daily may be considered far too often or unachievable. Similarly, only 2 out of 42 (5%)participant parents stated that ‘children’ start the conversations aforementioned – another potential for improvement. Having said that, around half the respondents also stated that ‘both adult and child’ do start conversations regarding the environment.

Regarding the general influence of children on energy decisions, the results are very broad with a similar number of participants choosing each option, with the majority stating ‘occasionally’, but children’s influence specifically on heating sees around two-thirds of parents state their children ‘neither ask for increases or decreases’ in thermostat temperature, suggesting that children currently may not act as positive or negative influences on heating use, thus there may be an opportunity to use children as agents of change to reduce heating use and in turn carbon emissions.

Phase 2 Results – Improving Energy Literacy Levels of Children + Phase 3 Results – Opportunity for Inter-Generational Interaction

Regarding the website, a total of 35 participants scored points within the Energy Detective activity. This means they have watched at least one interactive lesson video and then completed the accompanying set of home survey-style questions. The top scorer on the website reached a total of 230 points, with only 12 points (on average) available each day, this means they completed the activity at least once a day for nearly 20 days during the study. As mentioned in the Research Methods, this small competitive game style addition should have increased participation and mitigated some of the tedium that may have arisen[Flanagan and Nissenbaum (2019)]. The below table (Figure 3) lists the top users of the website and their number of interactions.

Table 3: Study 3 Kids4climate - Top 15 participants - Number of website interactions.

$\top Username$	Interactions
White Bellied Spider Monkey	230
Utah Prairie Dog	178
Monkey Faced Bat	79
Black Howler	61
Woolly Lemur	51
Black-Fronted Tern	36
Mosaic-Tailed Rat	32
Big Brown Rat	24
Ring-Tailed Lemur	22
Spiny Pocket Mouse	19
Birch Mouse	18
Phoenix Petrel	15
Slender Antbird	13
Blue Duck	11
Black-Shanked Douc	9

The below graph shows a percentage breakdown of how often each room was logged within the Kids4climate website - the garden and kitchen were limited to once a week to mitigate repetition and tedium for the children. On average, each daily room was completed 120 times during the study.

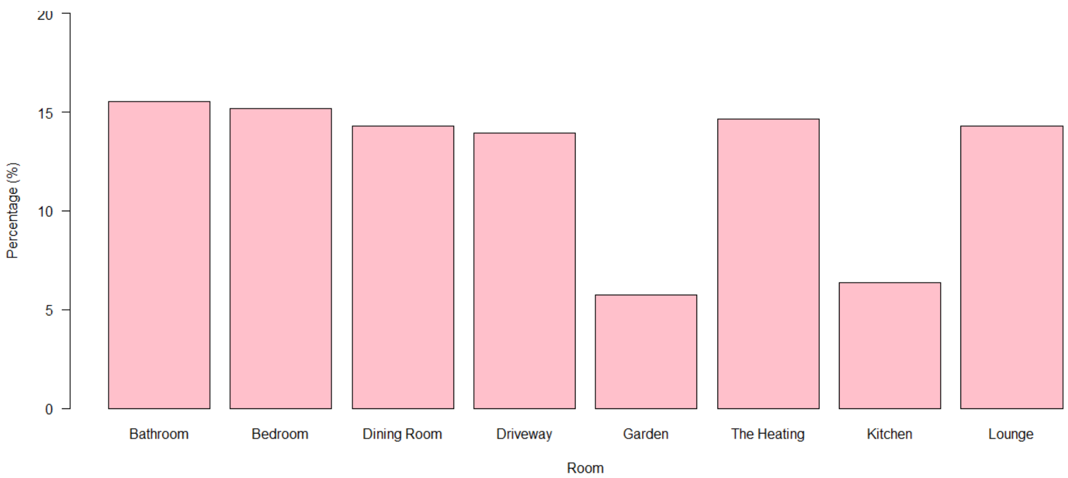


Figure 62: Study 3 Kids4climate - Website Interactions Breakdown (n=818)

The data collected through each room section of the website activity was never intended to be collected for formal analysis, it was simply used to encourage children to explore their homes and importantly it acted as a medium for conversation and interaction to happen between generations. To that end, only the data from the heating section (often the largest energy consumer in the home) is shown below in Figure 63.

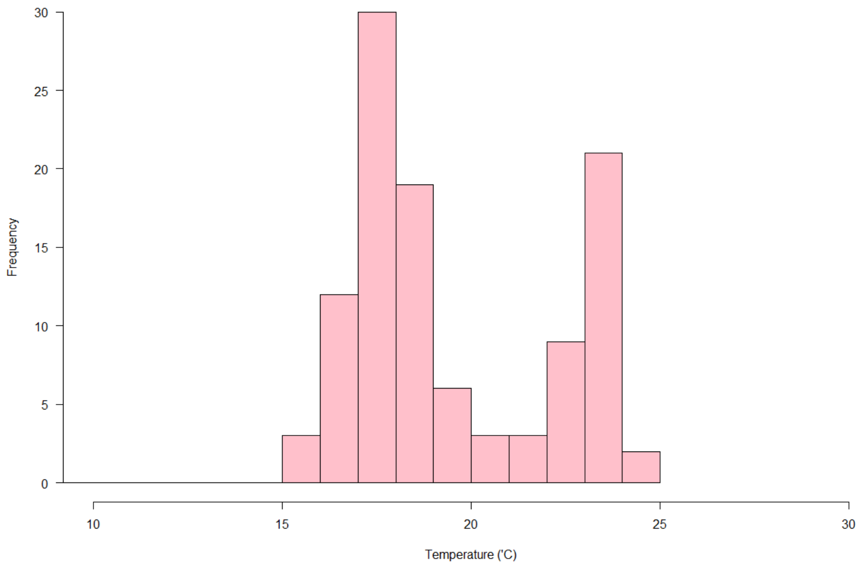


Figure 63: Study 3 Kids4climate - Self recorded Thermostat Temperatures

Figure 63 shows that the thermostat temperatures vary between 15-25 degrees at the time of recording, 18 degrees being the most frequently recorded temperature which falls in line within CIBSE Guide A (2015) guidelines.

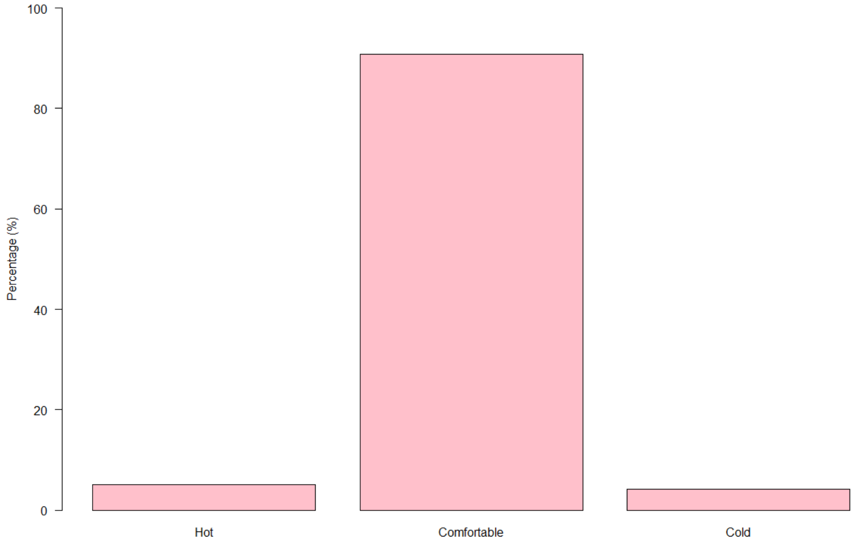


Figure 64: Study 3 Kids4climate - Self recorded Thermal Comfort

It can also be seen in Figure 64. that the vast majority of children felt comfortable at the time of recording.

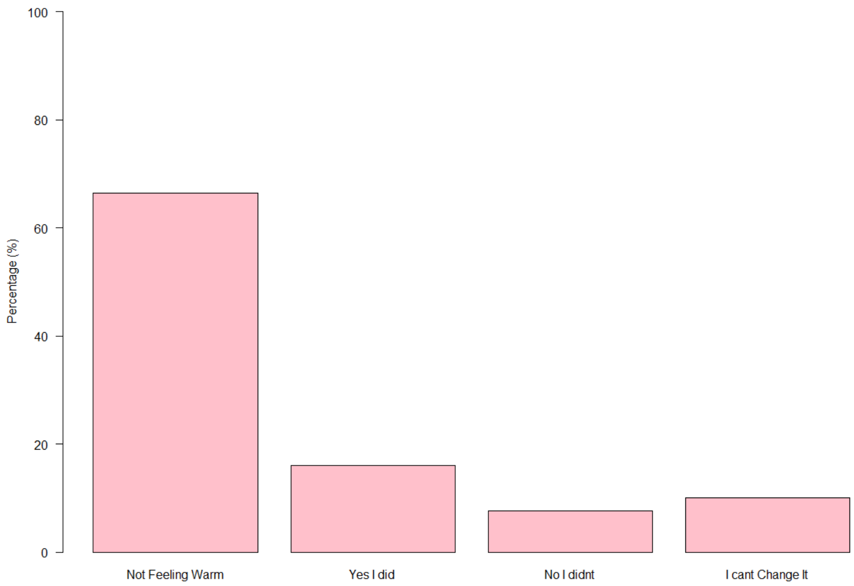


Figure 65: Study 3 Kids4climate - Opportunity to decrease temperature?

It can be seen in Figure 65. that the majority of children were not feeling warm, thus did not lower the temperature, but around 20% did ask to reduce it. Figure 66 shows the results from the final question - asking if the children could put on a jumper if they are feeling cold (rather than using the heating).

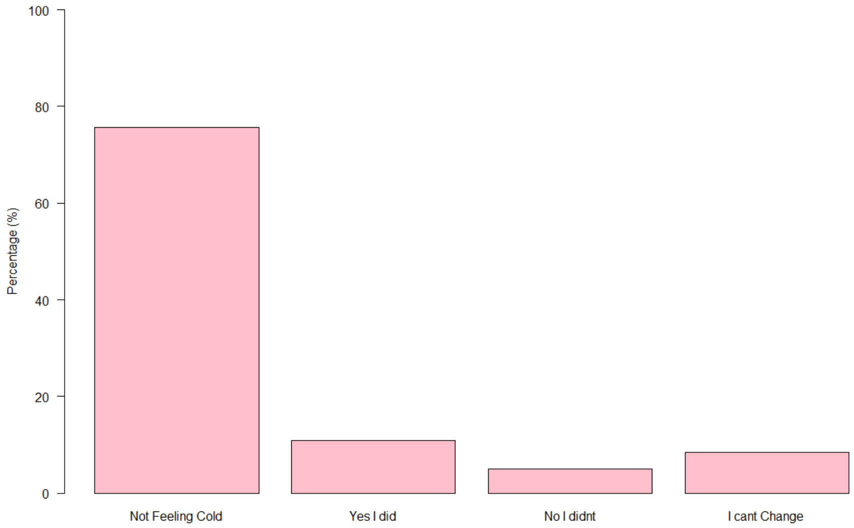


Figure 66: Study 3 Kids4climate - Opportunity to wear a jumper

Phase 4 Results – Reassessing Opportunity for Inter-Generational Interaction

The final survey was attempted by 42 participants, unfortunately, only 32 of these completed the survey in its entirety. The following Figure 67 shows the survey questions with their answers:

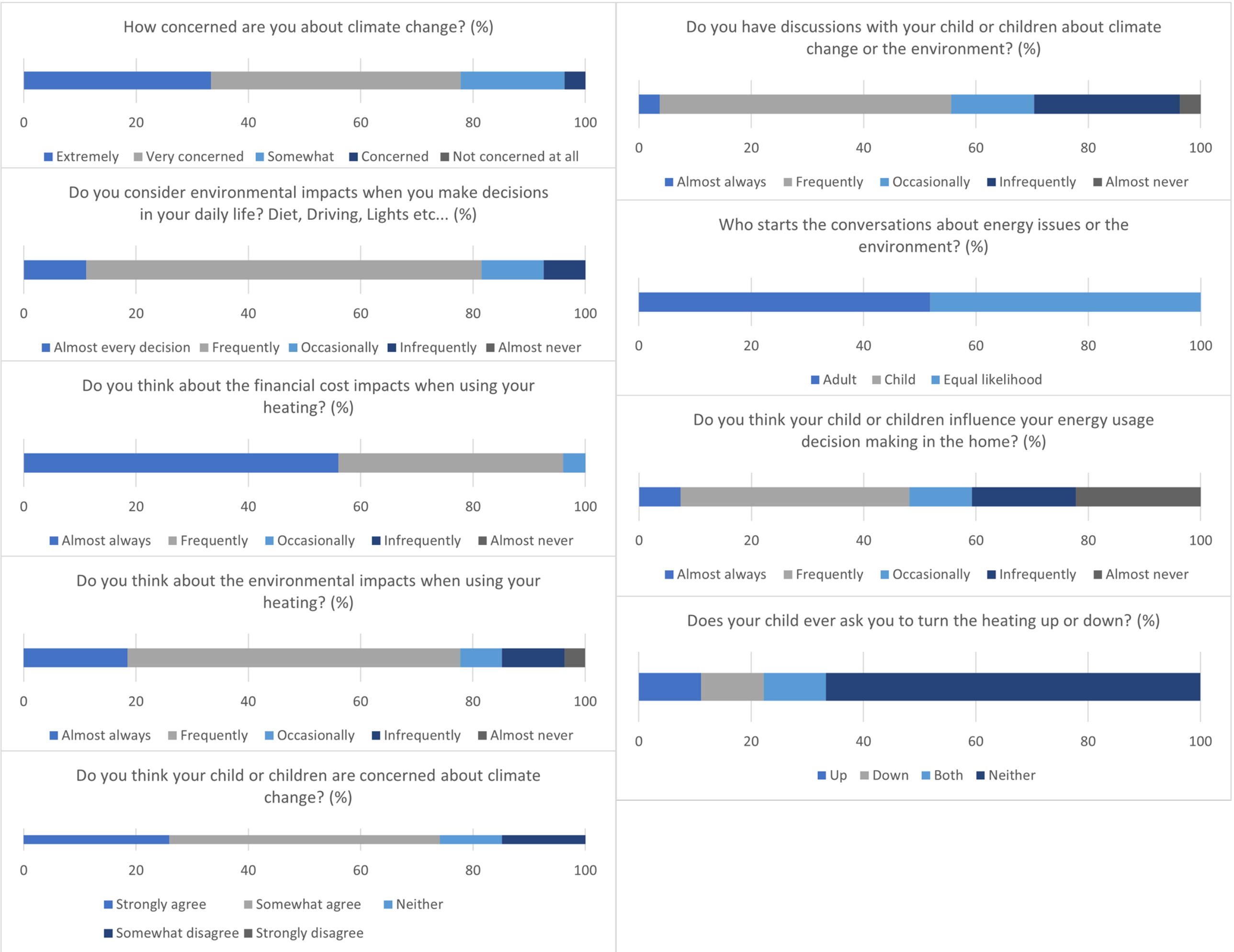


Figure 67: Study 3 Kids4climate Final Survey answers from participants (as percentages) (n=42)

The final survey also included additional questions that can be seen in the below Figures (68 and Figure 69), starting with one multiple-choice likert style questions, followed by several yes/no/unsure questions.

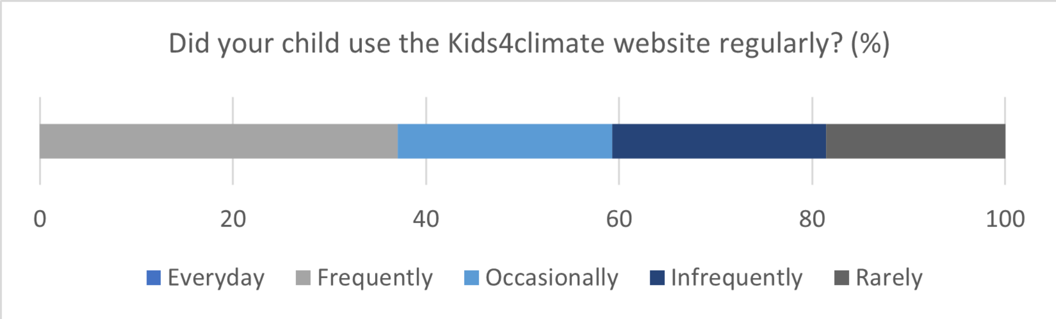


Figure 68: Study 3 Kids4climate Final Survey Additional answers from participants - Did your child play the game? (as percentages)(n=42)

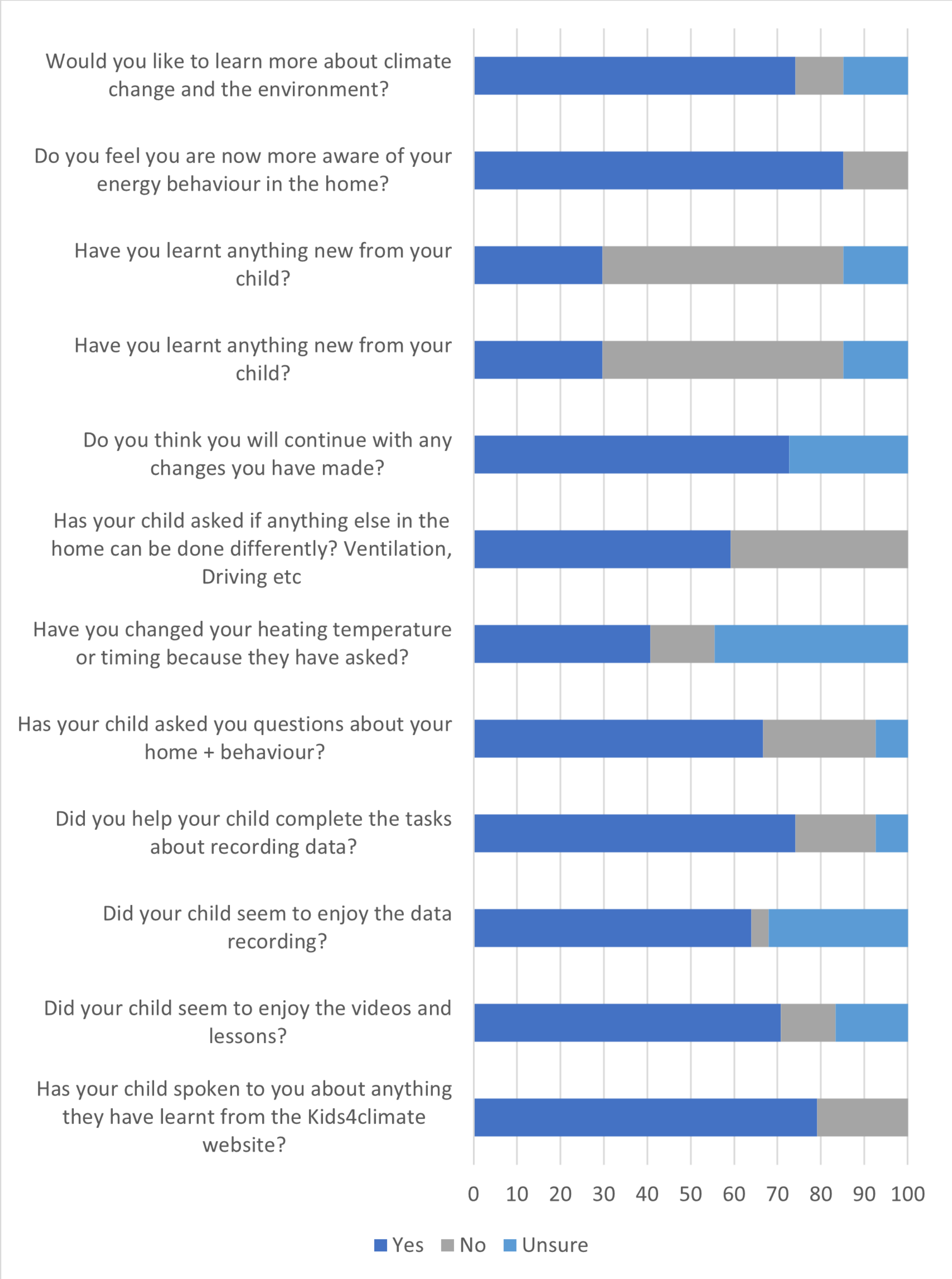


Figure 69: Study 3 Kids4climate Final Survey Additional yes/no answers from participants (as percentages)

Following the quantitative questions, the participants were asked to answer the following questions (i) Can you give an example of something you have learnt in the box below? (ii) Can you give an example of a change you have made in the box below? The responses can be seen in the below lists.

Can you give an example of something you have learnt in the box below?

- Heating
  - More heating leads to higher cost
- Standby + Electricity use
  - How much energy things use on standby - I assumed that new regulations meant things used way less power on standby.
  - The number of electric items we had on standby
  - The cost of running certain items
- Recycling
  - We've actively sought out recycle points for single-use plastic, tetra plastics and soft plastics. Our local collection doesn't collect these types of plastics. We are also using alternative packaging for food in the fridge to store such as beeswax to wrap food.
  - About climate impact of certain materials use
- Transport
  - Drive slowly
  - Avoid driving fast only to brake
- Other
  - Being curious about even the things that we know, and learning more!
  - Reduce shower time

Can you give an example of a change you have made in the box below?

- Heating
  - Reduced the temperature on my thermostat
  - Turned temperature down to 18 or less.
  - We turned the thermostat down to 18 degrees
  - Reduced the heating timer to set to just an hour in the morning but switched off all other timers and we now manually operate the boiler to come on and off
  - Wear extra clothing when cold, turn room thermostats a couple of degrees lower

- The child asked about the heating temperature settings on the thermostat

- Standby + Electricity use
  - Turning off sockets
  - switching lights off when not in use
  - Putting the washing machine on overnight
  - We undertook a full energy audit as a family and are saving almost 50kwh of electricity per month due to our (limited) use of this website. Our gas heating usage was already down to the bare minimum before the survey so not possible to save further meaningful amounts.

- Transport
  - Setting off in more time so able to drive leisurely, saving cost fuel.
  - Change related to timing journeys in the car
  - Electric car
  - Cycling rather than driving
  - Electric car
  - Driving Carefully
  - travelling by train and not a car where possible
  - Asked me to drive slowly

- Other
  - Eating less meat and animal produce
  - Using less water
  - Always open the window when bathing
  - Small flush for wee, unplugging aromatic/ smells plugins

Parents were also asked for feedback on the overall study. The following answers were provided:
Thank you for completing this survey, please comment below if you had any issues/concerns about the survey

- No none

- some questions contradicted slightly - in the bathroom, it talked about using windows for ventilation but in a different room said all windows should be shut.

- Hi - I'm afraid I didn't participate much in the project, apologies. Reasons - a) we were away for 3.5 weeks shortly after it started, b) I didn't realise we were supposed to fill in the same questions every day (ie, how many standby plugs are on, how many lights were on, etc. It took ages to do (over two days!) so would have taken quite a long time to do each day. Perhaps I misunderstood what we were supposed to do after the initial watching of the video and filling in the questions). c) My daughter is six and I think maybe a bit young in terms of understanding everything, especially in relation to the overall climate change crisis (which I'm obviously not going to go into in full with her - she's a bit young for the full existential crisis I think...) She's also a bit young to understand and influence our energy usage, though she does mention plastic in oceans quite a lot in school lessons...
- Fairly straightforward thank you and wish you all the best
- The picture of the house was not clear. Frequency of filling data not clear
- The website was very interesting, but had a slightly offputtingly amount of information. We did a lot of the back of using it, but probably avoided using it more as we just didn't have the time to commit during a normal week.
- None
- The exercise for the children did take a long time and my son's engagement suffered as a consequence. When I asked him to repeat the work, he was reluctant to do it, hence only completing it once. Sorry.
- Good luck with your studies.
- We are relatively energy aware and have made as many changes as we can financially, if anything this has brought it to or table and we discuss it more. Turning off TVs etc, and phones when not in use etc. The message sent to have been lost at school and seems distant to our children at primary level

4.4 Study 4 Results

This section shows the results of the five phases of the fourth study - 'Eco Homes'.

Phase 1 Results – Parental Energy Behaviour Baseline

The below Figures 70 and 71 show the results from the initial entry survey before the intervention. These results were produced by the parents of the children of both schools and all year groups.

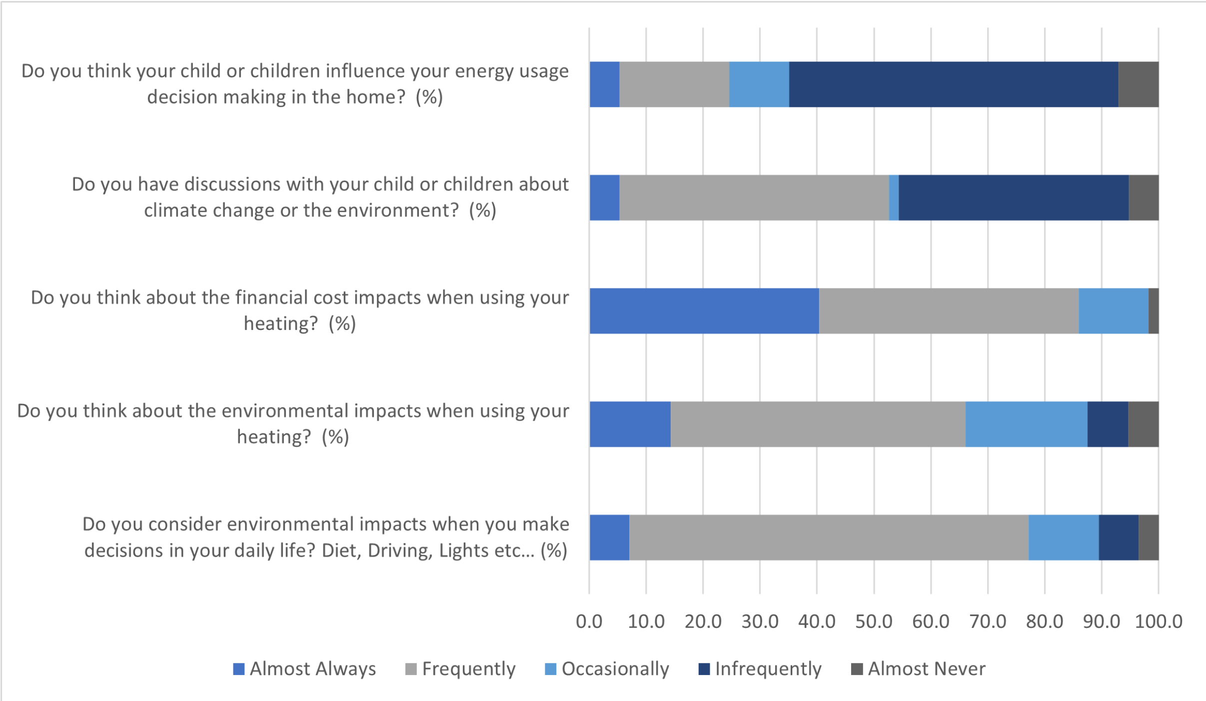


Figure 70: Study 4 Entry Survey Results - Both Schools and All Year Groups - Part 1

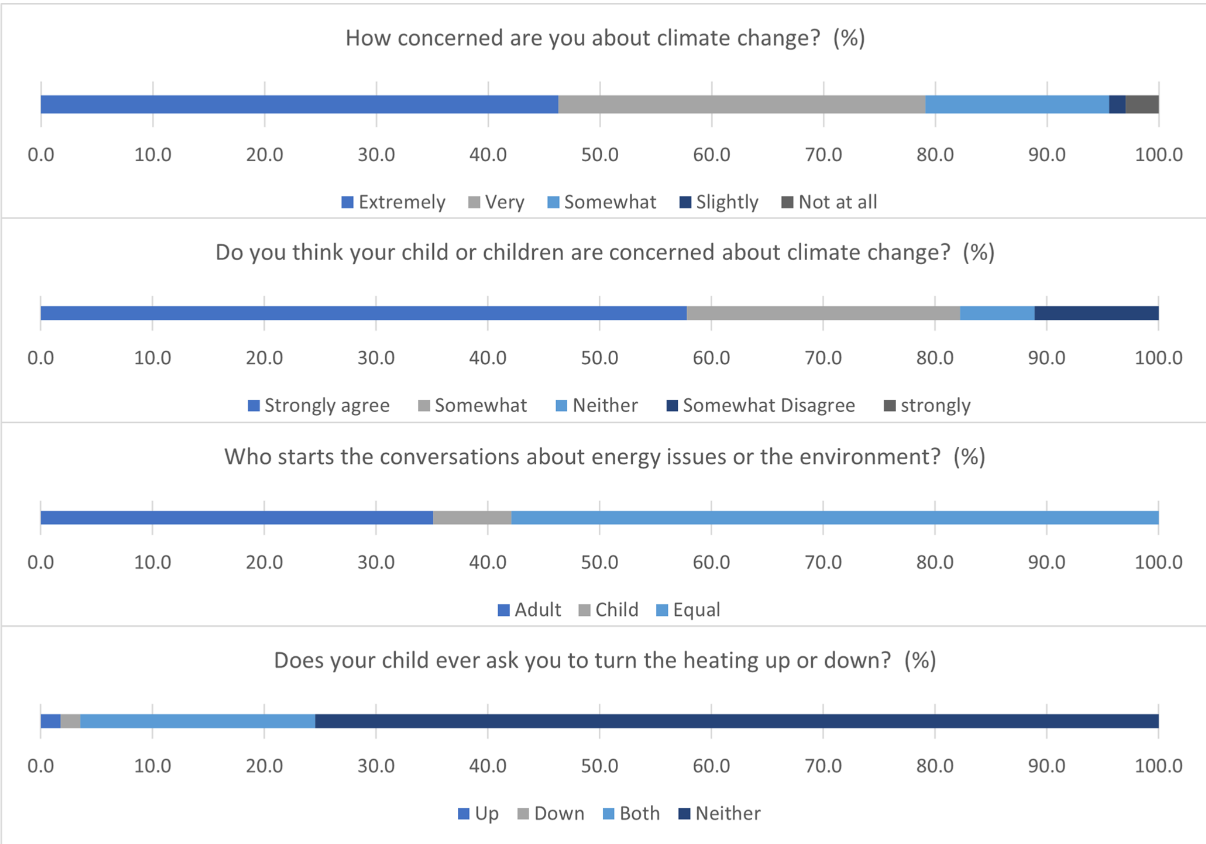


Figure 71: Study 4 Entry Survey Results - Both Schools and All Year Groups - Part 2

For school 1 (Walhampton Prep) a total of 52 participants (out of a total pool of 150 families) completed the initial survey (30% response rate). Two (2) of the 52 respondents stated they did not want their children to participate. Additionally, five (5) surveys were not completed to any level of detail. Thus the final n number was 45. For school 2 (Woodcot Primary), 12 participants (out of a possible circa 200 families) completed the entry survey (6% response rate).

The initial five questions were Likert-style questions with a 5-point scale answer. These have been grouped in figure 70. It can be seen from the first question's results that over 60% of participant parents stated their children 'infrequently or almost never' influence energy decisions in the home.

Similarly, around 50% of the participants stated that they 'infrequently or almost never' have discussions with their children about climate change. The largest response was 'frequently' with 40%, but 'almost always' was small at 5%. This question is a good baseline to attempt to improve upon with the study.

There are more people who 'almost always' and 'frequently' consider financial impacts when using their heating relative to considering environmental impacts. 'Almost always' is approximately 40% for cost, but only at 15% for environmental concern. This is in line with the literature of Barrow et al(1989) and Baker (2008) [Barrow and Morrisey (1989)] [Baker and Rylatt (2008)].

Interestingly, 70% of participants stated they 'frequently' consider the environment when making daily decisions. This would suggest an already positive approach by adults in this regard. This may however not occur within the home, but is likely considered with single-use plastics, travel or general behaviour.

Stated concern for climate change is high amongst parents, with 45% stating they are extremely concerned and around 30% stating they are very concerned (figure 71). Similarly, the parent's perceived idea of their children's concern for climate change is also high, in fact showing 55% of parents think their child is concerned about climate change and a further 30% somewhat agree that their child is concerned with climate change.

Regarding initiating the interaction, the majority of parents stated that it was equal between child and parent (55%), with the smallest amount (10%) stating their child predominantly initiates the interaction and around 35% of parents stating they start the conversation.

It can be seen in Figure 71 that a significant 75% of participant adults stated that their child 'neither asks for heating to be increased or decreased' – again, a large amount of potential influence that is yet to be utilised within the home to mitigate energy over-consumption. 20% stated that their child asks for the heating to be 'both increased and decreased' on occasions with 'up only' and 'down only' equally receiving 5% of the answers.

Below in Figures 72 to 80. The initial survey results have been divided between the control group and the intervention group. 15 responses were from the control group and 42 from the intervention group.

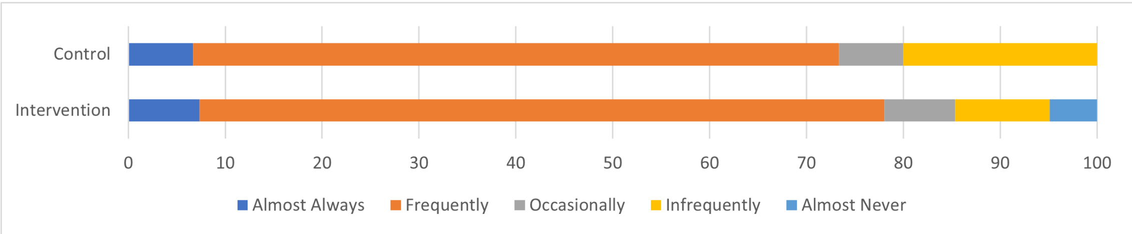


Figure 72: Study 4 Initial Survey Comparison - Control + Intervention - Do you consider environmental impacts when you make decisions in your daily life? Diet, Driving, Lights etc. . . (%)

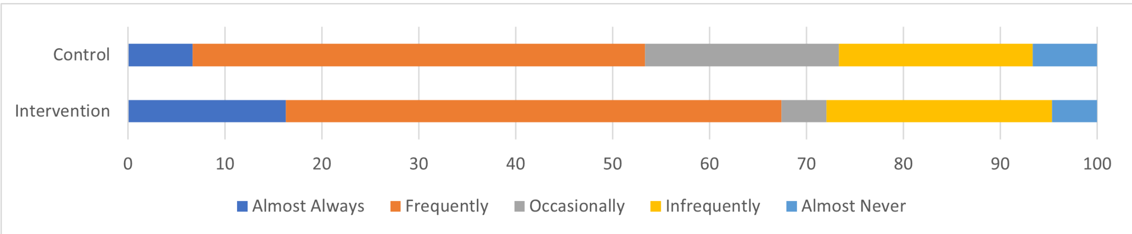


Figure 73: Study 4 Initial Survey Comparison - Control + Intervention - Do you think about the environmental impacts when using your heating? (%)

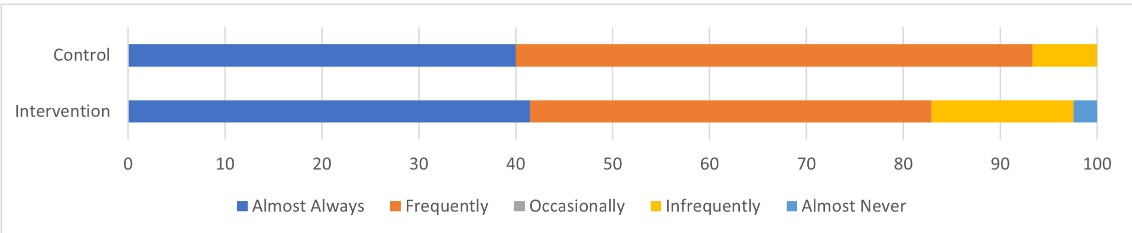


Figure 74: Study 4 Initial Survey Comparison - Control + Intervention - Do you think about the financial cost impacts when using your heating? (%)

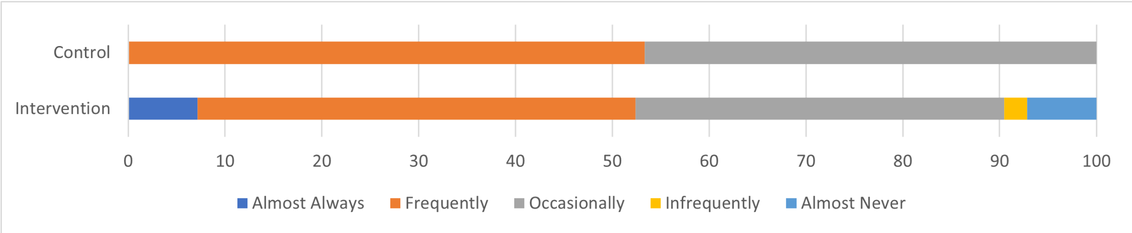


Figure 75: Study 4 Initial Survey Comparison - Control + Intervention - Do you have discussions with your child or children about climate change or the environment? (%)

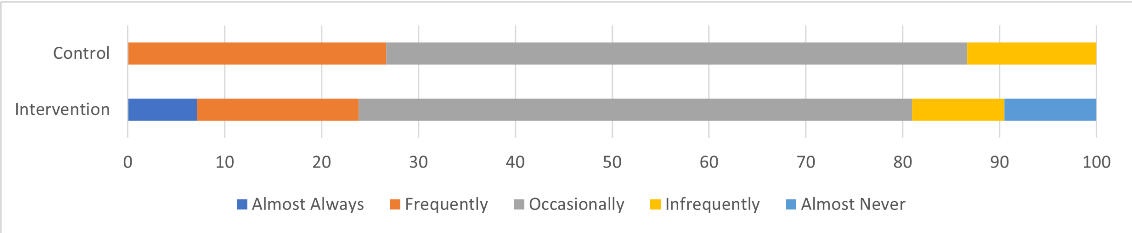


Figure 76: Study 4 Initial Survey Comparison - Control + Intervention - Do you think your child or children influence your energy usage decision-making in the home? (%)

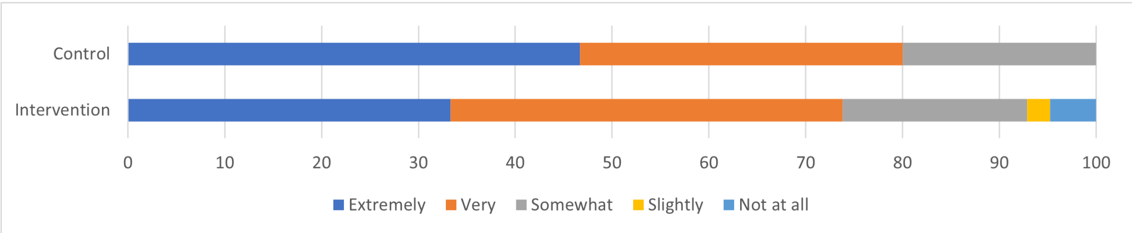


Figure 77: Study 4 Initial Survey Comparison - Control + Intervention - How concerned are you about climate change? (%)

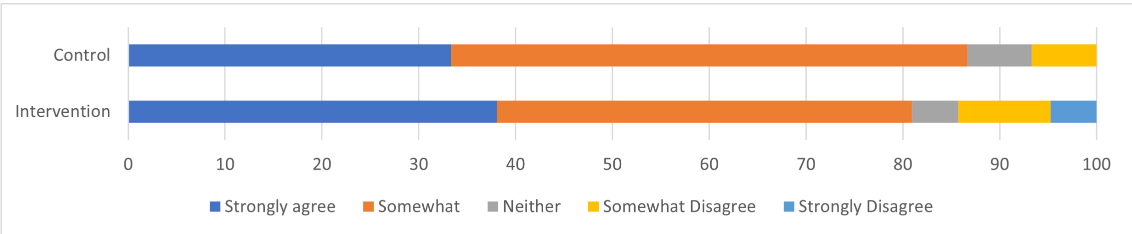


Figure 78: Study 4 Initial Survey Comparison - Control + Intervention - Do you think your child or children are concerned about climate change? (%)

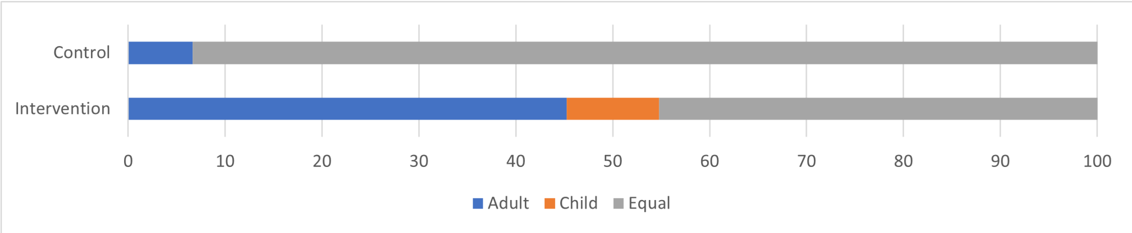


Figure 79: Study 4 Initial Survey Comparison - Control + Intervention - Who starts the conversations about energy issues or the environment? (%)

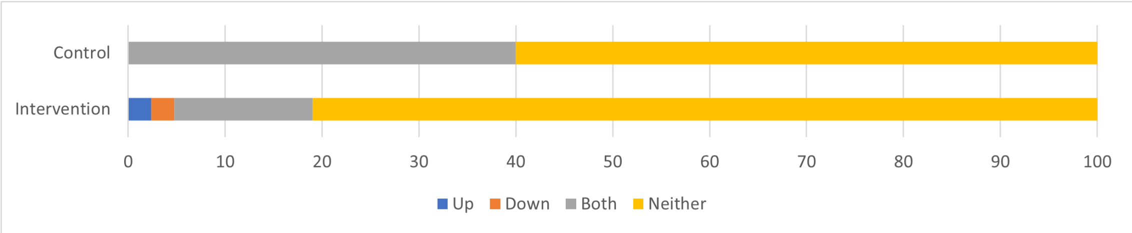


Figure 80: Study 4 Initial Survey Comparison - Control + Intervention - Does your child ever ask you to turn the heating up or down? (%)

Phase 2 Results – Improving Energy Literacy Levels of Children

Children were asked to rank nine items in their homes in terms of energy consumption. Items that used the least energy on the left, and those that used the most on the right. Items on the image and figures (81, 82, 83) below are labelled in the correct order, from left to right, of lowest energy consumed to highest energy consumed.

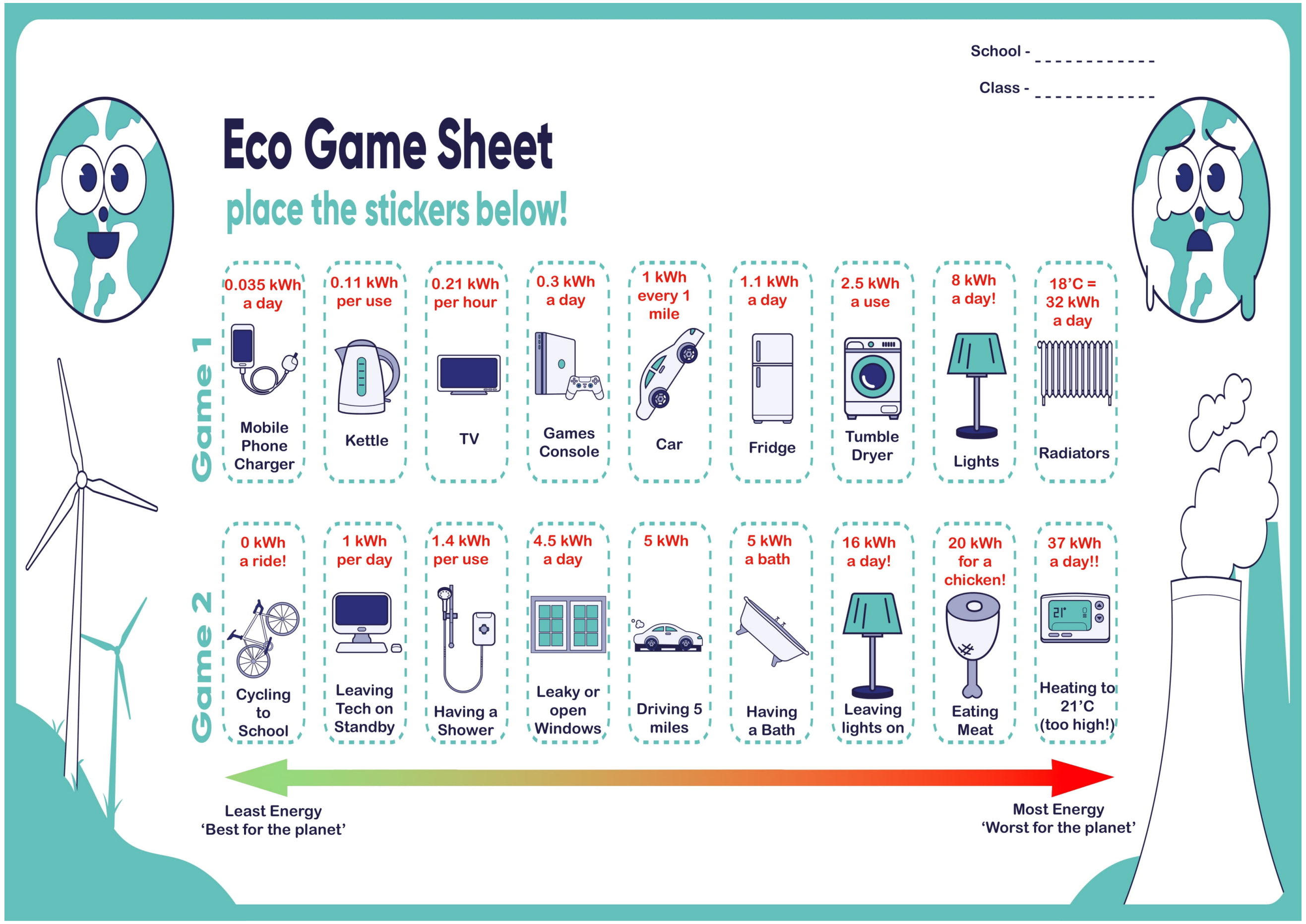


Figure 81: Study 4 Eco Homes - School Lesson Correctly finished Sticker Sheet

‘Score’ is a measure of how many places (or how much ‘error’) above or below an item is placed, relative to the correct placement for each item (which would be a 0 score). This score below zero represents an item’s energy usage being under-estimated whilst scores above zero represent an item’s energy use being over-estimated.

The S curve seen in the results will always be present due to the inherent ranking nature of the game. Phone charger is the least energy-consuming item and, therefore cannot be placed any lower than the correct placement, thus will always score a zero or above. The same is true for the Radiator at the upper end of the scale with a mirrored effect.

<u>Study 4 Classroom Activity - The Energy Game 1 (Items)</u>

The ’Variability of Score’ graphs in the following section have been created from the eco sticker games. Each item or behaviour has a correct place on the order from 1-9 (least to most energy-intensive). If an item is correctly placed, it is assigned a score of 0. If it is placed higher by one position, it is assigned +1, likewise, one position lower assigns a -1. All items and behaviours of all games are given a score and these graphs represent the combined scores of all the children in the group. It is important to note that by using this method for visualisation and analysis, items can be scored differently - Phone Charger can only be between 0 and +8, the car between -4 and +4 and radiators between -8 and 0 because of their different correct (0) positions. When analysing the overall game score (rather than an individual item), averages cannot be used as the plus and minus values cancel each other out, thus the overall score is a measure of only incorrect placings (+3 or -3 would both be a score of 3). This allows for an average score of variability to be made for the overall game (in other terms a score of ’how wrong’ the group was, the closer to 0 the better).

It can be seen at the left-hand end of the scale that ‘Phone Charger’ is the most over-estimated energy consumer in the home, reaching an error of +5 for both schools (the median is also the same), but the scores for Walhampton School show a smaller range between quartiles nearer the centre, showing that a larger percentage of the students at this school were more correct than at Woodcot School.

As mentioned previously, the game is a ranking style game of higher or lower. There are 9 different items meaning an item could be placed in 8 incorrect places and 1 correct place. All item placements for both schools show the maximum variance that is achievable – every single item has at least one answer in every incorrect position - except Woodcot (blue) Games Console which is only in 8 of the 9 possible places.

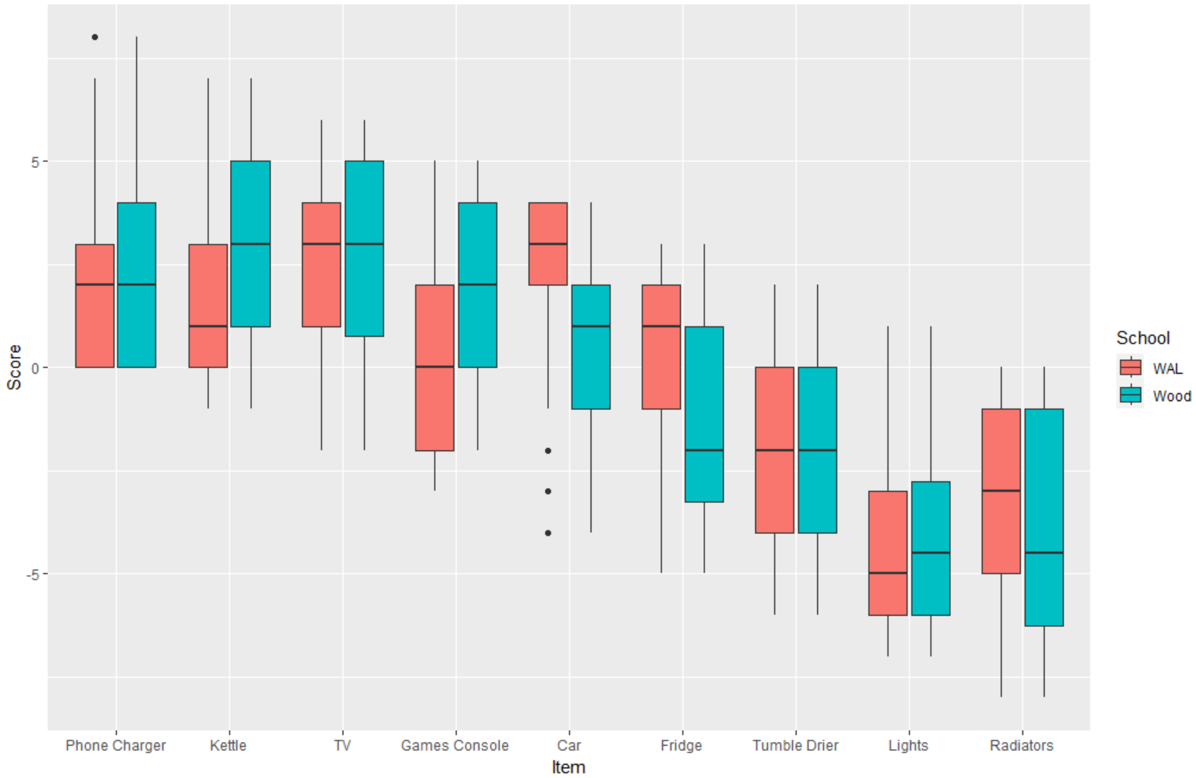


Figure 82: Study 4 Lesson Activity Game 1 - Boxplot of Both Schools - Variability of score. Wal = Walhampton School, Wood = Woodcot School

Although overall variability and medians appear similar in the first half of the items, the quartile ranges of Woodcot (in blue), appear to show a larger over-estimation of error than Walhampton (in red), this is especially prevalent for item number four – Games Console, which is the only item to see a median error score of 0 (correct) in the scores from Walhampton, whereas Woodcot scored around 2-3 places higher than this (over-estimating these items).

The pattern then shifts for the central items – Car, Fridge + Tumble Drier, which show Walhampton School (red) over-estimating item usage more than Woodcot (blue). The Item 'Car' is especially interesting in that it is the only item that has no overlap in central quartiles between the two schools. Walhampton significantly overestimates car energy consumption compared to Woodcot. Fridge also sees the second largest difference in medians between the two schools, whereas Tumble Drier is the only item to see perfectly matching results. These are both large white goods with similar average energy consumption over the year, but the school children have scored them quite differently.

At the right of the graph, with high energy-intensive items, 'Lights' are similarly highly underestimated by students from both schools. Lights see the lowest Median of all items, suggesting they are the most under-estimated item and the quartile range drops below the expected S-Curve that is produced from a ranking game. Radiators, the largest energy consumer in the UK home, show a median of circa -3 or -4 for both schools, almost as under-estimated as the previous Lights. The interquartile range almost reaches 0, far higher than Lights.

Study 4 Classroom Activity - The Energy Game 2 (Behaviours

Game 2 took place after the lesson had been completed by the teachers in the class. The second game aimed to measure the attainability of the knowledge and understand whether the energy literacy levels of the students had improved. If the scores were close to 0 in this second game, then it could be considered that the lesson had indeed taught children knowledge.

To be a true test of improvement, the questions would ideally be identical to the initial game before the lesson intervention. However, as the children had been shown the answers (which formed part of the follow-up discussions) and to mitigate any boredom or lack of enthusiasm towards the lesson, a slightly altered version of the game was presented to the children.

The second game looked at behaviours in the home rather than items in the home; a 'light' became 'leaving lights on', a 'car' became 'driving 5 miles', and a radiator became 'overheating a home'. This way knowledge that had just learnt about the items could be applied to the second sticker game and children would potentially understand the same differences between energy consumption.

It can be seen from the overall boxplot that the S-Curve previously discussed is still prevalent, but some behaviours stand out and diverge from the expected trend.

Almost every single child in Walhampton (red) chose to place Cycling in the correct place as the lowest consumer of energy. Woodcot student results form a more normal range of variability. The median for this school is only at +1 score, with the quartile range only reaching +3, thus most of the students were almost correct in placing this behaviour.

Stand-by results are almost identical for both schools; mean, quartile range and upper limit match perfectly. This behaviour sees a larger overestimation than all others. This may be due to the technology-centric lifestyles that children now live, thus they think they use a lot of energy.

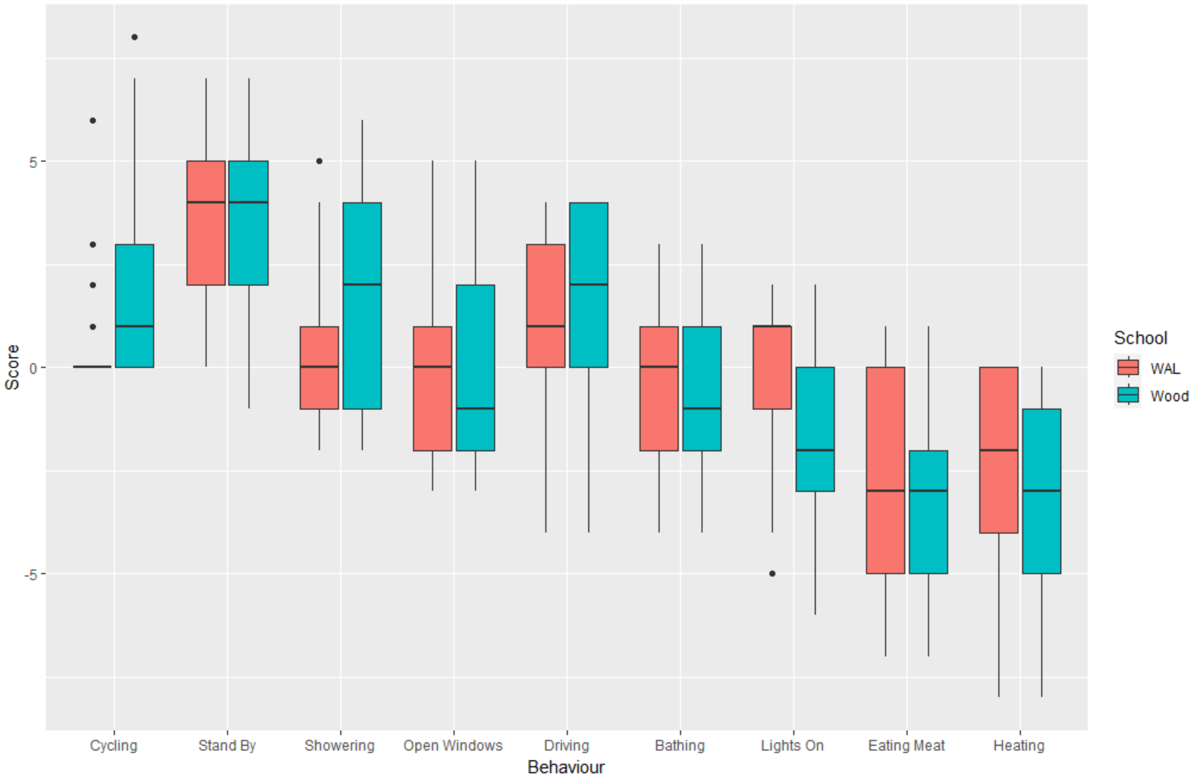


Figure 83: Study 4 Lesson Activity Game 2 - Boxplot of Both Schools - Variability of score. Wal = Walhampton School, Wood = Woodcot School

Showering varies considerably between the two schools, Walhampton having the smallest quartile range for this behaviour compared to any of the two school's behaviours. The median is exactly 0 suggesting the range of answers is well balanced. Woodcot on the other hand sees a much wider quartile range and the median is located on the score of +2. This quartile range is the largest of any boxplot, suggesting there was no obvious place for this behaviour to be ranked.

Open Windows continues the downward trend expected, but this is the first behaviour that Woodcot (blue) has a lower median than Walhampton, but both remain relatively similar. Driving does not follow the predicted S curve that is to be expected, but instead, the quartile ranges for both schools are above 0 and above the previous two behaviours, with medians reaching +1 and +2 for Walhampton and Woodcot respectively.

The next behaviour, Bathing, continues the downward pattern and is similar in results to that of Open Windows, reaffirming Driving as an outlier. All behaviours to the right of this one follow the same pattern of Woodcot (blue) under-estimating the energy consumption by higher rates than Walhampton (red). Leaving Lights on is the only behaviour that sees the median of two schools be positioned on either side of the correct central 0 line; Walhampton at +1 whilst Woodcot at -2. This is also the largest disparity in any behaviour between the two schools.

Eating Meat has the largest quartile range of any behaviour for Walhampton School, yet Woodcot's range is the joint smallest for that school. Both schools however underestimated the energy consumed with this behaviour. This would suggest that the children are relatively uninformed about the farming and agricultural sectors. Heating shows almost identical median scores to Eating Meat, with the medians being -2 and -3 for Wal + Wood respectively. At least one student at both schools placed the behaviour as the lowest energy consumer.

Phase 3 Results – Opportunity for Inter-Generational Interaction

All children who took part in the classroom intervention were allowed to take home another full game to play with their parents. This was the proposed intervention to cause potential inter-generational interactions to occur and ideally transfer energy knowledge from young to old.

The parent's game was identical but also included a sealed folded sheet with the correct answers to look at after the game had been completed, along with a QR code to log their results and thoughts.

<u>Study 4 Take home activity (with parents) - The Energy Game 1 (items)</u>

The above box plot shows the results of Game 1 for all children (both schools + all ages) aligned with the results from all adults (both schools). Only 'Kettles is the same for both groups of participants, all other items vary, with some showing stark differences. Overall, the adult scores are closer to correct (a score of 0) than the score of the children – when totalling how far from 0 each item's median is, the adult total is 9, whereas the children's is 21.

Starting at the far left of the chart, it can be seen that 'Phone Charger' was far more overestimated by the children than by the adults. All adults (bar one outlier) placed the phone charger in its correct place (first) or one place too high (second), whereas the children placed the item in all places from first to ninth with the median on a score of +2 compared to 0 on the adults (correct placement).

Kettle, as aforementioned, interestingly shows identical results for both adults and children. Adults over-estimated the energy used for this item more so than any other; with scores reaching +7, meaning some adults placed it at the far right, in the highest spot for

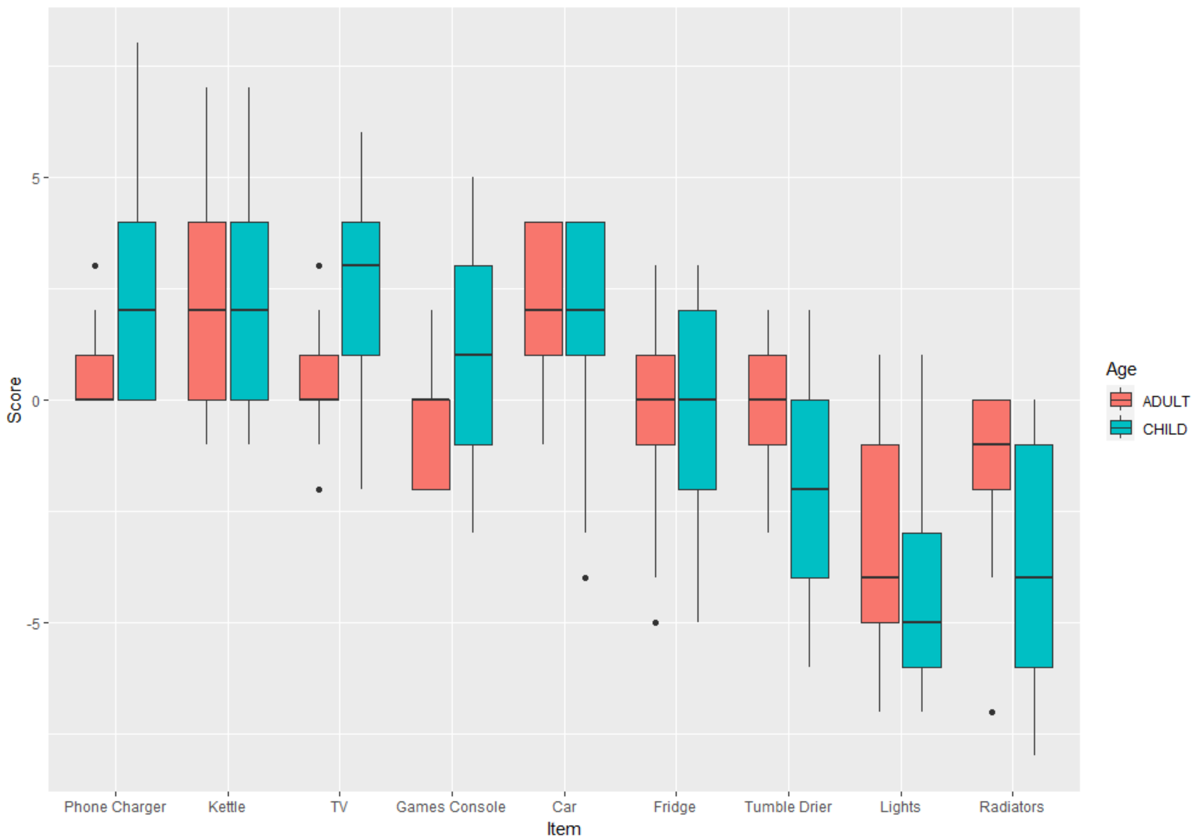


Figure 84: Study 4 Take Home Activity Game 1 - Boxplot of Children vs Parents - Variability of score. Includes all participants from both schools. Child n=179, Adult n=41

the game. This will be analysed further later.

TV, similarly to the mobile phone charger, was placed correctly by the majority of the adults. The median was again at 0 (correct) with the interquartile range only from 0 to +1. Games console results varied between adults and children, with adults underestimating the energy consumed and children overestimating it. This item seems to go against the trend that is seen in the previous items of slightly over-estimating.

Car, as the central (5th of 9) item has an equal chance of being over or underestimated by participants. In this case, the adults have over-estimated the energy requirement of cars by around +2 places (median) with scores ranging from -1 to +4 and the interquartile range located all positively, between +1 and +4.

Children and Adults similarly underestimated how much energy the fridge consumes with adults underestimating it to a lesser amount. This appears to be similar among all items. In this case, the range from highest to lowest scores is the same as children (bar an outlier), but the interquartile range is smaller (half the size – 2 scores instead of 4).

Energy consumption of a tumble drier was also underestimated by both groups, but again, less so by adults, whose median is correctly on 0 again. Lights is once again a very similar story, but this box plot is the most variable of all the adult items with an interquartile range of 4. The plot also indicates that this item was placed at least once in every position amongst all the adults, suggesting that the consumption of this item is more unknown than others.

Interestingly, Radiators, who scored very poorly with the children severely underestimating the energy consumption, actually only scored slightly lower than correct with a median of -1 and the most incorrect score only being -4 (of a possible -8). This is likely due to adults having a connection with heating - the bill - this will be discussed later.

Study 4 Take home activity (with parents) - The Energy Game 2 (behaviours)

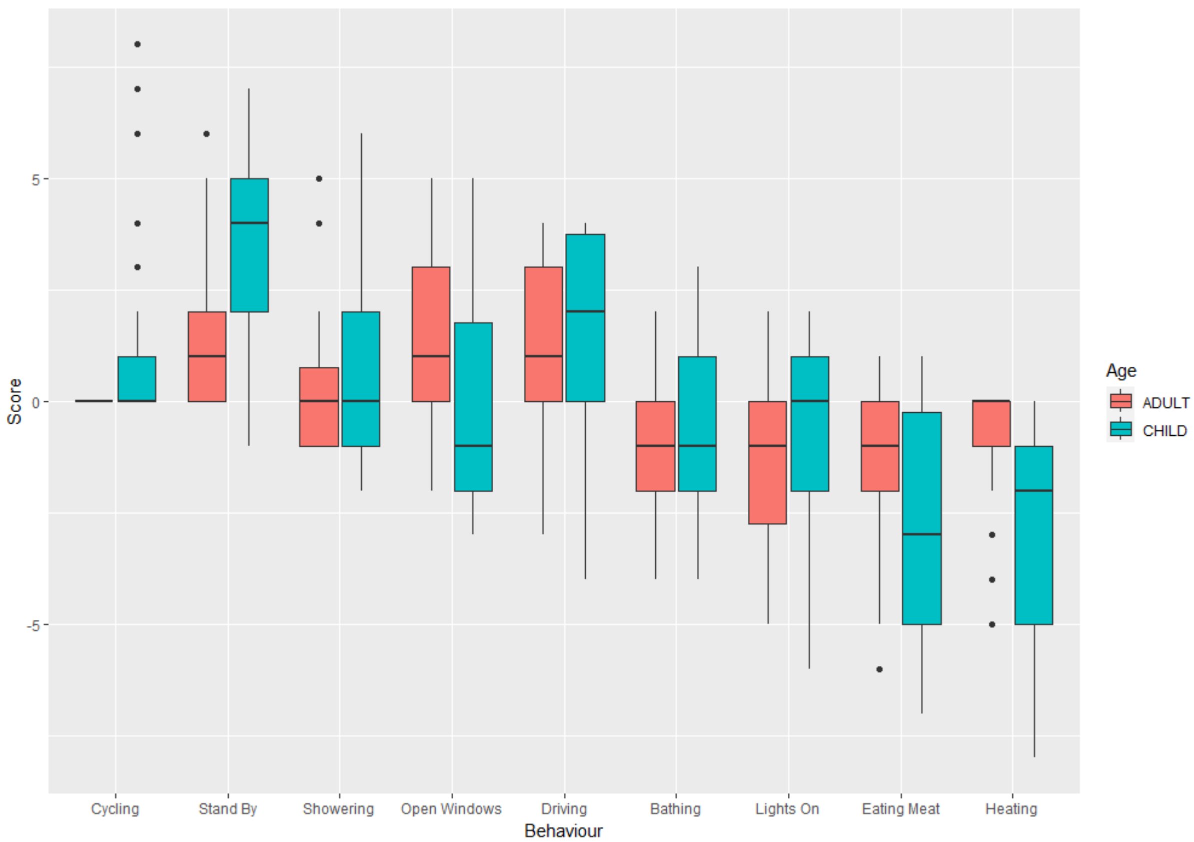


Figure 85: Study 4 Take Home Activity Game 2 - Boxplot of Children vs Parents - Variability of score. Includes all participants from both schools. Child n=182, Adult n=38

Every single adult was able to correctly place ‘cycling’ as the lowest energy-consuming behaviour within game 2. This is the only item or behaviour for which this occurred. Leaving Tech on Standby was the second lowest consuming behaviour, but this was placed in every sport up to +7, meaning one adult thought this was the largest consuming behaviour in the home.

Showering sees the median fall exactly on 0 and the interquartile range being between -1 and +1, suggesting that this behaviour was well placed almost correctly by most. Two outliers are +4 and +5, but these are still within the child’s range of answers, which were far more variable. Showering does not quite fit the expected S-Curve pattern and sits lower (more underestimated) than the behaviours on either side.
Leaving Windows Open and Driving are the next lowest consuming behaviours, and both score very similar in the adult game. The median for both is +1 and the interquartile range for both is between 0 and +3. Both behaviours have been scored more correct than within the children’s game.

Bathing is the first median to drop below 0 to -1, expected due to the inherent S-curve, but the adult scores are very similar to that of the children’s, with identical Medians at -1 and interquartile and overall range only differing by +/- 1 score. This is the most similarly scored item or behaviour throughout the two games, suggesting that both adults and children understand the energy behind bathing, especially relative to showers. This behaviour sees the start of the downward S-curve emerge.

Leaving lights on continues the S-Curve with Adults also having more incorrect median for the first time. Scoring -1 compared to the children’s 0, suggests adults underestimate the energy usage of lights more so compared to children. Overall, the interquartile range is an identical size and adults score better by only one position in the overall range.

The behaviour ‘Eating Meat’ is far more correct in the scores by the adults than the children. The median is at -1 and the interquartile range is from 0 to -2; less than half the size of the children’s. Finally, Heating, which is the behaviour that requires the most energy in the home, scores very well, with adult data showing a median of 0 (correct) and the interquartile range from 0 to -1 being the second smallest only after cycling. This is far more accurate than the children’s results, which is to be expected from the literature suggesting adults are more likely to be in control of this aspect of the home.

Phase 4 Results – Reassessing Opportunity for Inter-Generational Interaction

Once the game was completed, the parents/carers were provided access to a short survey form in which they could feedback on any points relevant to the study (as well as log their scores of the game). The following charts show the results of this survey. The first question asked the parents which item and behaviour surprised them the most, both for being surprisingly high or surprisingly low.

Study 4 Take home activity (with parents) - Surprising Items from game 1

It can be seen in Figure (86) below that Lights was the most surprising item (with 26 votes) when parents were asked 'Which item surprised them with how high it was?' This question allowed the participants to select as many options as wished. This was followed in second place by Radiators (with 17 votes). Five other items all scored less than 5 with TV and Fridge not being mentioned at all. There is a large difference between the two main home energy consumers and all the other items in the home. This would suggest that people are unaware of the significantly larger impact that lighting and especially heating have on energy use.

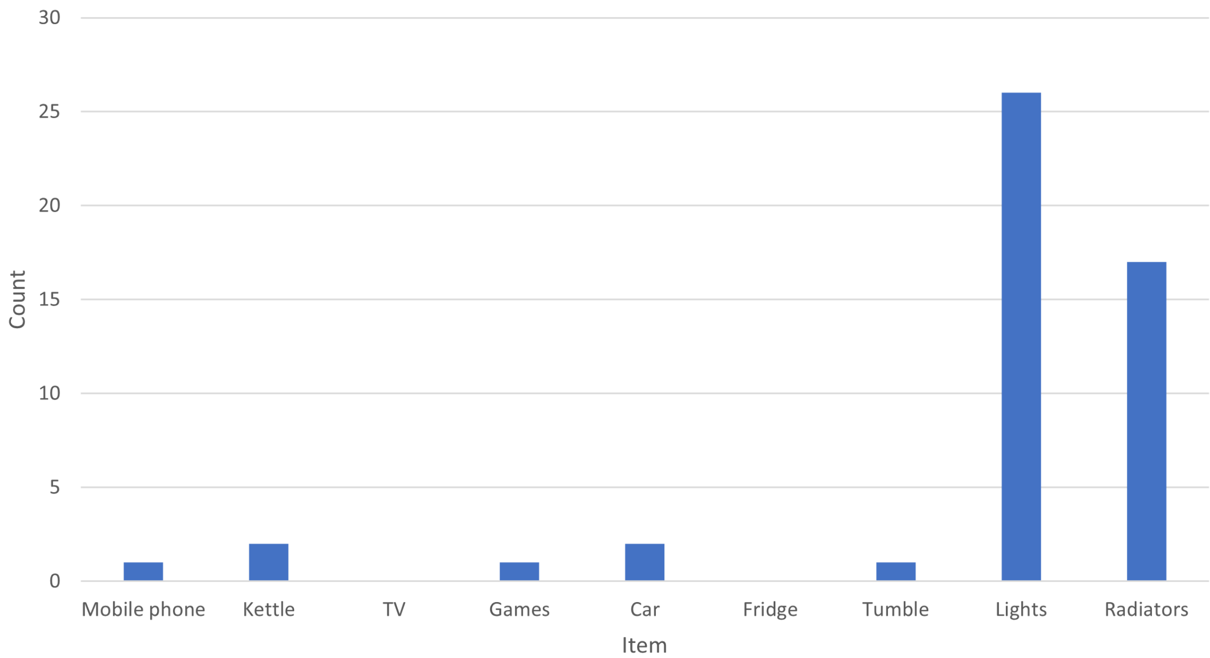


Figure 86: Study 4 Take Home Activity Parental Survey - Surprisingly high energy use items from game 1 (Both schools) (n=41)

Figure 87 below shows the results of the question ‘What items surprised you with how low they were? It can be seen that these results are far more variable than the ’high’ results shown above.

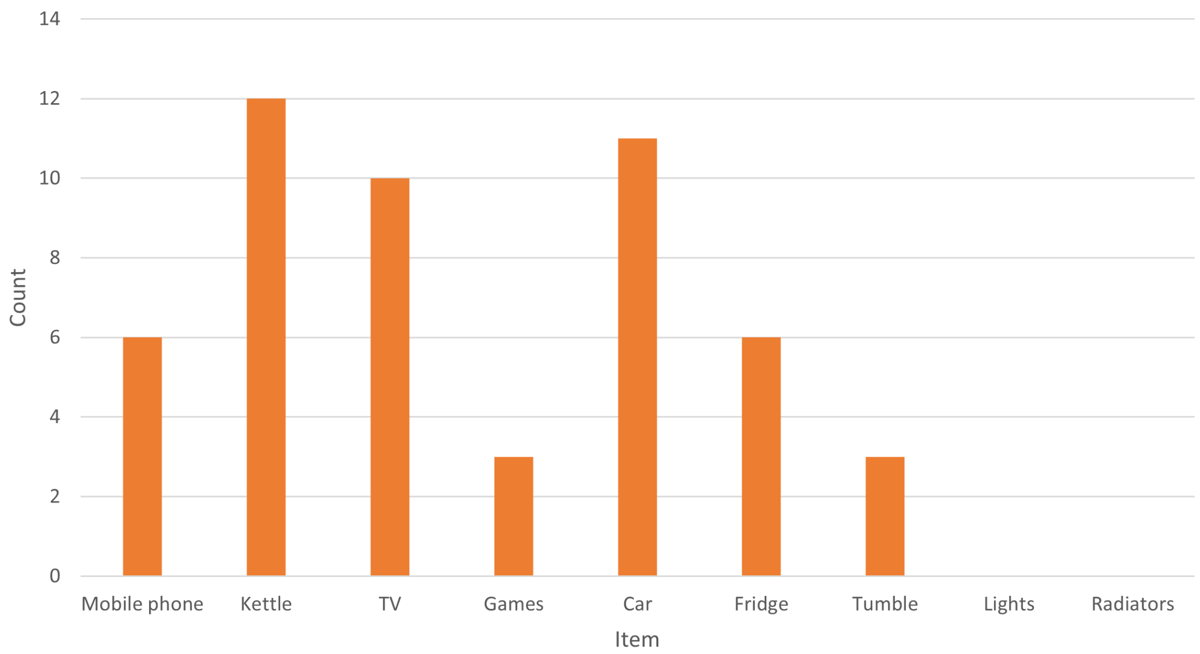


Figure 87: Study 4 Take Home Activity Parental Survey - Surprisingly low energy use items from game 1 (Both schools) (n=41)

The kettle is the most reported item in this graph, with ’Car’ and ’TV’ also scoring highly. These are commonly used items by adults in the home so these results could be expected. The UK government has also run a campaign aiming to ’only boil the water you need’ in recent years [Davies (2012)], which may explain why parents are most surprised by this item.

Lights and Radiators do not score on this graph, which makes sense following the previous questions, however, it is interesting to see that five of the nine items feature on both low and high surprise graphs. This demonstrates how energy literacy levels differ among the participants in this study.

Study 4 Take home activity (with parents) - Surprising Behaviours from game 2

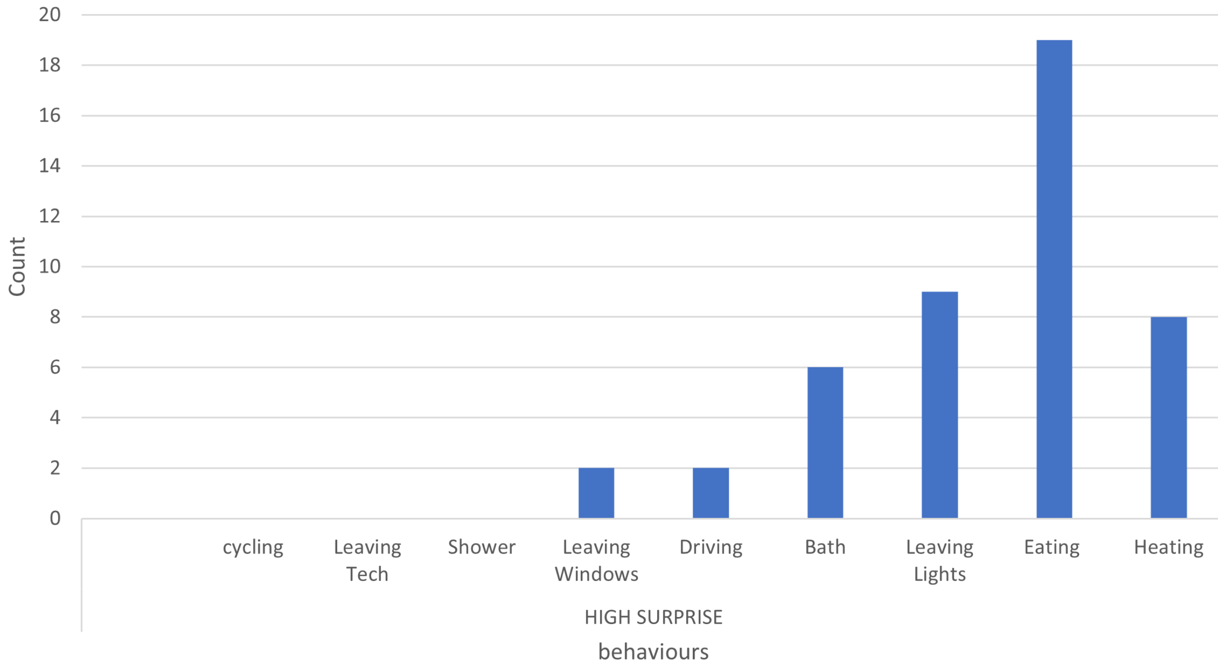


Figure 88: Study 4 Take Home Activity Parental Survey - Surprisingly high energy use behaviours from game 2 (Both schools) (n=41)

Figure 88 above shows the results to the question 'What behaviours surprised you with how high they were? It can be seen that 'Eating Meat' surprised the largest number of people. Heating aside, the results create the expected curve, with higher consuming behaviours presenting themselves as more surprising. As aforementioned, heating does not follow the upward trend, but this may be because participants have already played the first game in which it was the highest consumer, thus are less surprised the second time around.

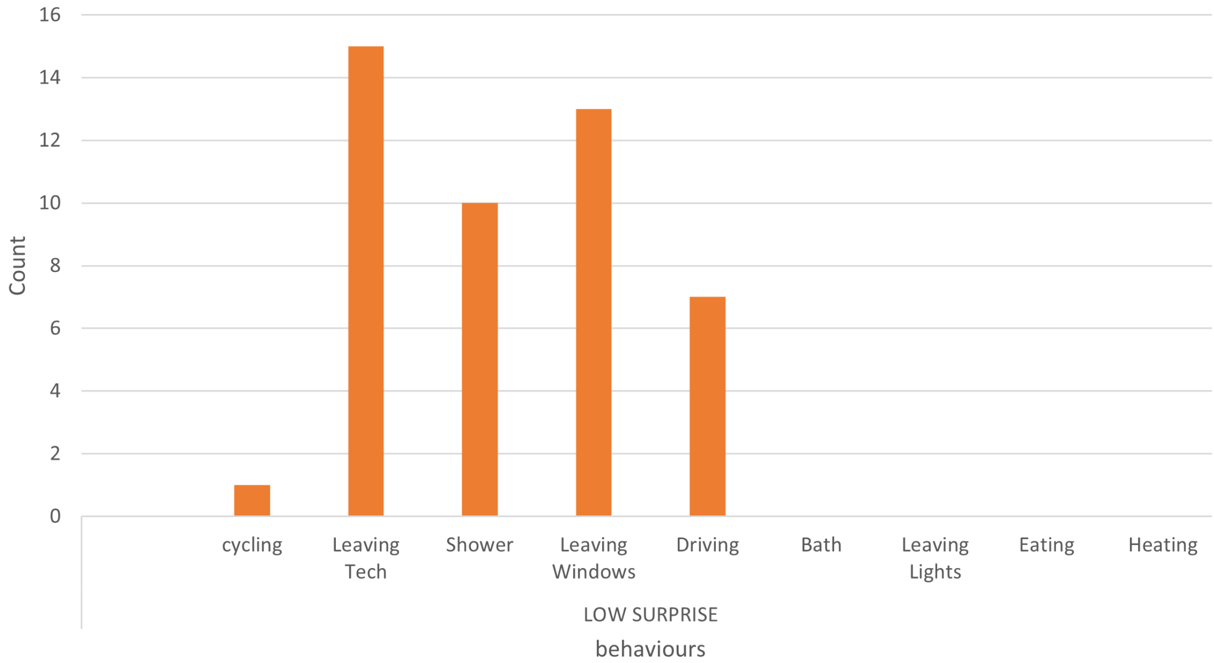


Figure 89: Study 4 Take Home Activity Parental Survey - Surprisingly low energy use behaviours from game 2 (Both schools) (n=41)

Figure 89 above shows the results to the question 'What behaviours surprised you with how low they were? Interestingly, leaving tech on standby surprised the most participants with how low its energy consumption is. This, similar to kettle usage, is likely due to government campaigns to turn items off rather than leaving them on standby [HM Government (2024)].

Linked indirectly to space heating of homes is the effective use of openings - leaving windows open or having a leaky draft in the home can lead to more requirements to heat, which participants seem to understand and are surprised at how low this behaviour is.

A theme is emerging of government campaigns or initiatives to educate the population on emissions; vehicles have been publicised greatly with the current transition to electric vehicles and it is apparent in this data that participants are once again surprised at how low the energy consumption from their car is compared to other behaviours in the home. This graph is a good demonstration of the information that the UK population need to be informed about to reduce emissions most effectively. Of course, there is more to the story than simply carbon emissions, reducing particle emissions and plastic use is also required for example.

Parental Survey Results

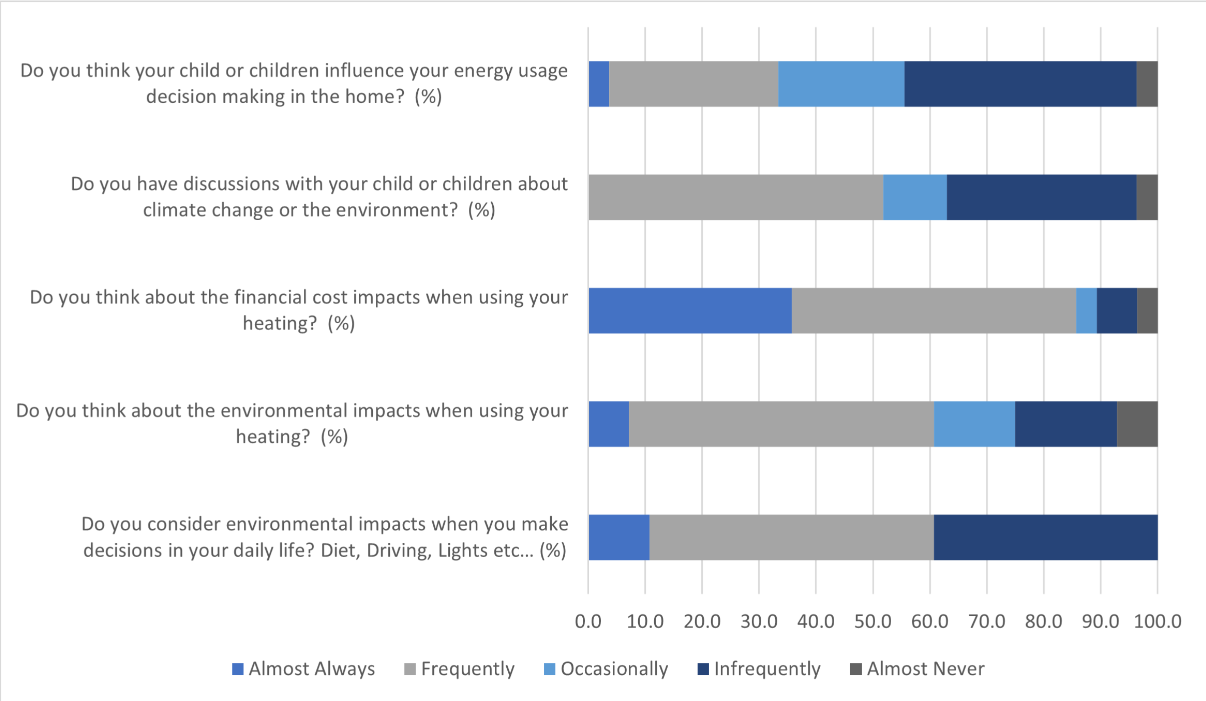


Figure 90: Study 4 Final Survey Results - Both Schools All Years - Part 1

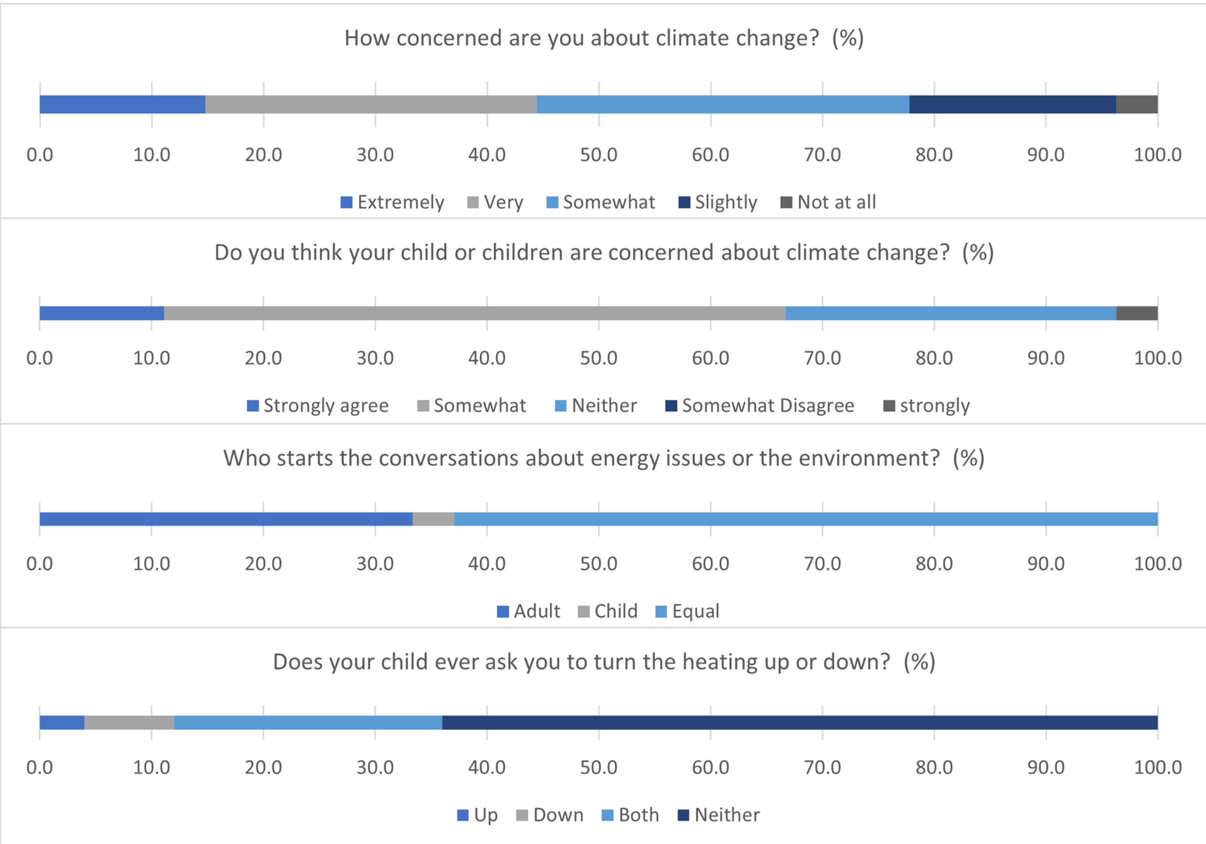


Figure 91: Study 4 Final Survey Results - Both Schools All Years - Part 2

For school 1 (Walhampton Prep) a total of 14 participants (out of a total pool of 150 families) completed the initial survey. For school 2 (Woodcot Primary), 24 participants (out of a possible circa 200 families) completed the entry survey. This gives a total of 38 surveys to be analysed.

Children's influence on energy usage decisions shows that 'Occasionally' or more positive makes up just over 50% of the answers, with 'Infrequently' being the largest choice at around 40%.

The discussions with child questions have seen a positive return, with 'Infrequently and Almost never remaining the same as in the initial survey, but 'Occasionally' and 'Frequently' increasing to make up approximately 65% of the feedback now.

Financial influence on heating remained almost identical to the initial survey, but environmental influence has seen a decrease in positive results, with 'Almost Always', and 'Frequently' both decreasing in choices slightly and the more negative choices (Occasionally, Infrequently and Almost Never) all increasing in return.

Environmental influence in daily life has also seen a negative change to the results, with 'Infrequently' increasing from 10% to 40% of results. However, 'Almost Always has seen an increase from 5% to 10%.

Moving onto part 2; concern regarding climate change has seen a similar negative change, with 'Extremely' reducing from 45% to 15%, Very remaining the same, Somewhat increasing from 15% to 30% and Slightly increasing from <5% to 20%.

Child's perceived concern regarding climate change has also seen a negative shift. Initially, Strongly Agree was at 55% but has now reduced to 10%, with most of these respondents appearing to now choose Very or Somewhat.

The 'conversation started by whom' question sees 65% of participants state 'equal' and only around 5% state the 'child'. This does not suggest a good level of success for the study when considered by itself, especially noting that adult only has not changed.

The final question - request to change heating up or down, has produced results that are under-whelming in terms of success for the study. It shows very little change; 'neither' has decreased from 75% to 65%, 'down' has increased by less than 5%, 'Up' has actually increased by the smallest of margins and 'Both' also has increased by the slightest.

The parents were then asked the same two open-text questions as the participant parents in Study 3. The results of these can be seen below:

Can you give an example of something you have learnt in the box below?

- We turned the heating a bit lower, also when we can we walk/ ride a bicycle to school
- If we drive less it will help climate change
- Lights off
- changing lights and changing our car

Can you give an example of a change you have made in the box below?

- heating was so bad
- A shower uses less than a bath
- It was interesting what used more energy
- There were some impacts I was surprised by in the sticker game
- Our house will be flooded in the next 7 years if no action is taken.

Finally, a feedback question was then asked of the parents and they could fill in the box with open text. Unfortunately, all three responses were simply different ways of saying they had no feedback or didn't take part.

Figures 92 to 100 below show the final survey results divided between the control group and the intervention group. N=13 responses were from the control group and N=15 from the intervention group.

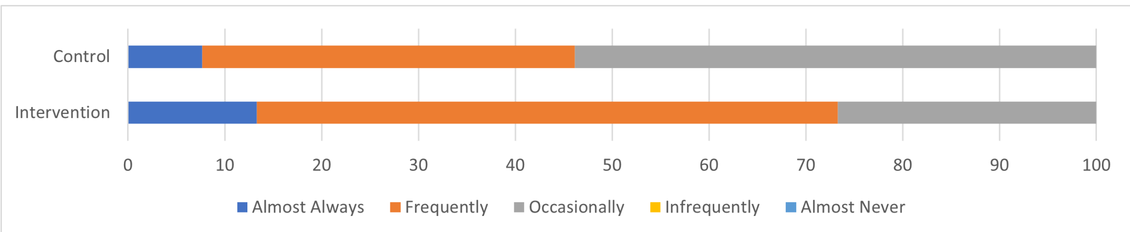


Figure 92: Study 4 Final Survey Comparison - Control + Intervention - Do you consider environmental impacts when you make decisions in your daily life? Diet, Driving, Lights etc... (%)

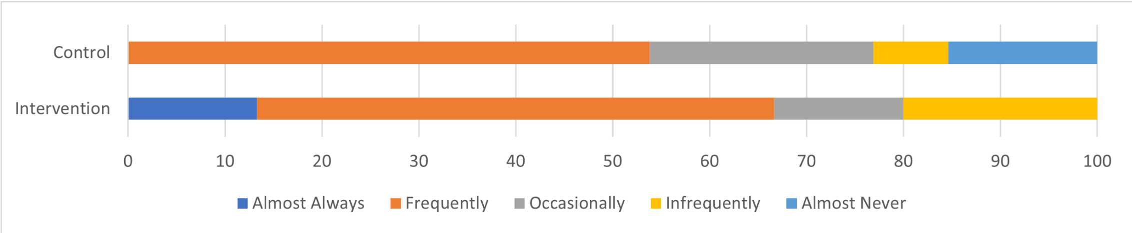


Figure 93: Study 4 Final Survey Comparison - Control + Intervention - Do you think about the environmental impacts when using your heating? (%)

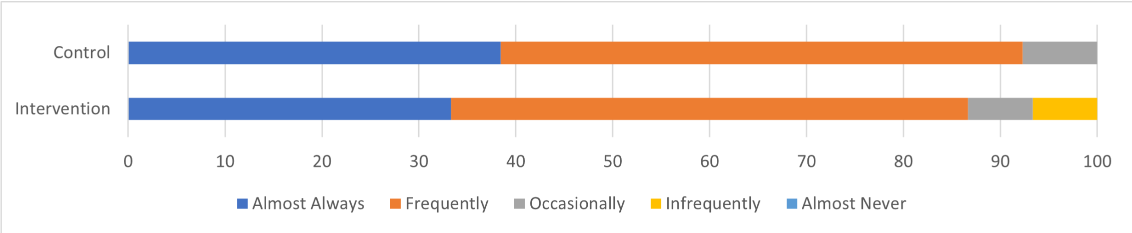


Figure 94: Study 4 Final Survey Comparison - Control + Intervention - Do you think about the financial cost impacts when using your heating? (%)

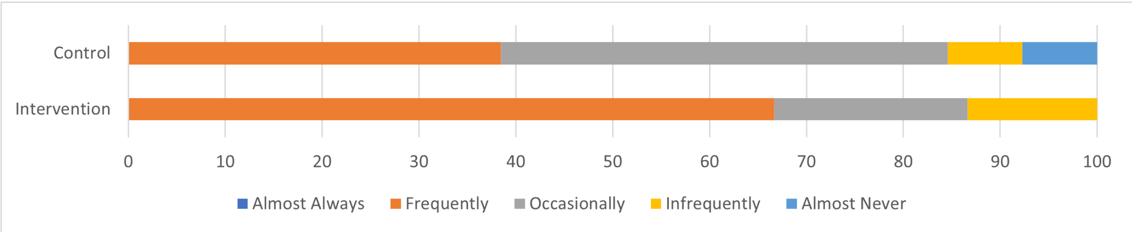


Figure 95: Study 4 Final Survey Comparison - Control + Intervention - Do you have discussions with your child or children about climate change or the environment? (%)

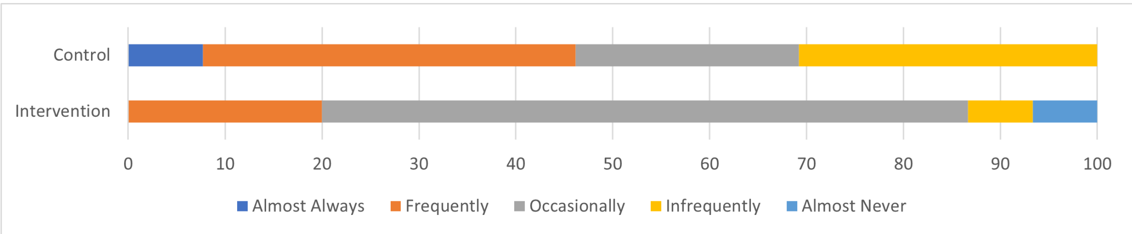


Figure 96: Study 4 Final Survey Comparison - Control + Intervention - Do you think your child or children influence your energy usage decision-making in the home? (%)

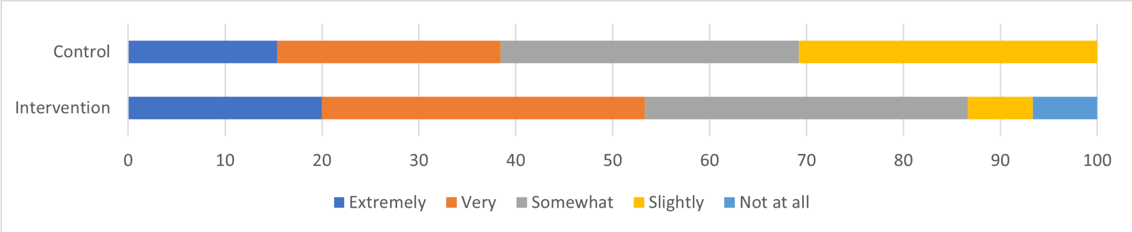


Figure 97: Study 4 Final Survey Comparison - Control + Intervention - How concerned are you about climate change? (%)

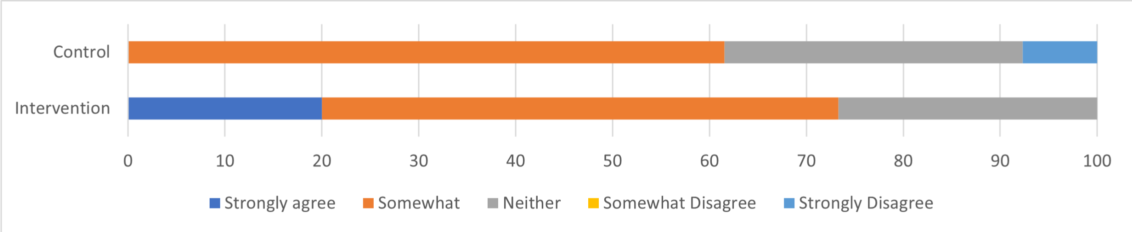


Figure 98: Study 4 Final Survey Comparison - Control + Intervention - Do you think your child or children are concerned about climate change? (%)

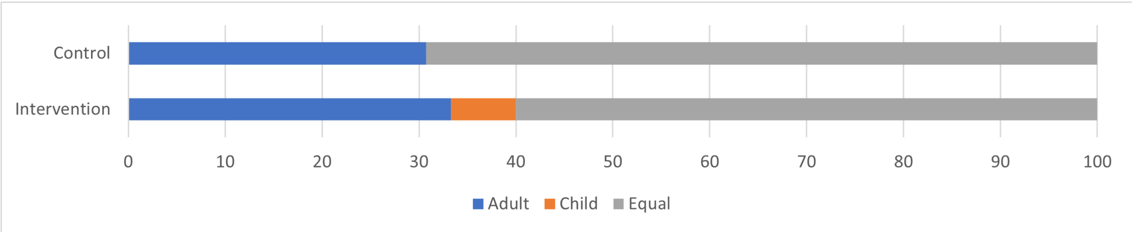


Figure 99: Study 4 Final Survey Comparison - Control + Intervention - Who starts the conversations about energy issues or the environment? (%)

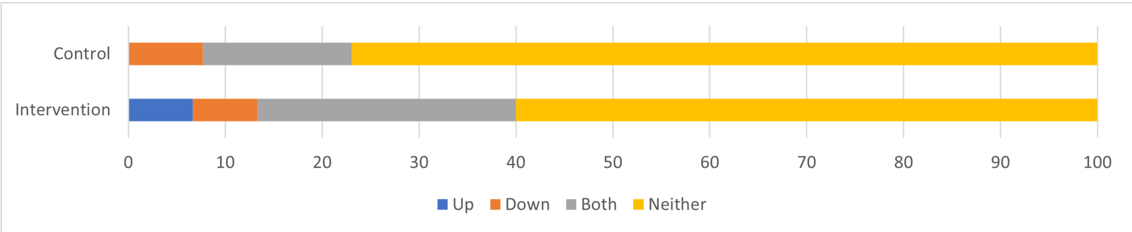


Figure 100: Study 4 Final Survey Comparison - Control + Intervention - Does your child ever ask you to turn the heating up or down? (%)

Phase 5 Results – Additional Longitudinal Interaction and Assessment

The final number of participants that completed the longitudinal game was n=3. For this reason, the results section will simply list the questions and answers below. The data has also been added to the Score Variability graphs, but the statistical power is very low. These can be seen in the two Figures below (101 and 102):

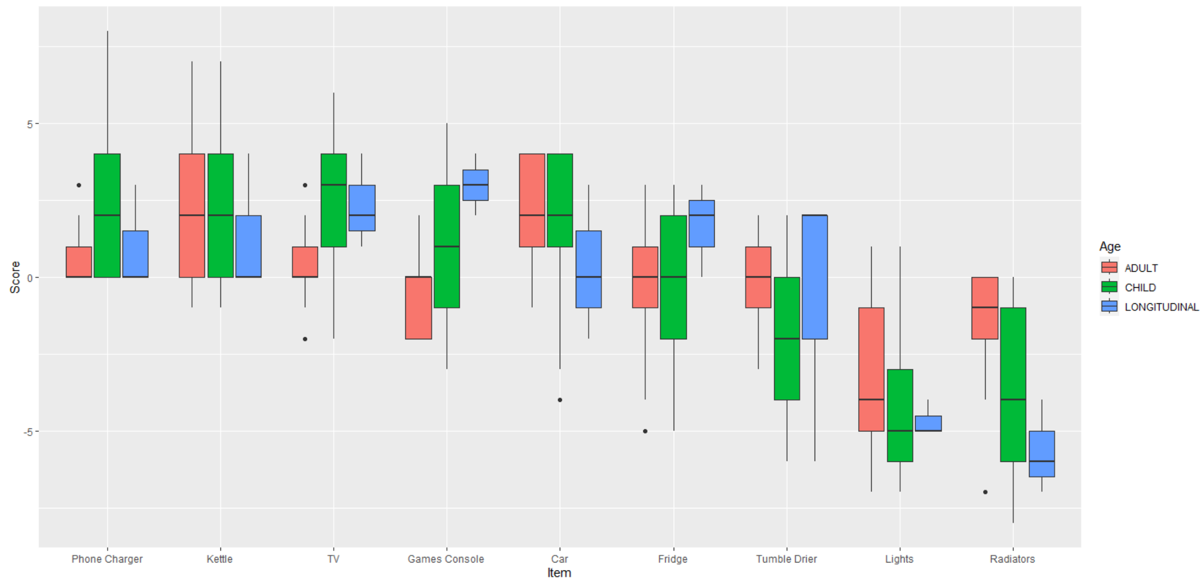


Figure 101: Study 4 Longitudinal Card Game Results added to Score Variability Graph - Game 1 Items - Both Schools All Years

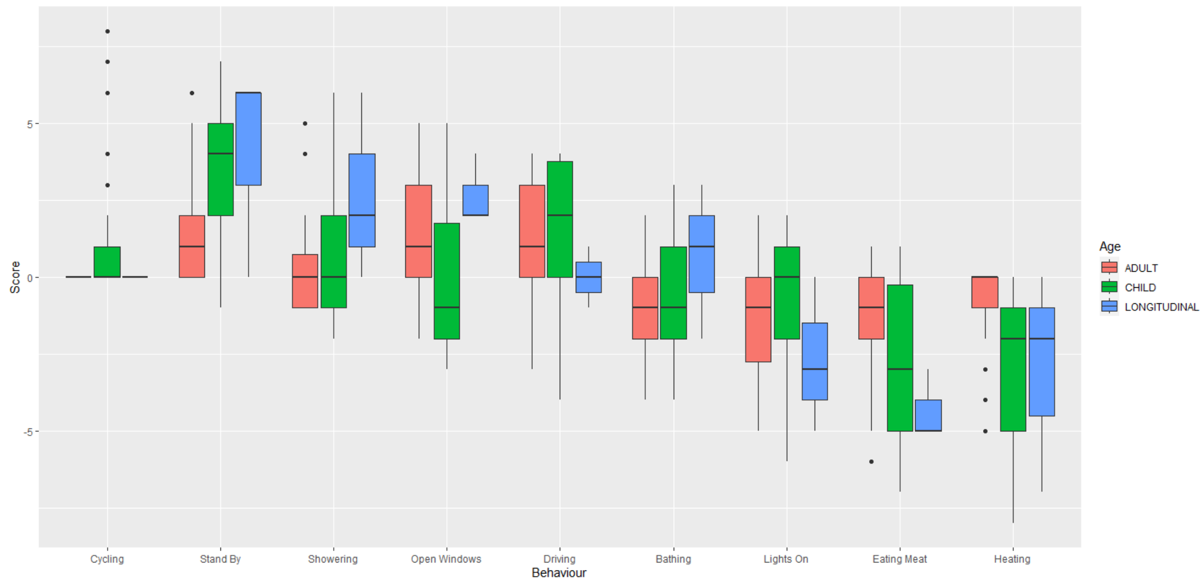


Figure 102: Study 4 Longitudinal Card Game Results added to Score Variability Graph - Game 2 Behaviours - Both Schools All Years

Did any Items surprise you in how HIGH they were? If so, which ones?

- Radiators
- Phone Charger, Radiators
- TV

Did any Items surprise you in how LOW they were? If so, which ones?

- Games Console
- Games Console
- Radiators

Did your child discuss energy issues related to any items whilst you played?

- No
- Yes
- No

If so, what was discussed?

- The energy used for different things in the home

Did any Behaviours surprise you in how HIGH they were? If so, which ones?

- Eating meat
- Having a shower
- Driving 5 miles

Did any Behaviours surprise you in how LOW they were? If so, which ones?

- Leaky or open windows
- Having a shower

Did your child discuss energy issues related to any behaviours whilst you played?

- Yes
- Yes
- No

If so, what was discussed?

- We were discussing how drafts in the home are caused by gaps in windows and doors that need replacing. How we let heat out of those gaps when heating the house

5 Analysis of the Studies

5.1 Study 1 Analysis

Study 1 Phase 1 Analysis – Household Energy Behaviour Baseline

This section is a short analysis of the results from the Method 1 Study - the 'LATENT Study'.

Question 1 showed that even if discussions about the environment don't happen 'almost every day', they do appear to happen in almost all households. There may be a case to argue that if discussions happen too often in a household, it may be considered an annoyance for the main occupier and may lead to outcomes other than positive behaviour change. The chi-square statistic for this question was 37.2042, and the p-value was < 0.00001. The result is significant at $p < .05$.With this research aiming to test differing methods of initiating interactions in the home, it is important to ascertain a baseline of the current rates - this question produced data that could be used as this baseline. That is to say currently 224 families out of 510 (that completed this question - 1576 gross total) discuss the environment frequently or almost every day (44%). This could be used as the baseline number to show whether a method of initiating interaction has been successful or not. A time frame would also have to be added; this question, being asked immediately after the interaction intervention, would not be ideal, but a week later, asking how many interactions occurred between the initial intervention and the time of the survey could hold potential.

As aforementioned in the methods section, this survey was completed by one person within the home, most likely the main occupant. There are, therefore, some potential biases and issues that arise; their opinions may not be the same as those of the other occupants in the home, or they may show signs of the VAG [Blake (1999)]. This question, for example, asks about interactions between generations, but this may occur with a differing child within the family (also potentially of different ages), or with the parent not completing this survey; thus, occasions might have been missed by the participant. Additionally, positive bias from the participant to appear better than the truth is always an issue with surveys, this will be looked at in further detail throughout the various interventions.

To start with, the education/Qualification levels of the participants were analysed; interestingly, 60% of the main occupants in both groups 1 and 3 have Degree or higher degree levels of education. The pie chart below clearly shows that significantly higher levels of education are represented in this group than in the UK average of 22.6% [EAG (2020)].

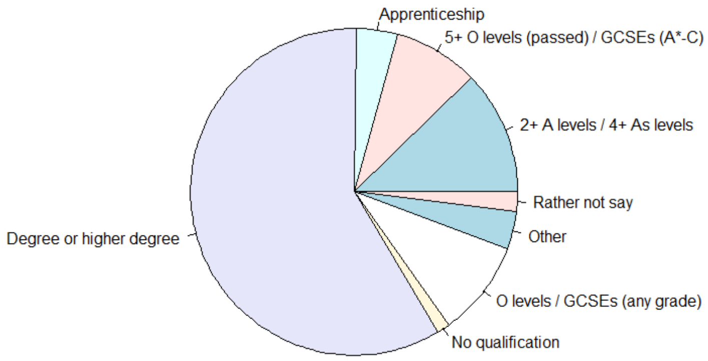


Figure 103: LATENT survey Highest Qualification Level - Group 1 Households with children

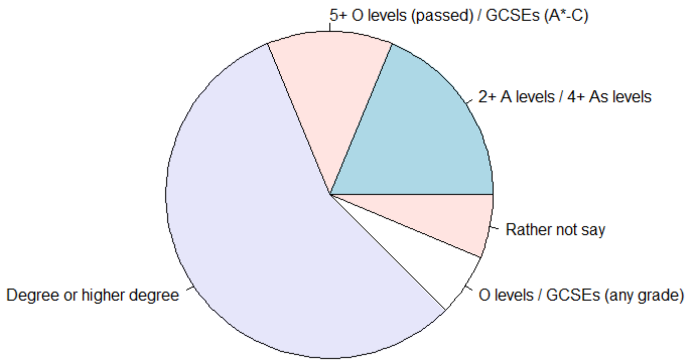


Figure 104: LATENT survey Highest Qualification Level - Group 3 Households with children and elderly

A 2006 American study by McCarhty and Kuh found that if one parent has a degree, then children are twice as likely to also go on and complete a degree [McCarthy and Kuh (2006)]. As this thesis aims to improve the energy literacy levels of children, it is important to initially gauge the overall knowledge levels beforehand. If there is no relationship between higher levels of education and higher levels of awareness/concern, then this research may need to be adjusted, but the literature would suggest that links are apparent [Santin (2011), DeWaters and Powers (2013)]. These high levels of degree completion in the participants may mean there is more concern, but this is not guaranteed to have lead to higher levels of concern in the children.

Income for the household was then analysed for groups 1 and 3, the results can be seen in the two Figures below (105 and 106):

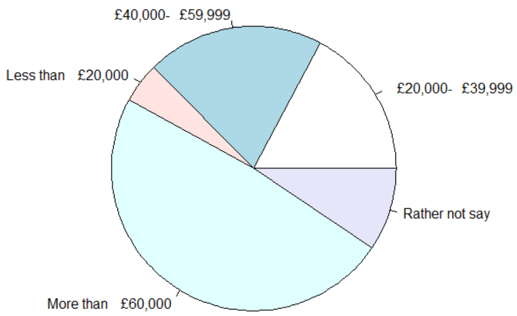


Figure 105: LATENT survey Income Level - Group 1 Households with children

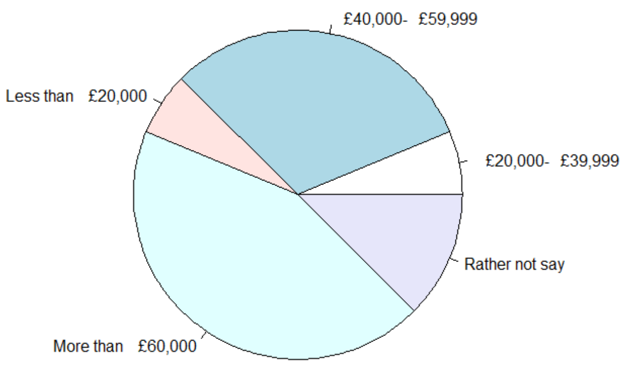


Figure 106: LATENT survey Income Level - Group 3 Households with children and elderly

In a very similar result to the education previously, the highest answer available for income is also the largest; 49% of Group 1 and 44% of Group 3 earn over £60,000. There appears to be a positive relationship between higher education levels and a higher income, which does match with society in the wider picture [ONS (2017)]. It is apparent from this analysis that the participant sample is significantly higher in income than the UK average of £31,400 [ONS (2021)c]. This may lead to skewed results when comparing the data to other national averages amongst other resources.

Another aspect within the LATENT study that may lead to greater inter-generational discussions is the parent's/carer's concern about the planet. When asked about their overall attitudes towards climate change, respondents of groups 1 and 2 stated their high concern, with 71% overall of both groups choosing at least somewhat or more concern. The Figures below (107 and 108) show the results.

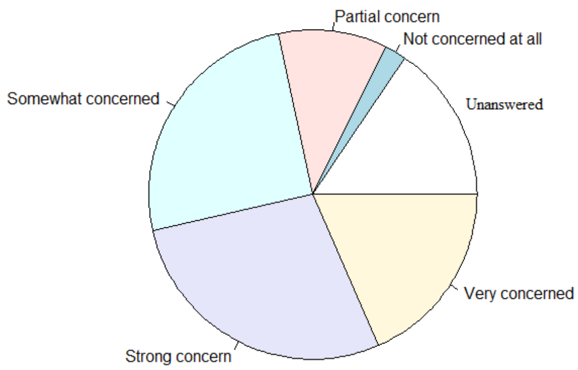


Figure 107: LATENT survey Attitude to Climate Change - Group 1 Households with children

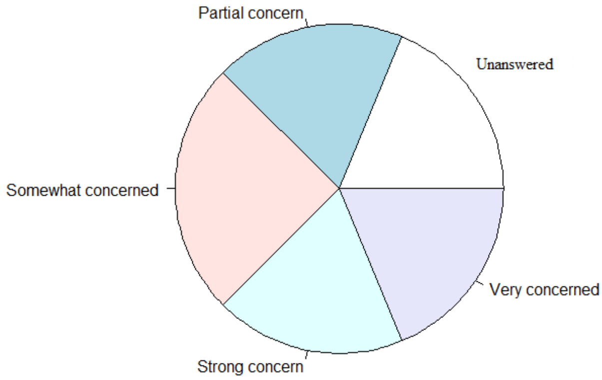


Figure 108: LATENT survey Attitude to Climate Change - Group 3 Households with children and elderly

The following Table 4 below shows a matrix of "Highest level of qualification" against "Annual household income". The Chi-Squared statistic is 278.9827. The P-value is <0.00001 therefore, the result is significant.

Table 4: LATENT Study - Highest Qualification against Household Income.

	Household annual income				
Qualification	<£20K	£20K-£39K	£40K-£59K	>£60K	Rather not say
O levels/ GCSEs (any grade)	63	139	92	59	45
5+ O levels/ GCSEs (A*-C)	39	133	78	101	44
2+ A-levels/ 4+ As levels	43	126	108	137	44
Apprenticeship	35	82	46	51	28
Degree or higher degree	110	480	494	1068	233

Interestingly, when combining both ‘Education/Qualifications’ and ‘Concern about Climate Change’ within the same graph (figure 109 below), it can be seen from the graph that as education levels rise, so too do levels of concern for the environment. Figure 109 appears to show that, at least within the LATENT participant pool, education may be a key driver for increasing concern about climate change. To act on a problem, one would first need to be concerned about the problem, but one must first need to be aware of the problem for this to happen - this is known as affordance. A large American survey in 2015 showed that higher factual knowledge about climate change (a component of energy literacy) was associated with greater concern and support for action, which this data falls in line with [Amin et al. (2023)]. Similarly, Appiah et al, (2023) found that higher energy literacy leads to more pro-energy attitudes and intentions, supporting the claim that better literacy increases concern/behavioural inclination [Appiah et al. (2023)]. In a similar, but practical way, a study by Teli et al (2016) found people could not lower their temperature to save energy because they simply didn't have a thermostat. Having the options, awareness and capability to make a difference is very important [Teli et al. (2016)]. It also shows that this research may have a larger potential target audience towards the lower end of the education spectrum. Those parents who are currently less concerned may also have a greater potential for a positive change compared to those who are already concerned and likely already try to mitigate any unsavoury energy decisions in the home. It may be possible to target these less qualified families for the future research of this project. Having said this, it is often the case that higher education levels lead to more income which also often shows a correlation with greater energy demand. These aspects will be analysed later within the Lasso Regression analysis.

It is important to note other aspects of behaviour that influence it such as financial reasons. Additionally, the Value Action Gap mentioned in the literature study may come into play here [Barr (2006)]. Even with a better Energy Literacy, occupants can not be guaranteed to behave more positively in terms of their energy in decisions [Barr (2006)].

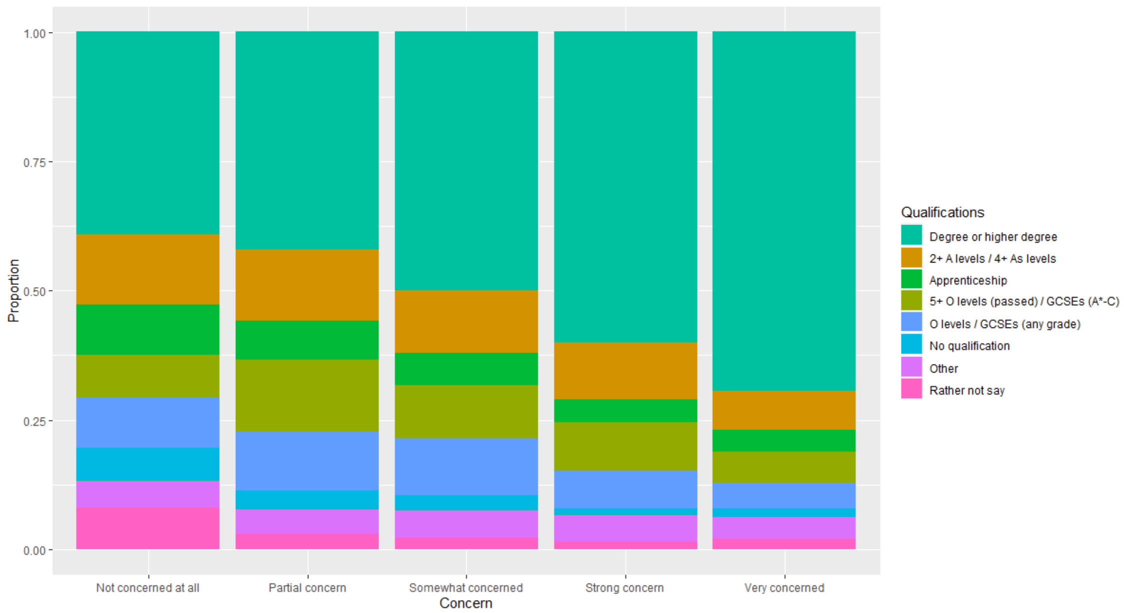


Figure 109: LATENT survey Attitude to Climate Change with Highest Qualification - All groups

Having said that, at the lower income end of the spectrum, it is likely that families are already having to make tough decisions within the home that are financially driven more so than environmentally conscious. It may be unwise to propose further mitigation to energy-intensive aspects such as heating when debates such as the 'heat or eat' topic may already be happening. This could be considered unethical, and the health of occupants must be put before this research. It may be more appropriate to target 'over-consumers' at the higher end of the income spectrum.

Question 2 asked who starts the discussions in the home, with Group 3 stating the adult does the majority of the time and Group 1 suggesting it is equal between 'adults' and 'both'. This would also be expected from looking at the previous analysis of the qualifications and then the associated concerns of the parents.

The literature review looking at the gaps in the national curriculum could be to blame for a lack of children starting the conversation. Both the literature review and the previous analysis on parent education appear to show that if children were improving their levels of knowledge and awareness, then concern would follow, and discussion and action may take place.

Following the point raised about the national curriculum, a comparison was completed between participant qualifications and the question 'Should classes about the environmental impacts of energy use be taught to children in our schools?'. From the data so far it could be expected that those with higher levels of education to be on the side of improving education. Figure 110 below shows the results.

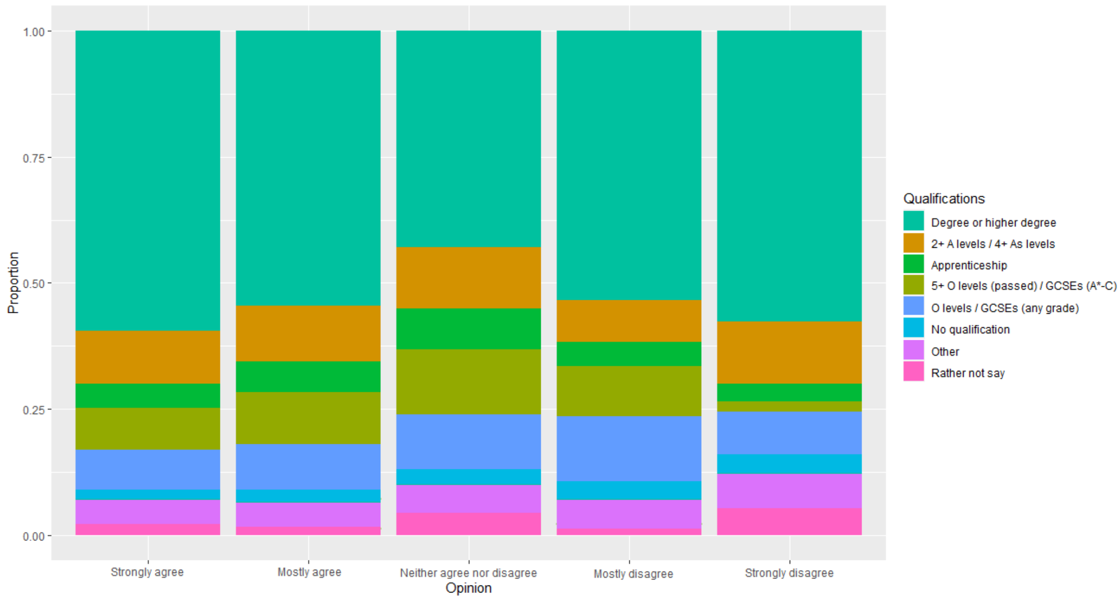


Figure 110: LATENT survey Opinion on Environmental Lessons with Highest Qualification - All groups

It can be seen that this is not the case and the spread is very even across the opinions on the need for environmental lessons in school. The largest proportion in each opinion is a degree or higher, suggesting that the qualifications are not inherently linked to a single view point. In fact, 'Strongly Agree' sees the largest proportion of degree or higher participants (60%), but then 'Strongly Disagree' sees the second largest proportion (58%). These are the two polar opposite views, yet see the highest proportions of qualifications and do not support the previous graph's points.

Table 5: LATENT Study - Number of participants for and against environmental lessons in school against their education.

	Degree	No Degree
Agree	1933	1338
Disagree	78	59

The small table above in Table 5 shows the number of participants that agree with environmental lessons being taught in schools and their corresponding education level (degree or no degree). The results of the chi-square test of independence (X2 (1, N = 3,408) = 0.172, p = 0.678) do not indicate a significant association between having a degree and there opinion for/against having environmental lessons in school.

Question 3 (+6) directly asked the participants if they felt their children (or elderly relatives) influenced energy usage in the home. These results again saw substantial differences. Completing a Chi-squared analysis on the three groups which returned the following results - The chi-square statistic was 102.5377. The p-value was < 0.00001. Following are some other interesting findings: If children are in the home, occupants are 5 times more likely to 'almost never' be influenced on their energy decisions. Whereas with elderly in the home, occupants are 19 times more likely to be influenced on their energy decisions 'almost every day'. This appears to show that the elderly are more influential in conscious energy usage in the home than children. But the reasons behind their influences are different. It was seen over 50% of written answers in question 7 were regarding the health and comfort of elderly relatives (Appendix Figure 204), children do not have the same requirements at the same levels and thus would play a smaller role in this. If this research were to be successful, an expected rise in the number of children who are interacting with parents regarding influencing energy decisions would be seen. For example not increase the temperature, but lower it because they understand the positive implications this can have.

If the participants stated that they had a child(ren) of secondary school age, they were separately asked to write an answer on whether they thought this child also influenced energy in the home. COVID-19 and homeschooling were mentioned several times, which should be noted. The theme with answers about increased energy consumption was one of heavy device use, long showers and significant internet usage, not influences on other occupant energy behaviour. Participants who did not see an influence tended to not write a reason, but there was little pattern to be seen from the answers as a whole. Environmental concern was only mentioned once from 403 responses – "Very Environmentally aware and talks regularly about energy consumption, but as parents, we both work for environmental conservation businesses". This secondary-age child is not comparable to average children and goes on to show again how qualifications, education and occupation are all important influences affecting the inter-generational discussions about the planet, at least in the sample. This also raises concerns that even though Climate Change is part of the GCSE curriculum, it still seems it is not being taught with enough justice that it remains in the minds of teenagers after the school day has finished.

Similarly, Question 4 (+5) again directly asked the participants if their children (and elderly relatives) asked them to turn the heating up or down. As per the previous question, whether the household had older or younger generations in the home was key to the outcome. The chi-square statistic was 35.6043 and The p-value was < 0.00001. With children in the household, occupants were just over 3 times more likely to 'not change the heating' than to 'increase the heating'. Whereas for households with elderly, they were just less than 3 times more likely to 'increase the heating' than to 'not change the heating'. This again shows the substantial difference in the influence that the elderly play compared to children. When looking at children individually, it was 6 times more likely that they ask for the heating to go up rather than down. It would be expected to see this result change following the intervention with the children as they learn that there are alternatives to increasing the temperature in the home.

With heating being the most dominant energy consumer in the home, the temperature set point in the home is one of the most influential aspects in the home to educate children about. Increasing the number of interactions between generations in the home regarding heating would theoretically lead to the greatest positive change. Therefore, an analysis was carried out using the LATENT results on this subject. The below Figure 111 shows the reported temperatures of the four household groups within the study.

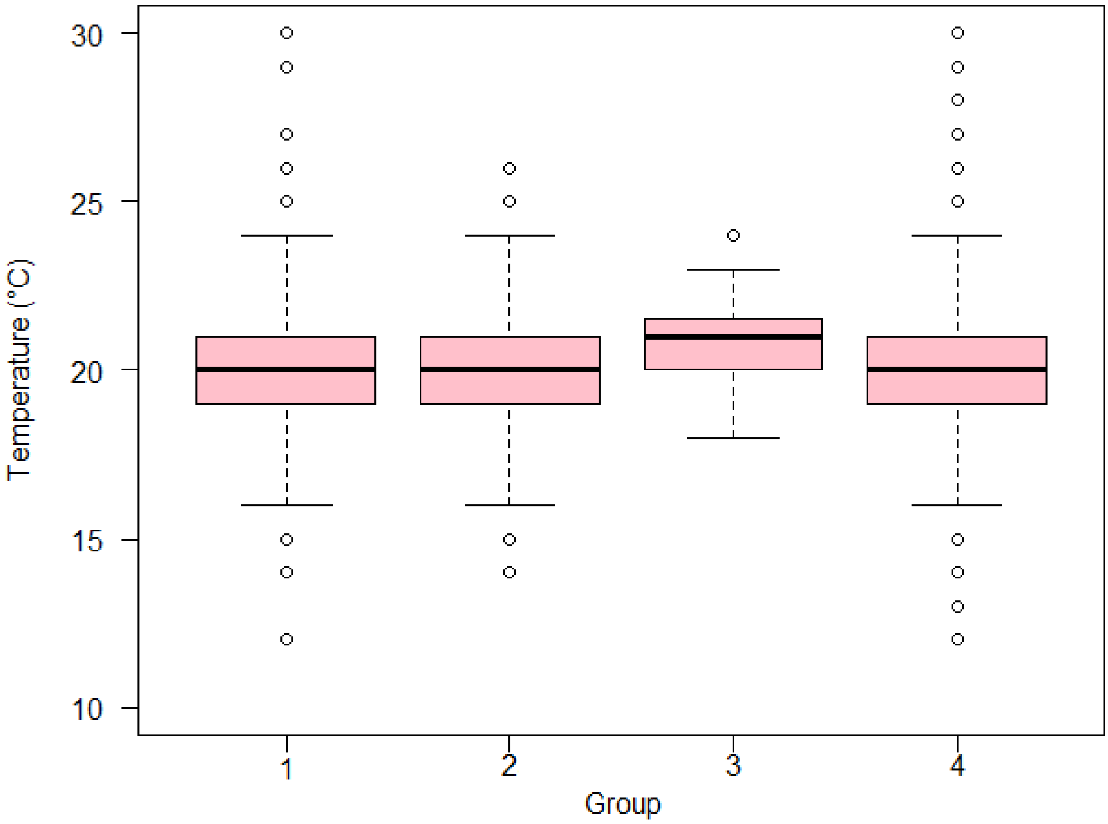


Figure 111: LATENT survey of self-reported thermostat temperature setpoint by Group - 1 with children, 2 with elderly, 3 with both, 4 with neither

The indoor temperatures vary very little between the four groups. It would be expected that Group 2, with elderly in the home, would be higher than the other three, especially following the written answers given previously, but Group 1 and 2 are almost identical to one another. In fact Group 4, with no children or elderly is also almost identical to 1 and 2. Group 3 sees a slight increase, but is only made up of 16 families so it is a far less reliable data set than that of groups 1 and 2 (1576 and 436 respectively). A Kruskal Wallace test confirms the p-value is more than the significance level 0.05, it can be concluded that there are no significant differences between the groups. To make certain, an additional pairwise comparison shows that there are no significant differences between paired groups ($p > 0.05$).

The lack of relationships may have to do with alternative solutions to keeping elderly occupants comfortable in the home. For example, several written answers to Q7 stated that secondary heating systems such as oil radiators are used in the rooms where the elderly spend most of their time. Others spoke of zoning specific rooms higher than the rest of the home. People may choose these options over increasing the entire home's temperature because they have learnt from bills or have been told that rightly so, heating a single room and only when needed is more energy efficient.

It would have been very interesting to receive answers from both sets of parents in this study. Attempting to gather data on interactions between adults and children, but only using one of two adults in the home has potentially halved the number of interactions that may have been expected.

In summary, this study and analysis aimed to assess the context of inter-generational influences on energy in the home and establish a baseline for key performance indicators. The LATENT survey has produced a brief snapshot into the daily life of an Igloo Energy customer. The additional questions added for this research have produced some interesting information on the main occupant's opinion on inter-generational influences in the home. It has become apparent that the current influences from children are small and infrequent, especially when compared relatively to those of older generations within the home. This study forms the baseline that Study 2 will use to assess if it has been successful.

Household Energy Classification

To further add to the analysis above, the following section will detail several statistical analyses that were completed on the LATENT survey results. The dataset included data from the online survey, EPC information, and annual meter readings. The dataset includes two dependent variables ('Gas Consumption' and 'Electricity Consumption') and twenty-two independent variables summarised in Tables 6, 7 and 8. The independent variables have been split into the three groups described below.

The first group, 'Predictors Model 1 - Building', includes physical building characteristics. From the original survey responses, the variable 'Local Authority' has been grouped by UK regions rather than the local authority, reducing the number of variables from 317 to 20. Using more traditional wall types, the variable 'Wall Type' has also been reduced from circa 100 variables down to 4. The same process has been applied to the 'Main Fuel Type'. The other variables have not been streamlined to allow participant answers to remain bespoke.

The second group, 'Predictors Model 2 - Occupants', includes socio-demographic variables. Household income has not been balanced or equivalised in any way. The variable 'Number of children' does not apply to Group B 'Homes with elderly', and to Group C 'Homes with neither children nor elderly', but has been retained for any potential analysis between family size within Group A 'Homes with children'.

The third group, 'Predictors Model 3 - Behaviour', includes variables on the occupants' heating behaviour. The variables in this group have all been taken from the survey or EPC data and are on the heat source, additional heating and heating behaviours in the home.

Table 6: Summary of the independent variables: 'Predictors Model 1 - Building'.

Predictors Model 1 - Building	Categories (N) E= Electricity Model. G=Gas Model
Total floor area	E - N/A (continuous: M=136m2, SD=61m2) G - N/A (continuous: M=135m2, SD=59m2)
Property type	E – Bungalow (212) Flat (204) House (1238) Maisonette (22) G - Bungalow (167) Flat (70) House (1030) Maisonette (12)
Local authority label	E - East Midlands (205) East England (216) London (147) Northeast (62) Northwest (136) Southeast (429) Southwest (171)Wales (64) WestMidlands (131) Yorkshire and The Humber (115) G – East Midlands (160) East England (124) London (104) Northeast (48) Northwest (120) Southeast (349) Southwest (137)Wales (45) West Midlands (111) Yorkshire and The Humber (81)
Wall description	E – 9in Solid Wall (412) Cavity Uninsulated (281) Cavity with Insulation (716) Other (217) G – 9in Solid Wall (316) Cavity Uninsulated (243) Cavity with Insulation (579) Other (141)
Window energy efficiency	E – Very Good (139) Good (497) Average (840) Poor (88) Very Poor (110) N/A(2) G – Very Good (80) Good (357) Average (694) Poor (75) Very Poor (72) N/A(1)
Main fuel	E – Biogas (1) Electric (189) Gas (1284) LPG (20) NA (25) Oil (133) Solid Fuel (23) Waste Combustion (1) G - Electric (12) Gas (1251) LPG (2) NA (1) Oil (4) Solid Fuel (9)
Current energy efficiency (SAP Rating)	E - N/A (continuous: M=61.0, SD=14.2) G - N/A (continuous: M=61.5, SD=13.3)

Table 7: Summary of the independent variables:'Predictors Model 2 - Occupants'.

Predictors Model 2 - Occupants	**Categories (N) E= Electricity Model. G=Gas Model**
Number of occupants	E - N/A (continuous: M=4.3, SD=0.9) G - N/A (continuous: M=4.3, SD=0.9)
Number of children	E - N/A (continuous: M=2.3, SD=0.6) G - N/A (continuous: M=2.3, SD=0.6)
Do you own your home?	E - No (342) Yes (2387) G - N0 (198) Yes (1896)
Please state your gender	E - Female (855) Male (1905) Non-binary (4) Self-describe (2) Rather not say (9) G - Female (632) Male (1492) Non-binary (3) Self-describe (2) Rather not say (5)
Person age	E - 0-9 (261) 10-17 (113) 18-64 (1620) 65-74 (410) 75+ (93) G - 0-9 (224) 10-17 (101) 18-64 (1215) 65-74 (317) 75+ (69)
How many years have you been living in your current home?	E – Less than 1 (230) 1-2 (322) 3-4 (378) 5-9 (535) 10-19 (583) 20-29 (387) 30+ (313) G - Less than 1 (165) 1-2 (222) 3-4 (293) 5-9 (401) 10-19 (463) 20-29 (306) 30+ (261)

Table 8: Summary of the independent variables:'Predictors Model 3 - Behaviour'.

Predictors Model 3 - Behaviour	**Categories (N) E= Electricity Model. G=Gas Model**
Main heat source	E - biomass Boiler (9) Electric Radiators (158) Electric Heat Pump (112) Electric Storage (29) Gas Boiler (2184) Gas Fires (6) Oil Boiler (253) Solid Fuel (14) G - Electric Radiators (8) Electric Heat Pump (12) Gas Boiler (2094) Gas Fires (4) Oil Boiler (2) Solid Fuel (2)
Set room temperature	E - N/A (continuous: M=20.0C, SD=1.7C) G - N/A (continuous: M=19.9C, SD=1.7C)
Heating schedule	E – Monitor/adjust Schedule (1156) Set Point (326) Set Schedule (1293) G - Monitor/adjust Schedule (859) Set Point (224) Set Schedule (1047)
What time is the heating on?*	Always, Morning (6am-11am), Afternoon (11am-5pm), Evening (5pm-11pm), Overnight (11pm-6am), No typical schedule, Other
Would the heating periods stated above change for a typical weekend?	E – No (1938) Yes (855) G – No (1455) Yes (685)
Weekend - what time periods do you typically have the heating on?*	Always, Morning (6am-11am), Afternoon (11am-5pm), Evening (5pm-11pm), Overnight (11pm-6am), No typical schedule, Other
Who has the last word in household heating decisions?	E – My Partner (182) Myself (1101) Other (16) Shared Equally (1479) G - My Partner (144) Myself (831) Other (8) Shared Equally (1144)
What are you most likely to do when you feel cold in your home?*	Put on additional/warmer clothes on, Turn the heating on for a short burst, Turn the heating on for a prolonged duration, Close windows, Use additional heating (e.g. a fire or electric radiator), Wait for the scheduled heating, Drink a hot beverage, Other
Do any of the household occupants use an additional electric heater during the winter months?	E – Never (208) Occasionally (95) Often (155) Rarely (61) G - Never (144) Occasionally (65) Often (101) Rarely (39)

* indicates Participants able to select multiple options from the available answers for both electricity and gas.

Within this section, the dataset was divided into three household groups: Group A. Homes with children (n=1,576), Group B. Homes with elderly (n=436), and Group C. Homes with neither children nor elderly (n=2,330). Gas and Electricity consumption are the two dependent variables analysed in this study; the same analysis was undertaken for each of these consumption data. The analysis undertook three Lasso Regression Models [Huebner et al. (2015)]. Each one looks at the 3 different aforementioned models; 'Building', 'Occupants' and 'Behaviour'. The models were repeated for the three household groups, allowing comparisons between groups and between gas and electricity consumption. The data analysis framework is summarised in Figure 112

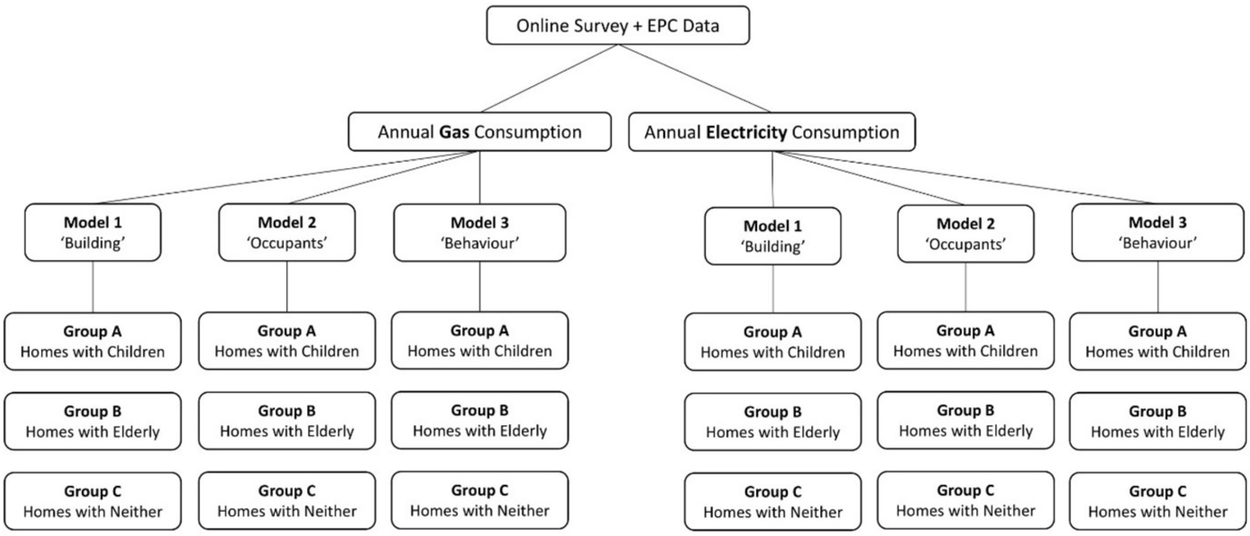


Figure 112: Data analysis framework of models ran within the Lasso Regression Analysis - Groups taken from the LATENT survey participants

First, the analysis reviewed each variable through descriptive analysis, identifying outliers. Then, an analysis of variance (ANOVA) of Electricity and Gas consumption between the three groups was carried out. This was followed by Lasso regression analysis to identify which variables are strong predictors of consumption for each group.

Lasso regression (Least Absolute Shrinkage and Selection Operator) was used as it not only produces data on predictors but also mitigates any multicollinearity – when several variables within a regression model may be highly correlated, which is detrimental to interpretation and analysis [Huebner et al. (2015)]. Lasso accomplishes this by "introducing a penalty term in the model and shrinking the regression coefficients to zero, allowing the model to achieve a higher level of accuracy when compared to traditional models" [Zhang et al. (2022)]. The regression values within Lasso may remain positive or negative depending on whether the correlation is positive or negative; the more the value is shrunk (the closer it gets to zero), the less powerful it is as a predictor. K-fold cross-validation was first used to find the optimal lambda value for each of the Lasso regressions; for the 3 groups, 3 models and 2 meter reading types (18 tests in total). The Lasso regressions were then completed using these lambda values.

Finally, within each group, relationships between each variable and consumption were tested using either the Spearman-Rank test or the Kruskal-Wallis test depending on the variable type (numerical or categorical).

Exploring the difference in annual electricity and gas consumption between household groups

The electricity and gas consumption appears to be very similar between household groups, see Figure 113. However, there are statistically significant differences between household groups for gas consumption (H(2)=2; p=2.2e-16) and electricity consumption (H(2)=2; p= 4.197e-13). This is to be expected and follows existing literature suggesting homes with more occupants, or with elderly or young family members consume more energy, usually to maintain thermal comfort [Pais-Magalhães et al. (2022)].

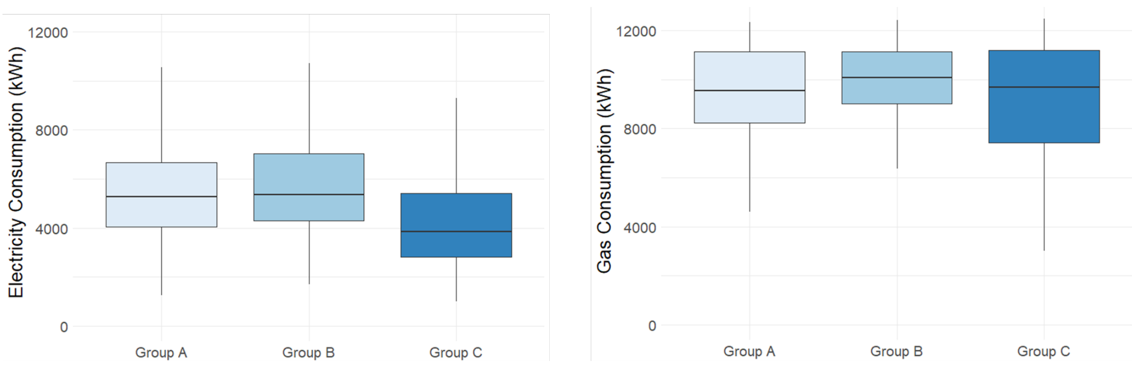


Figure 113: Annual Electricity (on the left) and Annual Gas consumption (on the right) for the three household groups

Group C (with neither) has the lowest median and mean of the three groups which is also to be expected [Zhu and Lin (2022)]. Again, following the pattern seen in the literature, Group B (with elderly) has the highest median and mean with elderly relatives usually requiring more energy consumption to maintain comfort levels and remain healthy [Estiri and Zagheni (2019)].

Identifying the predictors of annual electricity and gas consumption for each household group

Results from the Lasso Regression on electricity and gas consumption show a difference between the final predictors within each group (see Table 9). The two strongest predictors are highlighted in Table 3; these are the two predictors with absolute values furthest from 0. These results are explored in the following sections, starting with 'Model 1 – Electricity' and 'Model 1 – Gas', then 'Model 2 – Electricity' and 'Model 2 – Gas', and finally 'Model 3 – Electricity' and 'Model 3 – Gas'.

Table 9: Lasso regression analysis results for Groups A, B and C.

	Electricity			Gas		
Predictors Model 1 Building	**A**	**B**	**C**	**A**	**B**	**C**
Intercept	8150	8199	6737	17064	16024	1614
Total floor area	19	14	19	91	147	102
Property type	**-173***	**-762***	**-92***	**-1784***	.	**-757***
Local authority label	-3	.	-1	-6	-129	6
Wall description	.	**-99***	.	86	**167***	144
Window efficiency	.	.	40	**-148***	.	-49
Main fuel	**-213***	.	**-183***	.	.	**636***
Current energy efficiency	-32	-5	-25	-97	**-241***	-84
Predictors Model 2 Occupants	**A**	**B**	**C**	**A**	**B**	**C**
Intercept	1581	8040	1353	-3578	10356	-23
Number of occupants	**1025***	.	**967***	1817	.	**2393***
Number of children	-318	.	.	-872	.	.
Homeownership	49	.	**598***	**3612***	5192*	**3298***
Gender	**381***	**-821***	.	**2340***	.	1585
Age	.	.	.	278	.	.
Years in current home	-20	**-171***	-38	6	364	-175
Predictors Model 3 Behaviour	**A**	**B**	**C**	**A**	**B**	**C**
Intercept	12225	5298	5698	6855	26543	-5890
Main heat source	**-1440***	.	**-504***	229	.	1306
Set room temperature	109	.	44	779	.	695
Heating schedule	188	.	296	867	.	**1606***
What time is the heating on?	-59	.	-33	-149	**-683***	-49
Would the heating periods stated above change for a typical weekend?	-456	.	-460	**-2418***	.	**-1357***
Weekend - what time periods do you typically have the heating on?	.	.	-1	203	.	.
Who has the last word in household heating decisions?	-52	**240***	277	-644	.	184
What are you most likely to do when you feel cold in your home?	-23	.	14	-25	.	83
Do any of the household occupants use an additional electric heater during the winter months?	**582***	.	**522***	**1127***	.	1165

n*indicates the two most powerful predictors in each group.

Within 'Model 1 – Electricity', 'Property Type' is one of the two most powerful variables for all three household groups. For Group B, it is the most powerful predictor. 'Property Type' is also the most consistently powerful result of any variable within any group or model, suggesting that the type of property will be one of the strongest determining factors of energy consumption. 'Main Fuel' is then the second most powerful variable for both Group A and Group C, but has been reduced to zero for Group B, which interestingly has instead 'Wall Type' as the second most powerful variable, this has been reduced to zero for both Group A and C. Interestingly, 'Window Energy Efficiency' is only powerful for Group C and 'Current Energy Efficiency' which is simply the EPC Score of the property, shows very low levels of prediction power. EPC is the national standard to test how much energy a home will consume, yet other predictors are more powerful.

Within 'Model 1 - Gas', 'Property Type' is again the most powerful variable for two of the three household Groups; A and C. Yet it has been reduced to zero in Group B. 'Wall Description' sees a small increase from the Electricity Model to the current Gas Model and again is one of the top two predictors for Group B, suggesting that this variable is particularly important for predicting overall energy consumption in homes with elderly occupants. The variable 'Window Energy Efficiency' also sees an increase in levels of power from Electricity to Gas models for two household groups A and C, becoming the second most powerful variable for Group A. This suggests that the performance of windows is more important for electricity saving than for gas saving for households with children. The variable 'Main Fuel' remains one of the top two predictors for Group C, but has now been reduced to zero for Group A and remains at zero for Group B. Interestingly, the variable 'Current Energy Efficiency' has now become the most powerful predictor for Group B and is now also slightly more powerful for the two other groups. This reaffirms that SAP is more based on gas consumption, not electricity, overall consumption or unregulated energy.

Within 'Model 2 – Electricity', there is slightly less consistency between which variables are powerful when compared to 'Model 1 – Electricity'. The variable 'Number of Occupants' is the most powerful predictor for both Group A and C, but has reached zero for Group B. It would be expected that those homes with more occupants would consume more energy, but it appears that this variable is not powerful enough to be the case for homes with elderly. Groups A and B show 'Please state your gender' as a strong predictor. 'Do you own your own home?' is then one of the strongest two predictors for Group C. Whilst the variable 'How long have you lived in your home?' is a strong predictor for Group B only.

Within ‘Model 2 – Gas’, the variable ‘Do you own your home?’ is a strong predictor for all three groups. This may suggest that the difference in consumption between those owning their homes and those renting could be substantial, potentially because of the improvements one can make on their home relative to rented accommodation. The variable ‘Number of occupants’ is again a strong predictor for Group C, and the variable ‘Please state your gender’ is again for Group A, but both variables see decreases within other groups within the model. The variable ‘How long have you lived in your home?’ is a strong predictor for Group B once again, suggesting that this could be a reliable predictor for overall energy consumption.

Within ‘Model 3 – Electricity‘, Group B has had all but one variable reduced to zero through the Lasso Regression. The variable ‘Who has the last word with heating decisions’ is the only variable to remain a predictor. This variable is also a low-scoring predictor for the two other groups. The variable ‘Main Heat Source’ is a strong predictor for both Groups A and C, as well as the variable ‘Do you use additional electric heating in the winter?’. This result is unexpected as the literature would suggest that households with elderly more often use additional heating sources to spot heat individual rooms [Kane et al. (2015)].

Within ‘Model 3 – Gas‘, the variable ‘What time is heating on?’ has increased in power across all three groups (from Model 3 Electricity to Model 3 Gas) and become a top predictor for Group B. This may suggest that households with elderly abide by different heating time schedules, likely to maintain the thermal comfort of those elderly which falls in line with literature [Kane et al. (2015)]. Only one variable within ‘Model 3 – Gas’ is the same as ‘Model 3 – Electricity’, ‘Do you use additional electric heating in the winter?’, and it has remained a strong predictor for Group A. Interestingly, the variable ‘Heating Schedule’ has also increased in power (from Model 3 Electricity to Model 3 Gas) and is now a strong predictor for Group C, but reduced to zero for Group B, where one would expect a similar increase for the reasons suggested above.

Table 10: Spearman Rank test and Kruskal-Wallis test analysis results

	Electricity			**Gas**		
Predictors Model 1 Building	**A**	**B**	**C**	**A**	**B**	**C**
Total floor area	**0.00***	0.94	**0.00***	**0.00***	**0.00***	**0.00***
Property type	0.29	0.26	**0.01***	**0.01***	0.50	**0.00***
Local authority label	0.66	0.62	**0.02***	0.06	0.08	**0.00***
Wall description	0.17	0.65	0.74	**0.00***	0.37	**0.00***
Window efficiency	0.27	0.86	0.18	**0.00***	0.36	**0.00***
Main fuel	**0.00***	0.16	**0.00***	0.84	0.24	**0.01***
Current energy efficiency	**0.03***	0.63	**0.00***	**0.00***	**0.03***	**0.00***
Predictors Model 2 Occupants	**A**	**B**	**C**	**A**	**B**	**C**
Number of occupants	**0.00***	0.79	**0.00***	0.35	0.96	**0.00***
Number of children	**0.00***	NA	NA	**0.04***	NA	NA
Homeownership	**0.02***	0.76	**0.00***	**0.00***	**0.03***	**0.00***
Gender	**0.29**	0.11	0.45	**0.00***	0.98	**0.00***
Age	**0.02***	0.52	0.52	0.41	0.96	**0.00***
Years in current home	**0.04***	0.72	**0.00***	0.31	**0.01***	**0.00***
Predictors Model 3 Behaviour	**A**	**B**	**C**	**A**	**B**	**C**
Main heat source	**0.00***	0.11	**0.00***	0.34	0.27	**0.00***
Set room temperature	**0.00***	**0.04***	**0.00***	**0.00***	0.18	**0.00***
Heating schedule	**0.00***	0.80	**0.00***	**0.02***	0.65	**0.00***
What time is the heating on?	**0.00***	0.58	**0.00***	**0.00***	0.05	**0.00***
Would the heating periods stated above change for a typical weekend?	0.06	0.75	**0.00***	0.53	0.56	**0.00***
Weekend - what time periods do you typically have the heating on?	0.60	0.23		0.07	0.68	**0.01***
Who has the last word in household heating decisions?	0.23	0.20	**0.00***	0.18	0.17	**0.00***
What are you most likely to do when you feel cold in your home?	**0.00***	0.63	**0.00***	**0.00***	0.14	**0.00***
Do any of the household occupants use an additional electric heater during the winter months?	**0.00***	0.57	**0.00***	**0.00***	0.07	**0.00***

* indicates $p < 0.05$

Exploring differences with the predictors of annual electricity and gas consumption for each household group

The relationship between the outcome of 'electricity and gas consumption' and the predictors within each household group are reviewed by applying either Spearman Rank test or Kruskal-Wallis test depending on the nature of the data (discrete or continuous). The highlighted results in Table 10 are those that show a significant difference between groups. As above, these results are explored in the following sections, starting with 'Model 1 – Electricity' and 'Model 1 – Gas', then 'Model 2 – Electricity' and 'Model 2 – Gas', and finally 'Model 3 – Electricity' and 'Model 3 – Gas'.

Within 'Model 1 - Electricity', no variables show a significant difference between groups for Group B, but 'Total Floor Area' and 'Main Fuel', both show significant differences between groups for Group A and C, suggesting that these two variables may be the most important for gauging energy use in the home. Group C, electricity consumption shows a significant difference between groups for the variables 'Property Type' and 'Local Authority', the latter suggesting the local climate can play a role in electricity consumption; daylight hours or rainfall for example.

The 'Model 1 - Gas' results vary considerably compared to the electricity model; both 'Total Floor Area' and 'Property Type' show a significant difference between groups for all three household groups with 'Wall Description' and 'Window efficiency' showing significant difference between groups for Groups A and C. Group C shows a significant difference between groups for all variables.

Eight of the 18 tests of 'Model 2 – Electricity' show significant differences between groups for all three household groups. Group B has identical results to 'Model 1 -Electricity', as it shows no difference for any variable. Groups A and C both show significant differences within 'Number of Occupants' and within 'How many years living in the home'. The variable 'Number of Children' shows a significant difference between groups for Group A, but not for Groups B and C. Finally, 'Gender' shows a significant difference between groups for Group C only.

Within 'Model 2 – Gas', the variable 'Do you own your home' is the only variable to show a significant difference between groups for all three household types, suggesting again that there may be a benefit from the freedom that owning one's home brings in terms of mitigating gas consumption. It would be expected that the variable 'Number of Occupants' would have a strong relationship with gas consumption, but it only shows statistically significant results for Group C. This household type is only made up of single people or couples, potentially meaning the change from one to two occupants plays a larger role than the following change from more than two occupants. The variables ‘Gender’ and ‘How many years living in the home’ show significant differences between groups for two out of three household groups. The variable ‘Person Age’ only shows a significant difference between groups for Group C.

Within ‘Model 3 – Electricity’, the variable ‘Set Room Temperature’ shows a significant difference between groups for all three household groups. This is to be expected as space heating in domestic properties is the largest energy consumer [Reguis et al. (2021)]. The variables ‘Main Heat Source’, ‘Heating Schedule’, ‘Time Heating is on’, ’Action when Felling Cold’ and ‘Additional Heating?’ all show significant differences between groups for household groups A and C. Group B again shows very few significant differences for the variables included in this analysis.

The same can be said for Group B in ‘Model 3 – Gas’; there is no significant difference between groups for any variable. Yet, Group C shows a significant difference between groups for all variables. Group A in ‘Model 3 – Gas’ has almost identical results to Group A in ‘Model 3 – Electric’; showing only one change, no longer having a significant difference between groups for the variable ‘Main Heat Source’.

Discussion of Predictors and Relationships

The first step of the analysis was to review the variability in electricity and gas annual consumption between household groups; ‘Group A – With Children’, ‘Group B - With Elderly’ and ‘Group C – With Neither’. Although little difference in central tendency was observed, there was a significant difference between groups, with households with elderly residents consuming more energy. This analysis led to the review of the energy consumption predictors of each household group.

From the Lasso regression analysis, ‘Model 1 – Building’ results show that the variable ‘Property Type’ is the strongest predictor for both electricity and gas consumption, often reaching scores of a magnitude of ten times larger than other variables. Importantly, this result is observed across all three household groups. This falls in line with the literature, which showed physical building variables have the largest effect on domestic energy consumption [Huebner et al. (2015)], but it is important to approach energy consumption mitigation from other angles, especially when property type cannot be changed or improved in around half of the UK dwellings (e.g. rented accommodation, historic properties, etc.) [HM Government (2023)b].

It is apparent from the results of both the Lasso regression analysis and the inferential analysis, that variables relating to dwelling ownership seem to play a large role in terms of energy consumption. The variable 'Do you own your home?' is a strong predictor of the Lasso regression analysis for four out of six groups, and shows significant differences between groups for five out of six household groups within the inferential analysis. Similarly, the variable 'Length of time in home' is a strong predictor of the Lasso regression analysis for two out of six groups, and shows significant differences between groups for four out of six household groups within the inferential analysis. Literature considered the ownership of homes an important aspect of mitigating energy use [Huebner et al. (2015)].

The results of this analysis appear to fall in line with points raised by other studies; that those who own their home can upgrade their envelopes or systems over time, thus reducing their energy consumption compared to similar dwellings that are not owned by occupants. This difference between rented/ownership status, and thus the difference between who pays and who benefits from building upgrades, is known as the 'Split Incentive Effect'. Kristrom et al (2015) found that "owners are substantially more likely to have access to energy-efficient technologies and better insulation", thus could reduce energy consumption more than renters [Kriström and Bengt (2015)]. This issue is currently being discussed at the national level, with potential plans to enforce a mandatory EPC rating 'C' for all rented dwellings by 2025 [HM Government (2023)a]. This would require improvements to the buildings' envelopes and systems/technologies, which this study's result also suggests being the most powerful influencers and thus sensible improvements to be made first.

In the UK, 63% of households own their place of residence [HM Government (2023)b], but within this survey, 75% (n=3,688) of participants stated they owned their home. This higher rate demonstrates how the sample is not truly reflective of the UK. It can be expected that, with this higher rate of ownership along with the aforementioned opportunities homeowners have to implement upgrades, energy consumption may be lower in the survey than that of the UK average household. At the same time, households that have higher incomes generally consume more energy as it is less of a financial burden and homes may be large, as is the case in this participant group. This study's results show the homeowner group represents a larger average energy consumption than non-owners (both for gas and electricity), see Figure 114. This may be because other variables are affecting energy consumption. The average floor area in the sample is 117sqm, whereas the UK average is lower at 97sqm [HM Government (2022)a]. This will likely mean that energy consumption is higher within the study results than would be expected based on UK averages. Similarly, the average income for a household in the UK is £35K [ONS (2021)b], whereas 40% of the sample falls within the 'greater than £60K' category. This implies that participants have on average more disposable income and are less constrained to consume energy, thus the energy consumption data is higher than expected.

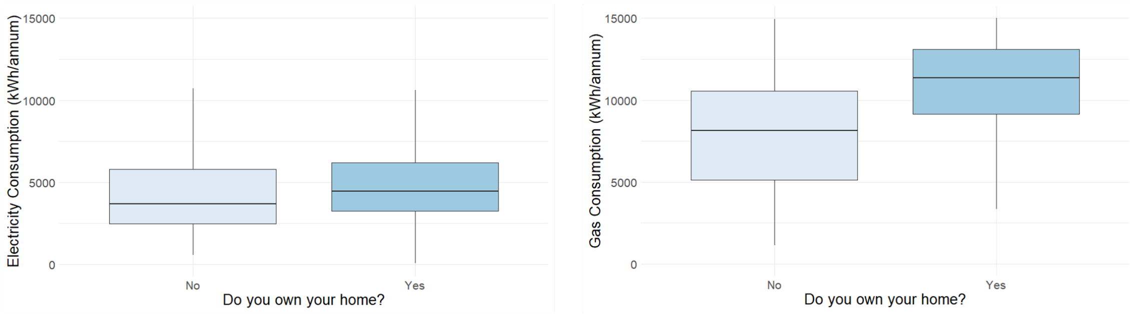


Figure 114: All household groups, variable ‘home ownership’ (Yes/No) for electricity consumption (on the left) and gas consumption (on the right)

This study and the review of literature have highlighted that variables such as ‘dwelling age’ are unreliable for a study such as this because this variable does not allow for dynamic measuring, it only refers to a single point of measurement in time. However, the variable ‘Wall Description’ is a current measurement of a dwelling that also encompasses any changes that may have been made to the property. Thus, it may be a better representation of building performance. The Lasso regression analysis shows that the variable ‘Wall Description’ is a predictor of gas consumption for all household groups and a strong predictor for Group B, but it is less powerful within the electricity models, with it only being a predictor for Group B. The skew to gas over electric may suggest that the wall types are more influenced by aspects such as heating (which is predominantly gas-sourced). In the future, this may change with the gradual transition to electric heating. The result, that wall type is only a strong predictor in homes with elderly, may also be based on heating use, but because of the higher temperature levels (and longer heating periods) that the elderly require to maintain thermal comfort as discussed earlier and put forward by Pais-Magalhaes et al (2022). Figure 115 shows gas consumption vs wall types for groups A, B and C respectively and that Group B (with Elderly) does not show the same pattern as groups A and C, which are very similar[Pais-Magalhães et al. (2022)].

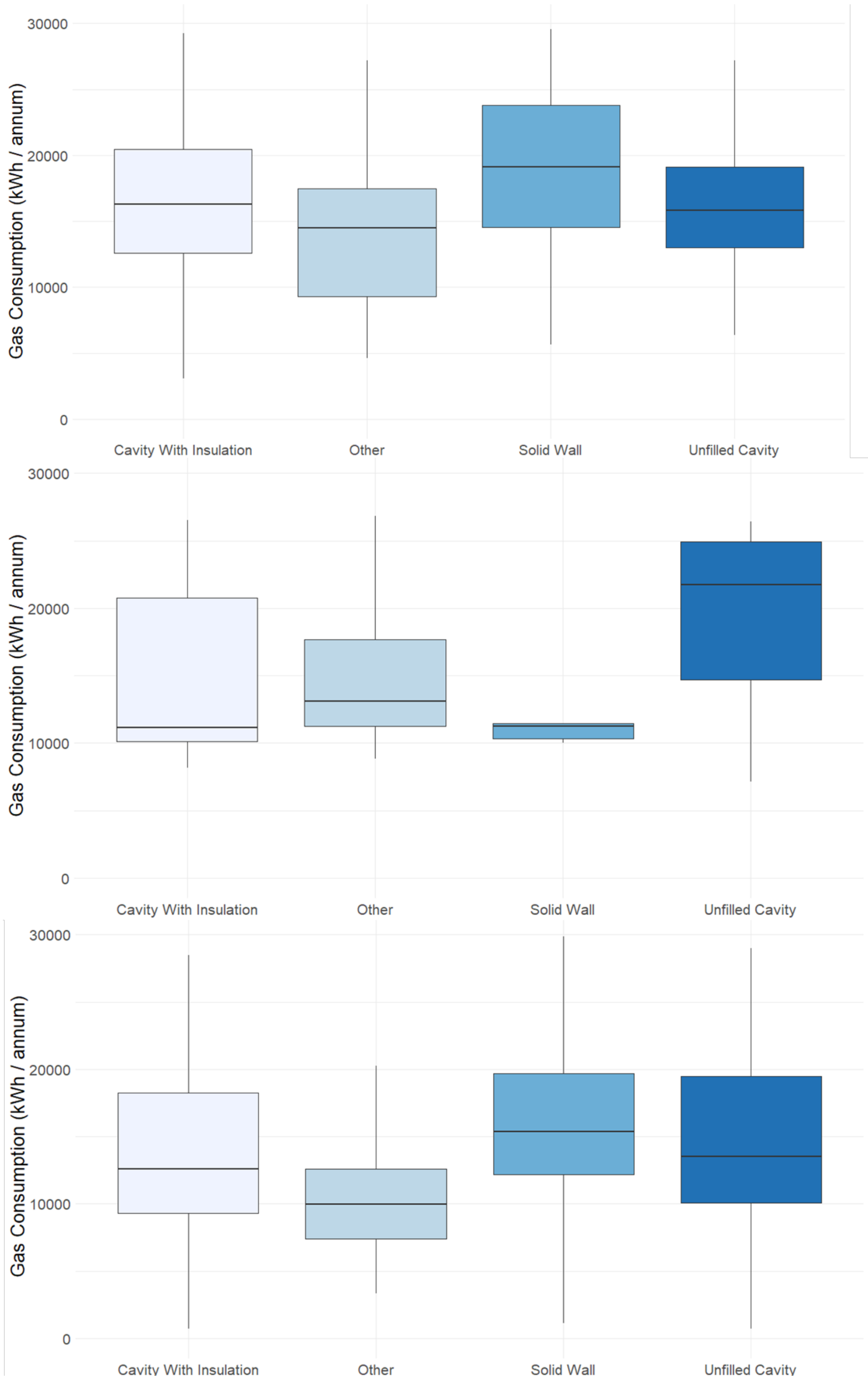


Figure 115: Variable 'Wall construction' vs. Gas consumption in kWh/annual for 'Group A – With Children'(top), 'Group B - With Elderly' (middle) and 'Group C – With Neither' (bottom)

On the variable 'current energy efficiency', It could be expected that the SAP rating would be the strongest predictor and show the strongest relationship with energy consumption as this is the tool used by the UK government to predict energy consumption. However, the results show that the variable is only a strong predictor for Group B gas consumption. Yet, it shows a significant difference between groups with all but one group within the inferential analysis (Spearman Rank). This does however reinforce the idea that the 'energy performance gap' may be at least partly due to variables not considered within SAP, such as occupant behaviour and unregulated energy consumption as previously discussed. More research is required that consistently measures similar variables (both for modelling and real-world measuring). The results also call into question the validity of any modern EPC as the score is marketed as a true representation of energy consumption. The mean average EPC rating for the participant group is 62 (E), which is very similar to the national average of 60 [ONS (2022)]. This variable is far closer to the UK average than many of the others analysed in this study.

It could be expected that with higher levels of ownership and income, homes in the sample may achieve a higher-than-average EPC rating. But this also holds true for the opposite, with higher-income families often being able to afford aspirational (and poorly performing) homes such as Georgian townhouses without having to worry about energy costs. Figure 116 shows EPC Results against gas and electricity consumption. The regression lines suggest that the higher the score, the less energy is consumed, which is to be expected, but the shallowness of the line suggests the differences between the scores are small (see Table 11).

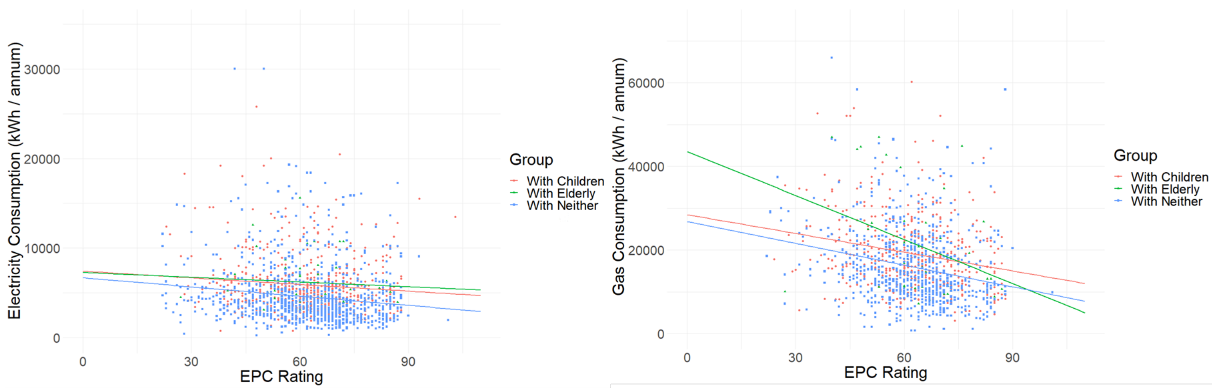


Figure 116: Variable 'current energy efficiency'(EPC rating) vs. electricity consumption (on the left) and vs. gas consumption (on the right) for 'Group A – With Children'(top), 'Group B - With Elderly' (middle) and 'Group C – With Neither' (bottom). Note DHW is included.

Table 11: Summary of Results from variables 'current energy efficiency'(EPC rating) vs. consumption (gas and electricity)

	Electricity			**Gas**		
Result	**Group A**	**Group B**	**Group C**	**Group A**	**Group B**	**Group C**
P Value	**0.00***	0.14	**0.00***	**0.00***	**0.03***	**0.00***
R2 Value	0.02	0.03	0.02	0.03	0.09	0.004

It can be seen from Figure 116 that the regression lines in the electricity graph maintain the same position as the EPC rating increases in rank order. Homes with elderly consistently consume more electricity. but as the EPC improves, the gap between the three regression lines increases, suggesting that having dependents in the home limits the potential energy saving that may come by living within a high-performing home. Another important factor is home occupancy times, which would vary between the three groups, with elderly likely to remain in the home during the day where as working age will not. The gas consumption graph on the right shows that having elderly in a poor-performing home will mean gas consumption is significantly higher than the two other groups, but this improves strongly as the EPC improves until having elderly in the home means that energy consumption will be less than the other two groups (A and C). The two regression lines of groups A and C maintain a consistent position and steepness to each other throughout the EPC rating range.

The results from the variables such as 'Number of Occupants' and 'Floor Area' are as expected; when there are more bodies to feed, wash and maintain comfort for, energy use increases [Huebner et al. (2015)]. Similarly, when there is a larger home to heat then overall energy consumption of gas and electricity increase. the variable 'Number of Occupants' is a strong predictor for 'Electricity - Group A', 'Electricity - Group C' and 'Gas - Group C', it is also a predictor for 'Gas - Group A'.

The variable 'Gender' is also important within surveys, especially regarding aspects such as heating. Males generally require a lower temperature to maintain thermal comfort [Kingma and Van Marken Lichtenbelt (2015)] or genders may have different roles in the home which means they behave in different ways or have knowledge of differing aspects of energy in the home [Rainisio et al. (2022)]. Within this survey, the variable 'Please state your gender' is a strong predictor for three of the six household groups ('Electricity - Group A', 'Electricity - Group B' and 'Gas - Group A'). The gender in the sample was 30% Female (n=1,499), 57% Male (n=2,815) and 13% Other (n=639).

Continuing with occupant factors, the variable 'Who has the last word on heating decisions?' is a strong predictor for 'Electricity - Group B' and is only disregarded in one of the six household groups ('Gas - Group B'). Thus, this variable can be considered an important aspect. 34% (n=1,700) of participants stated they have the final word, 44% (n=2,202) stated it was equally shared, 6% (30) stated their partner had the final say and circa 20% stated 'other' or did not answer.

It is important to remember that both gas and electricity consumption data within this study used billed meter readings, including regulated and unregulated uses from water heating, space heating and more. Thereby, singularly looking at the main heating source as a variable may not portray a true representation of energy in the home. Having said that, within the Lasso Regression analysis, the variable is a strong predictor for 'Electricity - Group A', 'Electricity - Group C', and 'Gas - Group A', suggesting when there are elderly relatives in the home (Group B), the heating source is not an important factor in predicting energy consumption, but when there are children in the home (Group A), the main heat source is. This is the opposite result when compared to the variables 'How many years lived in home' and 'wall description', which appear to be far more powerful predictors for homes with elderly.

The 'Additional heaters used' variable, which would be expected to be a powerful predictor for group B (with elderly) based on the literature, interestingly is a top predictor for the groups without elderly in the home. Zone heating with additional heaters is common with the elderly in the home or within homes with unheated areas such as conservatories for example.

Summary of findings

Domestic energy consumption is a significant and highly complicated issue, dependent on an array of variables and influences. This study aimed to gain insight into what aspects influence gas and electricity usage in three different household groups: homes with children, homes with elderly and homes with neither older nor younger generations. Using Lasso Regression analysis on three different models of variables (Building, Occupants and Behaviour), results identified which factors are the most powerful predictors of energy consumption within each group.

Property Type was found to be the most powerful predictor of both gas and electricity consumption across the six groups (three for electricity and three for gas), fundamentally suggesting that the physical building should be the first variable considered when discussing energy consumption in homes. However, this is one of several factors that cannot be changed - a detached dwelling cannot be changed into a flat. The first significant conclusion from this work follows that if the most significant variable cannot be altered, then it reaffirms the idea that less studied aspects such as occupant behaviour should be considered more in policies addressing change in reduction in energy consumption. Improving occupant energy behaviour could be one of the most effective ways to achieve a reduction in energy consumption in dwellings that can have little else improved. Although this analysis discusses only several factors occupants control, it has shown that some may act as powerful predictors, thus with more evidence and modelling could be applied to potential future energy model predictions such as the design stage SAP.

Homeownership is the second most powerful predictor and shows a significant relationship with five of the six groups, with the results showing that those who own their homes use slightly more electricity and gas than those who do not. This is unexpected when compared to literature, in which it is seen that those who own their homes often retrofit their home to improve performance and thus reduce energy consumption. Having said that, the participants in this study are higher than average in terms of home ownership, qualifications, income, levels of retirement and house size which may explain these results.

The variables 'Main Fuel Type', 'Number of Occupants', 'Gender' and 'Additional Heaters' are the next most powerful predictors, each being one of the two highest scoring results across three total of six groups. Only the first of which is considered within the SAP calculation, the latter are not, yet appear to be important variables that can be used to predict energy consumption in the home. This could be more evidence to inform the Energy Performance Gap. Current Energy Efficiency (EPC Rating) as a variable is also only a top predictor in one of the six groups (elec B) but is used nationally as the main comparison of energy consumption between dwellings. This study has produced results that add to supporting evidence that shows SAP needs to be updated to fall in line with the way homes are used today. Of course, more research and accurate models are still required, but if SAP included both regulated and an accurate assumption of unregulated energy use (possibly dependent on the occupant demographics within the property – as studied here), it would support reducing the energy performance gap.

The variables 'Set room temperature' and 'Floor area' show significant relationships with more groups than any other variable, but are not top predictors within any group. Having said that, they still show results within the Lasso regression analysis, rather than being reduced to 0, thus they can still be used to predict energy consumption. These two variables are intrinsically linked to space heating; the most significant energy use in the home and one that can be completely controlled by the occupiers. Is there a potential for improvement in how occupants use their heating systems? The government, or energy providers, could target users with campaigns that promote more conscientious use of heating systems in homes, helping in the reduction of energy consumption in the UK.

Comparing the three models, Building Variables should be the first part of any decision that aims to improve energy use. For example, a fabric-first approach to retrofitting would be more influential than improving systems or technologies within the home. But these, along with occupant behaviours, are also important influencers that should be encouraged to be considered more often [Delzendeh et al. (2017)]. This is especially important within dwellings that are unable to be retrofitted in traditional ways such as insulation improvements.

The results from this study seem to show that occupant behaviour not only plays an important role in energy consumption in the home but also should be incorporated into future alterations to energy models.

Limitations of this analysis

There are several important aspects to note regarding the limitations of this study. The participant group of this study appear to be higher than the UK average across multiple metrics for families in the UK, thus the results are not true representations of the UK demographics. Some key variables that are higher within the sample, include 'Average household income', 'House size (Floor area)', 'Home ownership rates', 'Standard of highest qualification held', and 'EPC Rating'.

Although the gas and electricity metering has been automatically collected and the building data has been extracted from the EPC certificates, most data has been self-reported by the participants. This not only leads to human error in occurrences but also an internal bias. Surveys were also completed by one occupant within the home, which means inherently there may be some bias. The participants would have given answers on their own behaviours over other occupants in the home. Also, there may be some bias in the response, as participants may have answered inaccurately or falsely to appear better or simply did not know the true answer and gave their opinion. Previous research by Gauthier, (2015) has shown that when asked about their behaviours, participants will often suggest they behave differently than they do in real life [Gauthier and Shipworth (2015)].

The gas and electricity meter readings have been collected over one year, which may have been a hotter or colder than average year. Heating Degree Days (HDD) are a way of balancing data such as this to make it comparable to other years and could be used if further analysis is required.

This survey was carried out before 2022, UK energy bills have increased substantially over the past two years and thus the economic factors of today's climate may have led to some participants behaving and data differently.

This study has shown that occupant behaviour, although not the most influential factor, should still be considered when attempting to model or predict energy consumption in the home. It is especially important during the design stage as a method of mitigating the energy performance gap that has become apparent in recent years. Although not a true representation of the UK, this study suggests that some demographic or occupant behaviour factors (such as the use of a secondary heating system) could not only be used as predictors for electricity and gas consumption but may be as accurate as traditional predictors such as EPC scores. The inherent inclusion of unregulated energy within this study (by using meter data) has shown how influential it can be and how future predictions should aim to include this aspect.

5.1.1 Limitations

The LATENT study was already underway when this research commenced. It followed the multi-year SENSE study that also took place in partnership with Igloo Energy. This research was allowed to merge with the study and utilise the proposed survey that was already being created. This survey was sent to 26,000 people, a number far larger than any potential participant group this research could ever gather without external input. Although the input into the survey for this research was minimal and there was no way to initiate inter-generational interactions through a simple online survey, it still allowed the exploration of what is currently happening within the home in terms of inter-generational interactions.

Although not an important aspect of this research, the opportunity to explore not only the younger generation but also the older generations in the home was seized. It was expected that those with elderly in the home would have different energy behaviours to those without or with younger generations in the home. It was also expected that the influence from the older generation to the main occupier generation would be driven by health and comfort reasons, rather than because of energy awareness. It was still pursued as it does represent an inter-generational influence that could be compared with that of the younger generation. The survey was a tree-branch-style online survey so any additional questions would not negatively affect any participants that did not meet the criteria to answer the question. Older generations were then removed from any future study as the focus remained on the younger generation only.

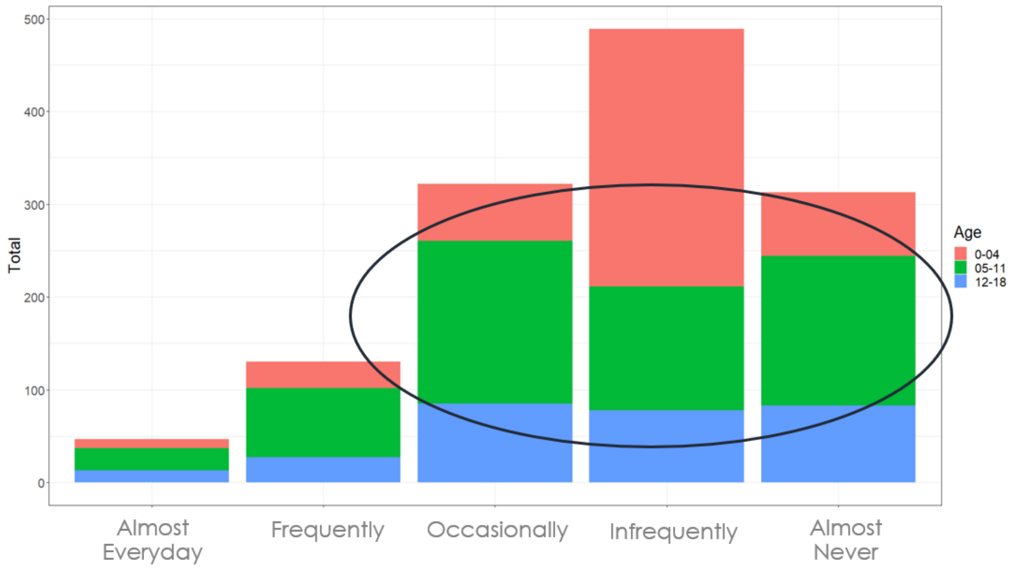


Figure 117: LATENT Results from the question 'Do you think your children influence your energy decisions?' (separated by the age of the respondent's children)

The study showed that within the Igloo customer base, children are currently not reported to influence energy consumption (see Figure 117). However, a significant relationship in energy consumption between households with and without children was found. It can be seen in Figure 117 in green that those answers to the right (primary-aged children circled) are missed opportunities to pass on knowledge to the current adult generation. Hypothetically, if this survey was to be redone after the participants had undertaken the intervention it would be hoped that the green sections had shifted to the left.

A question that arose during a presentation at a conference of the Study 1 results was that the answers to this survey were opinions from one individual occupant. For example, asking if children influence decisions are actually asking their opinion on the matter. The child may actually ask the other parent more often, but this opportunity has been taken away from the survey. Although logistically impossible, it would be very interesting to collect physical numeric data on the number and type of requests the young (and elderly) generation make to the main occupants.

5.1.2 Summary

Following the initial analysis and the Lasso Regression analysis, it can be seen that energy in the home is influenced by a large array of different variables, from the building to social norms to habitual behaviour and finances. LATENT showed that current influences from children are small and infrequent, especially when compared relatively to those of older generations within the home, whilst the Lasso regressions showed that the building is the most influential aspect on energy demand, but occupants are still an important contributor to the energy performance gap. Most importantly, a baseline has been created for Study 2 to compare against.

5.2 Study 2 Analysis

In using the two separate participant pools for Study 1 and Study 2, there is an argument to state that the two cannot be compared. The baseline from the LATENT pool may not accurately represent the school participant group within Study 2. This is very true when looking at aspects such as the aforementioned indices of deprivation scores. There is also no requirement to fulfil in creating a four-phase study. However, some comparisons and analyses will be made simply to ascertain where any pros and cons may lie within the separate methods.

Phase 2 Analysis – Improving Energy Literacy Levels of Children
The oral feedback from the teachers was very positive; the children want to learn more and have persistently asked to incorporate climate change with other parts of the day. Research and differentiation into children with special educational needs had not been undertaken, and these topics may be quite stressful for those children with such needs. Overall though, the lessons were considered well-planned, and the resources were "very fun". The transition of these to an online format for the Method 3 Study required thorough planning to make the online experience more stimulating.

As discussed within the literature review, many aspects of face-to-face learning allow good engagement and learning to take place. Being within the school environment, with a set routine as Tabvuma et al (2021) showed, can promote the learning that takes place, thus completing the intervention at school should lead to a high retention of new knowledge [Tabvuma et al. (2021)]. From the results, it can be seen that the continued requests to use climate change as the lesson topic indicate that the intervention lessons must have been taken on board by the children.

Phase 3 Analysis – Opportunity for Inter-Generational Interaction
The game itself saw mixed feedback; the children orally stated they enjoyed both creating it and playing it, but only 44% of the parents thought their child enjoyed it. This low number also goes against the results sheets, which were generally completed fully (the sheet allowed the child to play the game twice). It is more likely that the parent had to help their child and thus did not enjoy the time themselves. Again, this group of families may not be the most favourable choice for interventions – a warning by a schoolteacher

before the work stated that the school generally see very low levels of parents showing interest in their child's education. Thus, following that comment, a 16% response rate in the questionnaire and 36% in the game sheet returns seems successful.

The success of the lessons could also be considered a negative of the home-based intervention, such as the take-home activity in this study. With opportunities such as media, leisure and distractions constantly available in the home, it can be hard for people, especially the young, to devote time to school work [Panek (2014)]. The take-home activity, although not 'homework', could easily have been mistaken as so by children, especially as it was given by teachers at school to be done at home (but not compulsory, it was optional). This could have been one of the reasons why not all children completed the activity. This had already been considered when developing the activity, and was why a game style was used as the medium to log behaviour in the home.

The take-home activity was a 'subliminal game' [Flanagan and Nissenbaum (2019)] intended to create opportunities for inter-generational discussion on the topic of climate change and energy behaviour in the home. It was seen in the results section that the activity led to an expected set of results, with thermostat temperatures and thermal comfort results similar to those of the LATENT study. But the act of investigating their home sparked some thoughts in the children's and parents' minds. This can be seen within the feedback from the teachers, below are several Figures 118 and 119 of work completed in other lessons after the children had asked to continue with the environmental themes learnt during the 'eco day'.

Global Warming

Global warming hurts everyone in everyway
So if we don't stop now our Earth could be gone by May.
We need to stop eating meat and dairy
because this could make some people lairy.
Cows, pigs planes and trains create gases
As we speak our Earth is turning into ashes.
The weather is changing every day, give poor Mother Earth
a break
Our worlds existence is at stake.
We need to stop this, we can't replace our Earth
Show people what our Earth is worth.

By Ashleigh

Figure 118: Additional Work completed by children in Study 2 - Climate Poetry

Figure 119: Additional Work completed by children in Study 2 - Planet Cookies

Phase 4 Analysis – Reassessing Opportunity for Inter-Generational Interaction

It must first be noted that the response rate was low for this survey, so conclusions may not be as confident as initially expected. The parental feedback survey results are interesting; it shows that the school intervention lessons worked well in the sense that the children went home after the day, and 61% of parents who completed the survey reported discussing climate change and how they can help the planet. Overall, 72% of these children were reported to have spoken about helping the planet to their parents - a significantly higher number than the 40% baseline that the LATENT survey reported, which was a far greater initial participant number. Unfortunately, under half of these parents (41%) stated that they had learnt something about sustainability from their child. This is a lower percentage than would be ideal for this research, but it is a positive step showing that knowledge can indeed be exchanged from younger to older generations – an important aspect following this research. It could be suggested, given the basic level of knowledge taught in the lessons, that the current energy literacy level of the parents was relatively low. The catchment area of this school is a very different group from those who took part in the LATENT study. Or it may be that parents already knew about any information or knowledge that the children were passing on, thus creating the same response. A second question that asked if the parents already knew the information being discussed may have been a good addition.

Also, less key to this study, but still relevant, 59% of children asked their parents to change something, and 40% of these parents said they did indeed change how they do things because of their child's comments, with a further 65% of these saying they will likely continue the change for the future. These promising results show that interactions do occur after an intervention such as this and that there is also a positive outcome from the interaction.

It can be seen by the split in results and feedback between Y3+4 and Y5+6 that the attitude of the teacher may play an important role in the success of an intervention like this. The teacher who helped design the lessons was one of the younger class teachers; thus she had already shown an interest in the topic from the outset. The older class teachers were seeing the intervention less as an opportunity and more as a hindrance to the school day. This is understandable as teachers already have a substantial workload and demands set on them. This was attempted to be mitigated as much as practicably possible by developing the lessons with the National Curriculum as a baseline throughout. This requirement to meet the National Curriculum would be removed if the learning part of the intervention took place outside the school environment, but as aforementioned, the learning and activity would have to be engaging enough for a child to complete it within the home.

Table 12: Study 2 Final Survey: Table of Key Findings.

		Did your child play the game?		Did your child talk to you about their lessons?	
		Yes	No	Yes	No
Learnt from your child?	Yes	4	1	5	0
	No	4	0	2	1
Changed because of their comments?	Yes	3	1	5	0
	No	3	0	3	1

The above Table 12 shows a matrix of the number of participants who answered the four questions. Each set of results within this was analysed with a Fisher's exact test to determine if there was a significant relationship between variables. The results of Fisher's exact test (p = 1) do not indicate a significant association between 'playing the game' and 'learning from the child'. Equally, (p = 1) between 'playing the game' and 'changing behaviour' thus does not indicate a significant association. For the second set of tests (Did your child talk to you?), the results are different. The results of Fisher's exact test still do not indicate a significant association between 'talking about the game' and 'learning from the child', but p = 0.375 - far lower. Lastly, between 'talking about the game' and 'changing behaviour', p = 0.444 thus does not indicate a significant association but is again lower.

When comparing the two age groups (Y3+Y4 and Y5+Y6), there are no parental responses that are the same, with all but two questions yielding more positive results from the parents of the younger classes. The average difference between these two groups is 33.4%, suggesting there was definitely a variability at some point within the different phases. It could be inherent to the children's ages, simply different workloads, styles of teaching, ways of learning, or different interests. This may be because the differentiation within the content and lessons taught may not have been correct to suit these age differences. It has already been mentioned that the individual teachers may have delivered the lessons differently, with their own styles or own opinions and biases, leading to different aspects being emphasised to differing importance. For example, the largest difference in response scores came from the question 'Has your child asked if things in the home can be done differently?' with only 33% of the older children's parents saying yes compared to the 89% from the younger children's parents. There may have been differences in the home between the two ages, also, with the older children having different hobbies or different requirements in the home.

5.2.1 Limitations

Having undertaken the literature review and analysing the online vs in-school factors that affect learning, a small in-school intervention was chosen initially. This also had the added benefit of being able to test differing topics with feedback from children and teachers, thus content could be reviewed before another study takes place. Input from teachers at the chosen school was also beneficial whilst developing lessons and content, which would not have been possible moving directly to an online intervention. Having said this, the chosen school was not ideal in every way; chosen because of prior connections with staff (a convenience sample), the school is located in an area of significant deprivation, which meant not only was it not an 'average' school, but it may have a variety of indirect issues that would affect the results of the study. For example, parents working longer hours/shift patterns and not spending enough time together with children to complete the take-home activity. Thankfully, the study saw a good uptake in both the classroom aspect and the take-home activity and survey.

The other main issue that fortunately was also avoided, but was significant during the design process was Covid-19. This aspect meant that all discussions with the teachers were online, all work for the lessons (including PowerPoints, activities and resources) had to be made available online with the ability to be printed and completed at home and finally the take-home activity (which required dice and cutting out) needed to be completely achievable for a child without instruction. The UK was in full lockdown sporadically during 2020/2021 and it was expected that the lessons would be delivered online by the teachers as the University of Southampton had banned all face-to-face experiments for all researchers. Thankfully, schools had returned to in-person learning in time for the intervention to take place.

The lessons were delivered to four classes at the school, each with around 30 students, ranging from Y3-Y6 (totalling 130 children from ages 8-11). Although lessons had also been prepared for Y1 and 2 earlier, discussions with the teachers led to these not being taught simply due to the expected low ability of children that age to understand the concepts. The survey for study 2 was attempted by 50 parents, although only 18 answered all of the questions. These were evenly split between Y3+4 parents and Y5+6 parents, allowing for comparison between groups.

Compared to Study 1, in which 40% of respondents stated they interacted with their children and discussed the environment, Study 2 saw 61% of participants report they interacted with their children. The study and the survey may have put too much emphasis on the changes that main occupants could put in place, rather than the persistent nudge and interactions that were the main focus of this study. Study 2 initially aimed towards emphasising a reduction in heating specifically, but this participation group was the wrong population for such a push. Being towards the lower end of the income scale, it was likely that families already used their heating systems as sparingly as possible. Further questioning on existing habits could have been beneficial to this, or using a different population. For example, aiming at over-users who can make a difference may be a better idea for the next study.

Oral feedback from the children and teachers showed that the teaching part of the intervention was very successful, with all children enjoying it and collectively requesting to use the topic frequently afterwards. In terms of calculable success, the feedback showed that children had taken on board at least some new knowledge in a variety of topics covered. It could be seen from the poems written in the weeks following that the children understood the role emissions played in the atmosphere and the build-up of greenhouse gases leading to global warming and sea level rise.

The take-home activity also appeared to work well, with well-completed score sheets being returned. Unfortunately, sheets were only returned from the Y3 and Y4 teachers; the older classes did not return any physical sheets and only provided oral feedback. The scores showed that the children were investigating their home as the game encouraged, and the corresponding feedback from the survey and children showed that many interactions were taking place whilst it happened. Although providing positive tactile feedback, the same game, based online, would have been easier to provide to children and then log scores during the play-through. If this study was to expand to multiple schools or a significant number of people, the game would have to move online to make it feasible.

As mentioned several times previously, the two contrasting participant groups of Study 1 (LATENT) relative to Study 2 (School) are quite considerable. The LATENT Igloo customer base with high levels of income and qualifications is hard to compare directly with the relatively deprived and unqualified Gosport 001A neighbourhood. The differences can be seen in the return rate of surveys and within some of the results. Parents in Gosport may have to work longer or more jobs in order to support a family, thus may have less time to interact with their children, whereas LATENT participants may very well be the opposite, with a 'stay at home parent' available.

The school-based intervention appears to have worked well, with children learning knowledge and interacting with their parents at home. By utilising a school, it was possible to provide daily reminders to children to play the game at home, thus improving the likelihood of interactions. It was also possible to reward children who completed the activity with a physical gift or the promise of additional benefits during the school day - something that would be difficult to achieve in a home-based online study (e.g. emails/text reminders, online vouchers, etc.). As seen in the Literature Review, the school environment does promote good learning environment, which was clear in this study too. Tasks were short and high pace (Taggart, 2024), there was alot of to and fro discussion with immidate feedback fro children and staff (Borup and Archambault, 2023 and Panek, 2014), the children were in the correct classes expecting the specific topics with little to no distractions (Tabvuma et al, 2021) and finally had other children to bounce ideas (Jiwas et al, 2011). All of these key factors discovered during the literature review were achieved here [Taggart et al. (2024), Borup and Archambault (2023), Panek (2014), Tabvuma et al. (2021), Jiwa et al. (2011)]. However, topics were held back by the National Curriculum, which meant lessons could not be purely about energy in the home, for example. Differing opinions and motivations of teachers also meant that some of the students may not have been so interested, as the teacher's investment was not high. This may have led to missed opportunities.

5.2.2 Summary

In summary, with the low participation return rate of the phase 4 survey, the results and any patterns that may have emerged must be taken as only slightly representative. However, the results do suggest that opportunities can be produced for inter-generational interactions to take place in the home. The limited results of this study also suggest that children can be successfully taught the knowledge that needs to be passed to parents within these interactions. It is known that the school environment provides excellent foundations to promote energy literacy and knowledge transfer. Further, regarding the school aspect, this study has shown that environmental education can be combined into the curriculum effectively, creating maths, science, geography, and DT/Art lessons solely based on the environment.

5.3 Study 3 Analysis

The key sets of data include information on the interaction frequency and gas meter readings. 19 full sets of this data were collected, but when looking at heating use specifically, it is important to take weather into account, especially when the participants are spread around the UK.

Phase 1 Analysis – Parental Energy Behaviour Baseline

This study was completed using the same participants as Study 1 LATENT. These are from a pool of the population that not only does not represent the UK average but also does not match the participant pool from Study 2 (locals of the Gosport area). Uptake was low from this potentially large group of participants with only n=63 participants completing the initial survey. This may have been because there was not enough incentive to take part - a random financial reward to a percentage of the participants at the end, or it may have been because of the barriers that were in place. The first of which was that the study was prolonged over time and involved their children, the participants may have thought it would put too much strain on their children in terms of time or effort. Similarly, the requirement for a gas meter reading may have turned some participants away. Several people completed the initial survey but then did not include meter readings (nor take part any further in some cases). A third barrier, which may be even more influential, is the trust that may have been lost between the participants, Igloo Energy and the University of Southampton. Participants may simply have not wanted to take part in something that has caused them stress and increased financial burden.

Looking at the initial survey questions, all participants stated positively about their concern for climate change. Although this is a positive outcome overall, it will be difficult to improve upon this when this baseline is reassessed at the end of the intervention. Having said this, when comparing financial to environmental influence on heating use, it is clear that financial influences are more powerful (65% stating 'almost always' for financial influence compared to 17% 'almost always' for environmental). In an ideal world, environmental influence on heating would be equal to, if not larger than, the influence of money-related issues. This is however the current influence, and this research will aim to at least increase the environmental influence on aspects such as heating use from improved energy literacy levels of adults.

Also showing similar potential for improvement is the participants' perception of their child's concern for climate change. Only 17% of participants stated they 'strongly agree' their child is concerned about climate change, but 50% stated 'somewhat agree' and 10%

stated they disagree. This baseline should see some improvement if the study is successful. Likewise, the discussions with children about the environment are more negative and should see some improvement. 55% of participants stated 'infrequently' to this question.

Other results that could be impacted by the intervention are 'request to change heating', which sees 60% of current participant children 'neither requesting heating up or down' and less than 5% requesting it be reduced, the smallest response rate and the one that would see the most benefit to a household's overall energy consumption.

Phase 2 Analysis – Improving Energy Literacy Levels of Children

Of the 63 participants who completed the survey, only n=35 participant children took part in the online intervention. This is an unfortunate drop in participant numbers for the study. This may be because of one of the previously discussed barriers, but now the child is also involved in the decision-making. Two children completed the website activities far more regularly than the other 33, with the least participating 50%, all only completing the activities on the website once or less. This lack of participation, for whatever reason, does suggest that the home online environment may not be the ideal place to teach or learn.

Testing the improvement of energy literacy levels within this study was not done. Knowledge about the environment and energy in the home was shown to the children through the stop motion videos, which in total were watched 229 times. However, there was no follow-up to test how much of this knowledge was retained by the children. The only test of any improved energy literacy levels was through the survey answered by the parents at the end of the study. These are analysed below, rather than in Phase 4, for ease of reading.

Analysing the question 'Can you give an example of something you have learnt in the box below?' first, it can be seen that the answers fall into five categories. These do not quite match the eight different topics the videos and online activity had, but consist of (i) heating (ii) standby + electricity use (iii) recycling (iv) transport (v) others. The answers given fall in line with the knowledge and facts taught in the lessons, suggesting that the children did indeed improve their energy literacy levels from the website and that the knowledge has also been passed on through interactions. Parents have learnt about electronic devices, recycling single-use plastics and the impact of materials (embodied energy). This is a positive outcome for the study in achieving the aims and objectives.

The second question, 'Can you give an example of a change you have made in the box below?' also shows a positive outcome. 22 responses were taken for this question, and they show a varied range of topics and outcomes. Three respondents stated they have reduced the thermostat with a further one stating they have reduced the duration of heating. These are key behaviours that have been improved by the intervention. Interestingly, transport (particularly electric cars) has created a lot of responses even though it was not one of the most discussed topics on the website. It may be that children are now noticing how often they use car travel each day, and this is leading to discussions.

Phase 3 Analysis – Opportunity for Inter-Generational Interaction

The self-reported thermostat temperatures taken by the children during the game show a normal range of temperatures similar to the two previous studies and in line with CIBSE Guide A. The most frequently recorded temperature was 17 degrees with no one reporting temperatures above 25 degrees. This falls in line with another reported aspect - the comfort of participant children, with around 90% stating they were comfortable. This is likely because the full range of temperatures from the previous question was between 15 and 25 degrees.

Similarly, the same results are present for the opposite question on being too cold and putting on a jumper. 80% stated they were comfortable. This question may be more suited to the participant group of Study 2, who were more likely to underheat based on their indices of deprivation.

This does however mitigate the effectiveness of the question 'If you are warm, can you turn the temperature down a degree?'. It was expected that heating use would be slightly high in this participant pool given they are higher income and generally older than the UK average. However, over 60% of the children stated they were not feeling warm enough to lower the thermostat. Around 20% of children did change it (it was explicitly stated to ask their parents to lower it, rather than requesting the children do it themselves), which does suggest that this simple interaction between child and adult did lead to a positive energy behaviour change.

The continued logging of data around the home was intended to produce a 'snapshot' into the occupant behaviour in the home, with children potentially picking up on patterns or bad habits the parents were showing. However, with any continued intervention, boredom starts to show at some point. The website activity did not allow for as much differentiation within the detective game as Study 1 did. The combination of rooms and questions, each depending on a dice roll led to many combinations that may have positively kept the child involved - this was not present in this iteration of the home intervention. Nor was there a one-on-one competitive style side to the game, it was based on the online leaderboard comparing against other children. This oversight and lacking of aspects may have lead to the lack of participation.

Phase 4 Analysis – Reassessing Opportunity for Inter-Generational Interaction

Analyses between Phases 1 and 4 – Gas Consumption

As per the Study 3 Process diagram (Figure 23) at the start of this chapter, the second comparison output is the difference in gas consumption between the prior period and the intervention period. Having access to meter readings provides the opportunity to combine quantitative and qualitative data. To mitigate any differences in weather/location, the gas meter readings were balanced using Heating Degree Day data (HDD). Using the IP address Latitude and Longitude from the initial survey, it was possible to find HDD from online databases for airports and other weather stations as closely located to the participant addresses as possible.

It is important to note that the majority of those homes with a gas boiler also use it for Domestic Hot Water (DHW), thus these readings are not purely heating and may be skewed by homes that have more or less bathrooms or similar. This is discussed below.

With this information, it was possible to extrapolate an annual consumption based on the participant family's consumption during the proposed periods. It was assumed for this calculation that the ratio of space heating to domestic hot water heating was the industry standard 70/30 split. Table 13 below shows the final assumed annual consumption based on typical consumption and consumption during the intervention along with the difference between the two.

Table 13: Study 3 Kids4climate - Results of assumed annual Gas consumption before and after intervention.

Participant Families	Expanded annual consumption prior to study (m^3)	Expanded annual consumption post Kids4climate (m^3)	Difference (m^3)	Difference as %
A	1099.9	840.8	-259.1	-23.6
B	1575.5	1111.1	-464.4	-29.5
C	202.8	137.1	-65.7	-32.4
D	1756.3	1320.9	-435.4	-24.8
E	1309.8	1035.7	-274.1	-20.9
F	2545.1	1624.1	-921.0	-36.2
G	3446.8	23561.0	20114.2	583.6
H	1186.8	938.6	-248.2	-20.9
I	1371.8	1085.5	-286.2	-20.9
J	951.6	820.6	-131.1	-13.8
K	1208.3	1021.1	-187.2	-15.5
L	2610.6	2970.8	360.2	13.8
M	530.0	375.6	-154.5	-29.1
N	1454.3	541.3	-913.0	-62.8
O	3017.9	11694.1	8676.2	287.5
P	1810.1	1087.3	-722.8	-39.9
Q	618.2	412.1	-206.0	-33.3
R	1139.1	628.7	-510.5	-44.8
S	1752.1	1036.9	-715.3	-40.8

It can be seen that 16 of the 19 families (84%) consumed less gas based on the usage during the Kids4climate study intervention compared to prior usage. Overall, this was a promising result and analysis will follow in the later sections. The two extreme increases (+583% and +287.5%) are likely due to errors in reporting gas meter readings as a lot of the survey data had to be cleaned or removed due to incompleteness or errors during input. The third increase was a more realistic 13.8% could be more realistic and may represent an elderly person having a change in health circumstances, or the addition of a baby to the family.

All but one of the above 19 participants used the website at some point thus the next step was to see if there was a relationship between the number of interactions and the above-shown reductions. If there is no relationship between the two then it is clear that the intervention has not been successful in reducing energy consumption. The table below (14) adds data on the number of interactions with the website and the reduction per interaction.

Table 14: Study 3 Kids4climate - Difference in gas consumption per interaction with website

Participant Families	Number of Interactions	Difference %	Difference % per interaction
A	7	-23.6	-3.4
B	8	-29.5	-3.7
C	178	-32.4	-0.2
D	5	-24.8	-5.0
E	15	-20.9	-1.4
F	9	-36.2	-4.0
G	0	583.6	NA
H	22	-20.9	-1.0
I	61	-20.9	-0.3
J	9	-13.8	-1.5
K	2	-15.5	-7.7
L	36	13.8	0.4
M	9	-29.1	-3.2
N	9	-62.8	-7.0
O	79	287.5	3.6
P	9	-39.9	-4.4
Q	5	-33.3	-6.7
R	3	-44.8	-14.9
S	230	-40.8	-0.2

From this data, one could assume that the intervention successfully reduced gas consumption in the home, but there are still several aspects yet to be discussed; the potentially most influential of which is the Price Cap increase that occurred almost directly in the middle of the study duration.

Figure 120 also shows the above table data simply; it can be seen that the Line of best fit portrays a negative correlation, which is a good result for this study. This graph has the two previously mentioned outliers removed, but even when they are included, the line still has a negative gradient. The low number of results means this data is not very powerful.

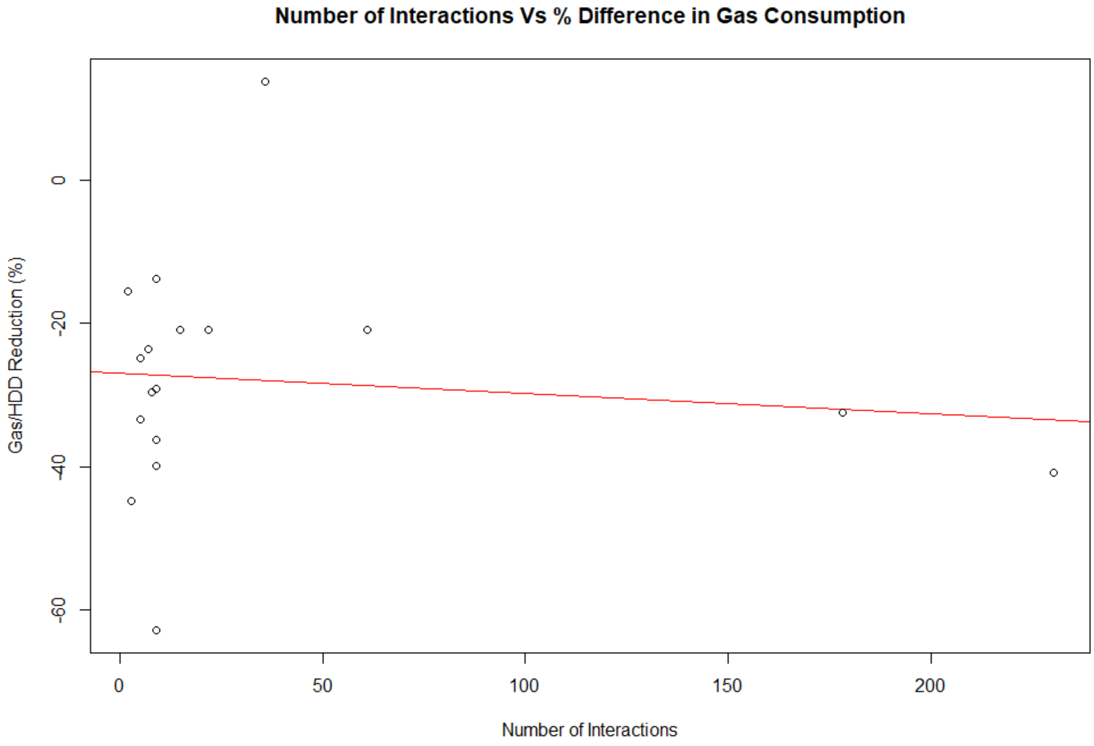


Figure 120: Interactions vs Gas/HDD Reduction

Phases 1 and 4 Analysis – Survey Comparison

As per the Study 3 Process diagram (Figure 23) at the start of this chapter, the first comparison output is the survey completed by LATENT participants (Study 1) and the final survey within Kids4climate (Study 3). The descriptive analysis was followed up by inferential tests to assess the relationships between each variable before and after the intervention. As the variables are categorical and paired, the Fisher's Exact Test was applied, with the results shown in the captions.

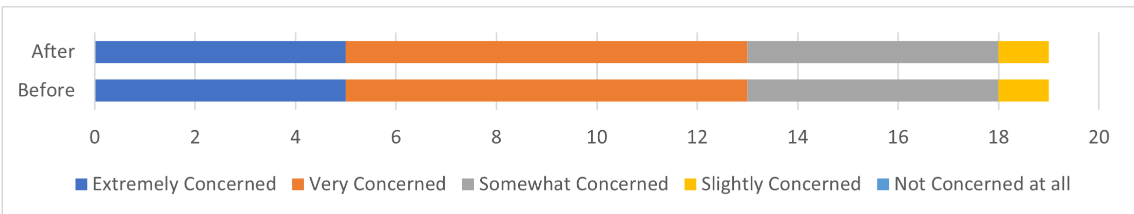


Figure 121: Study 3 Kids4climate Survey Comparison - Initial + Final - How concerned are you about Climate Change? (n=19) - Fisher Test (P=1) No significant association

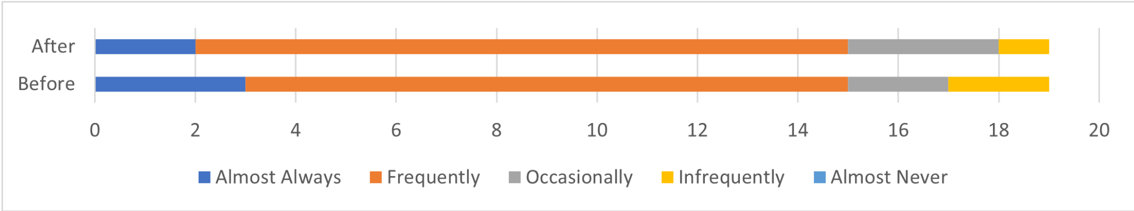


Figure 122: Study 3 Kids4climate Survey Comparison - Initial + Final - Do you consider environmental impacts when you make decisions in your daily life? (n=19) - Fisher Test (P=1) No significant association

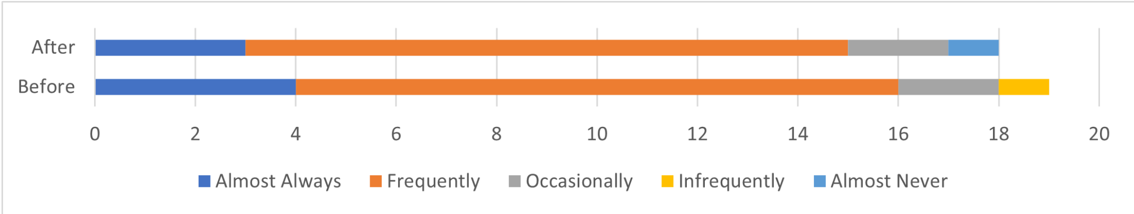


Figure 123: Study 3 Kids4climate Survey Comparison - Initial + Final - Do you think about the environmental impacts when using your heating? (n=19) - Fisher Test (P=1) No significant association

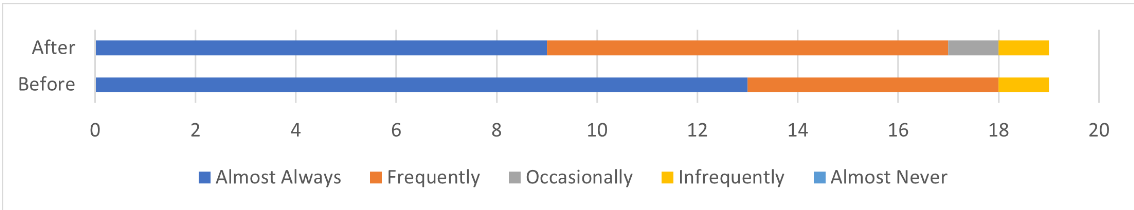


Figure 124: Study 3 Kids4climate Survey Comparison - Initial + Final - Do you think about the financial cost impacts when using your heating? (n=19) - Fisher Test (P=0.6432) No significant association

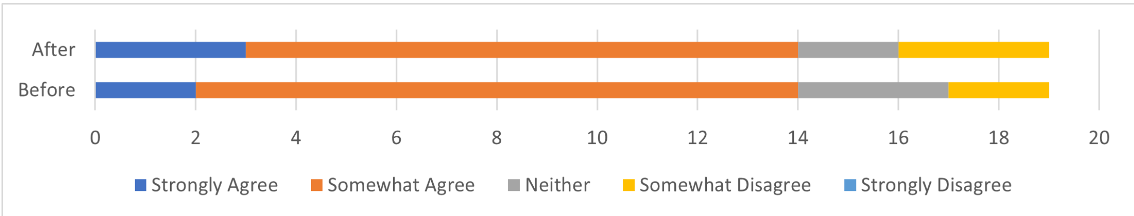


Figure 125: Study 3 Kids4climate Survey Comparison - Initial + Final - Do you think your child or children are concerned about climate change? (n=19) - Fisher Test (P=1) No significant association

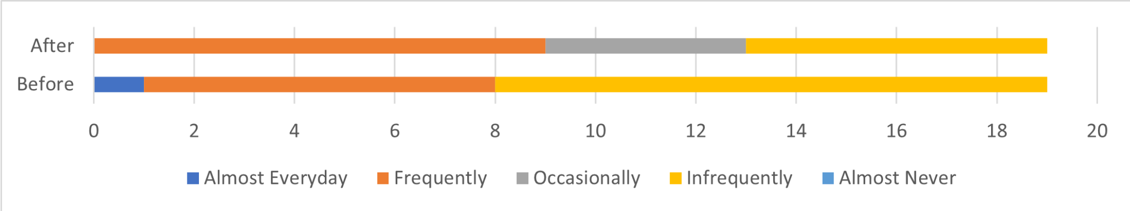


Figure 126: Study 3 Kids4climate Survey Comparison - Initial + Final - Do you have discussions with your child or children about climate change or the environment? (n=19) - Fisher Test (P=0.6961) No significant association

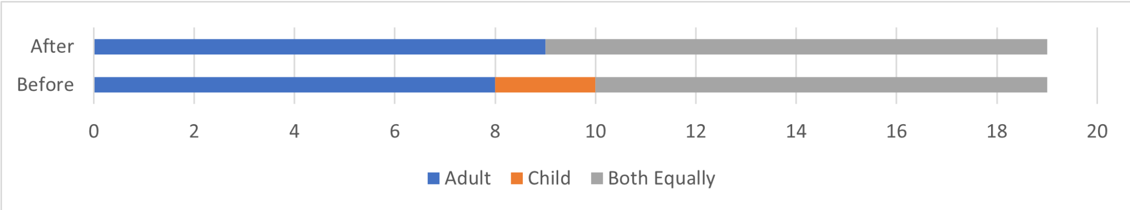


Figure 127: Study 3 Kids4climate Survey Comparison - Initial + Final - Who starts the conversations about energy issues or the environment? (n=19) - Fisher Test (P=0.5795) No significant association

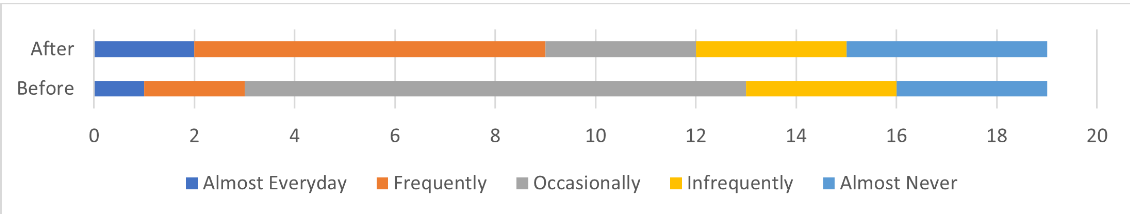


Figure 128: Study 3 Kids4climate Survey Comparison - Initial + Final - Do you think your child or children influence your energy usage decision-making in the home? (n=19) - Fisher Test (P=0.1682) No significant association

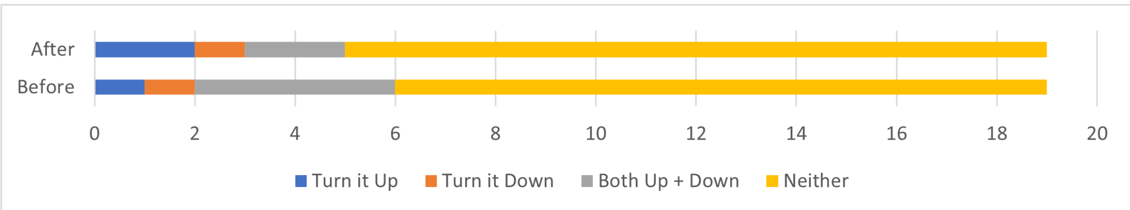


Figure 129: Study 3 Kids4climate Survey Comparison - Initial + Final - Does your child ever ask you to turn the heating up or down? (n=19) - Fisher Test (P=0.8638) No significant association

Looking at these comparisons, one can see very little has changed overall, with all Figures showing no significant association between before and after the intervention. Figure 121 "Climate Change Concern" shows an exact replication between before and after the intervention. In a similar result, figure 122 "Considering the environment when making decisions" sees 1 less participant in the 'Almost Always' answer but also sees 1 participant move from 'Infrequently' up to the 'Occasionally' answer. This lack of positive changes may show that the intervention does not have a substantial enough effect for knowledge to be passed inter-generationally, but this does not fall in line with the considerable improvements seen in gas consumption before to after the intervention - most likely the price cap increase is the main driver behind reduced energy consumption.

Figure 123 "Do you think about the environmental impacts when using your heating?" has seen a decrease in participants choosing 'Almost Always' and thus moved negatively, not in line with the results the study would expect to see. Having said, this Figure 124 "Do you think about the financial cost impacts when using your heating?" Has seen the largest change with 30% fewer participants now being driven financially than before. This is in stark contrast to expected due to the price cap increase that occurred on the 1st of April 2022.

Interestingly, Figure 125 also shows very little change, just one participant choosing 'Strongly Agree' rather than 'Somewhat Agree' - it is important to remember this question asks the parent/carer to give their opinion on if they think their child is concerned about climate change. When this question was asked by teachers to children in their class, the overall consensus was far more concerned from the majority of children. It would be more beneficial to have children answer a survey, but this raises complicated concerns such as ethics and usability. It could also be that parents do not know their child's stance on this.

Figure 126 saw unexpectedly neutral results overall, with parents at the better end now having fewer discussions with their children (about climate change) than before the intervention, but also several participants have moved up from 'Infrequently' to 'Occasionally'. Looking at the frequency of website interaction alongside this to see if more website use leads to more discussion may be interesting. As this result has not seen a drastic improvement, only the 5 participants' responses improved from infrequently to frequently, it may show that this intervention as a whole has not succeeded in its testing of initiating interactions.

To further the points of the above paragraph, Figure 127 shows that participants actually reported a decrease in the number of children initiating the discussions about energy and climate change. This result could be that the parents have learnt from the child that it is an important issue and are now raising the subject more, or that the intervention has had such a low effect on the participants that the children now dislike the subject. This could be because of the need to repeat the intervention daily, with children seeing it as taking their free time.

The reported answers to the question 'Do you think your child or children influence your energy usage decision making in the home' (Figure 128) have seen a significant increase in the 'Frequently' from 2 responses before to 7 responses after. The way in which children are influenced is not asked nor stated in this question, but it could be assumed from the increase that this is due to the intervention promoting discussion between children and adults. This of course can not be said for definite.

Finally, Figure 129 again remains almost identical, showing that the intervention has not increased the number of children who have asked to lower the thermostat temperature. Having said that, the number that requests 'neither' has decreased, and the number that requests 'both' has increased. Very little pattern can be seen here; unfortunately, one would hope to see requests to lower the temperature increase the most as the children improve their home energy literacy.

The last survey question in this section allowed the parents to openly state what changes they may have made due to learning from their child during the study. Answers were positive overall, with two participants saying they specifically reduced their thermostat to 18 degrees and three more families mentioning reducing heating use with scheduling or wearing extra layers in the home. These are encouraging comments that are beyond what the intervention was trying to achieve. There were also many comments on other aspects, such as water use, electricity use and transport, all saying they are reducing the use of these and in turn their consumption of energy as a whole. Interestingly, several ideas were not discussed within the lessons but do have merit behind them, such as driving slower or putting the washing machine on overnight. Children are always listening and picking up ideas from around them, and it is promising to see that they are now discussing some of these with their parents, presumably with reducing energy consumption in mind. This may be an added secondary effect of the intervention.

An Nvivo analysis was carried out on these results in an attempt to quantify any patterns that may have been within the written feedback. The statements were uploaded to the software and then coded. This involves cutting and grouping words, sentences and phrases to form themes that are unclear when looking at individual responses. The following themes were created:-

- Current Behaviour
- External Factors
- Feedback
- Increasing Discussions
- New Behaviours
- Other Influences
- Parental Opinion

Each theme was produced from a varying number of points; 'feedback' saw the most with 15 different mentions throughout the results, and these could further be split between positive, negative and neutral feedback. Negative feedback contained 10 different mentions, by far the largest (the next being neutral feedback with three and several mentions with two). This is a concern for the study, as this high level of negative response was not intended. Several times, the lack of direction and what to do on the website was mentioned, along with time and repetitiveness, mentioned in a variety of different ways. It is apparent from this analysis that the website intervention required further work.

The reluctance of children and parents to repeat the website activity is also a matter for concern. The previous take-home activity in study 2 was a single-play game, and this did not receive the same criticisms, suggesting it may be a better way forward in the next study.

As aforementioned in the results section, the final survey included a set of questions in addition to the initial survey. These are shown again and discussed below and include aspects such as frequency of use and whether interactions have occurred since the start of the intervention.

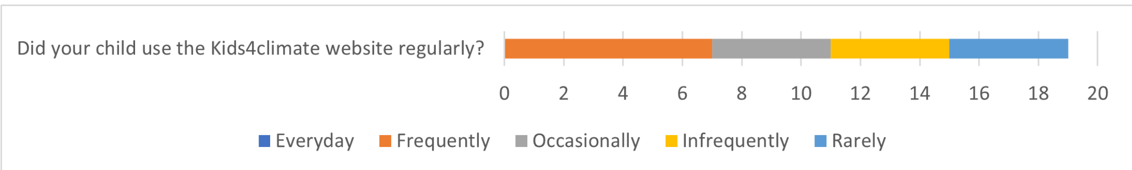


Figure 130: Study 3 Kids4climate Final Survey - Children's Use of Website

It can be seen in Figure 133 (of the final 19 participants only) that, unfortunately, no parents have reported their child completing the website activities daily. This 'daily' requirement put forward in the initial call for participants was a concern for several parents, who replied suggesting that they would only be able to make a few days a week or even not at all. This is definitely a negative aspect of the home/online side of the Kids4climate study. There was also no drive to complete it daily as there was no reward for completing or penalty for not completing, which may otherwise be possible in the school. The next iteration of the study is already being designed to incorporate rewards such as stickers.

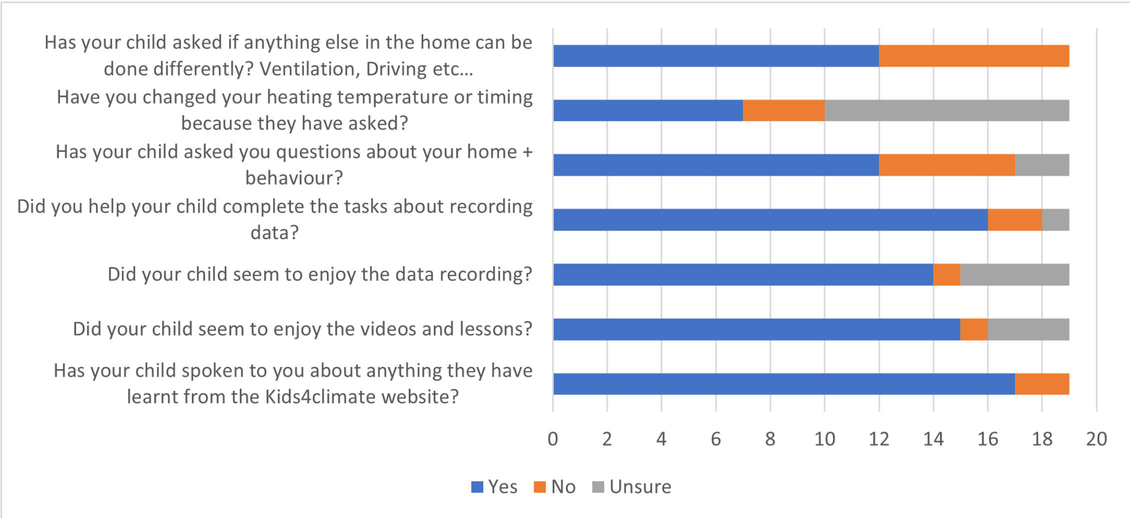


Figure 131: Study 3 Kids4climate Final Survey - Questions about the Child

Figure 131 shows the combined results from several more of the questions in the final survey. The first sees a positive response rate of 12 of 19 participants saying yes (63%). If two-thirds of children have recommended behaviour change to their parents, the UK as a whole could see a quantifiable reduction in emissions. The second question shows that seven participants (37%) have changed their heating temperature or timing after being asked to by their children. seven participants stating 'unsure' actually chose the answer 'they have not asked', but for ease of reading, they have been included within the unsure category. It is important to note that although the answer to the second question may have been no, the child has still asked the question, thus an interaction has occurred, which is the main investigating factor of this study.

A large proportion (12/19 or 63%) of participating parents stated their child questioned their behaviour in the home. This is a good result for the study; it is good to see that children are indeed taking on the knowledge shown in the videos and then noticing what their parents are doing in the home, then additionally putting those two things together and questioning bad energy behaviour and decisions.

It is also nice to see that the vast majority (84%) of parents helped their children with the activities. This was an important part of the study - making the website content just hard enough that the children would still be interested, but also having to ask their parents to help with some parts. This not only promotes opportunities for inter-generational interactions to occur but also promotes the parent taking on a teaching role and potentially learning some new knowledge themselves.

Similarly, the parents seemed to have the impression the children enjoyed both the videos and the data logging activities, with 14 and 15 out of the 19 participants (74% and 79%) respectively choosing "yes" to these two questions.

Finally, the last question in Figure 131 above shows that 17 of 19 children (90%) spoke to their parents about something they have learnt from the Kids4climate website. This is the most positive answer and shows that the website does indeed lead to inter-generational interactions taking place from child to parent and may even pass on knowledge about energy. The analysis has already shown that not all these discussions or requests will garner positive behavioural change in the home, but the website did take a holistic approach to the lesson contents to maintain interest from the child.

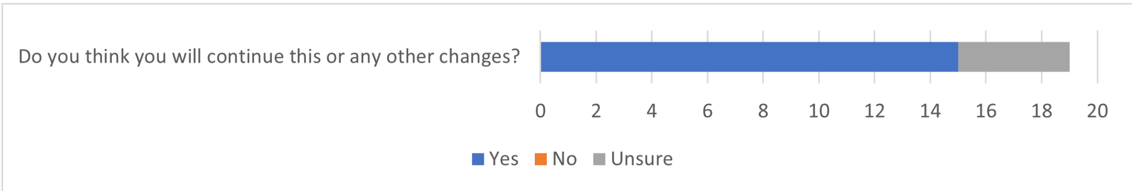


Figure 132: Study 3 Kids4climate Final Survey - Asking if parents would continue behavioural changes.

The prolonged habit of good energy-related behaviour would be the theoretical ideal outcome from this study - going beyond initiating inter-generational interactions and using them to teach parents, but it is hard for sporadic changes to become new habits. Figure 132 above shows that 79% (15/19) of participants think they will continue at least some of the changes that they have started since the intervention took place. It would be very interesting to return to these participants the following winter and see if the changes they have made are still in place or if they have reverted to their old habits and behaviours. It is also important to highlight that these changes may have been more influential at the time due to the Energy Price Cap increase. This raises the question: Would the positive change suggested by the child hold the same weight if energy costs had lowered instead of increased?

The final three questions of the survey can be seen in Figure 133 above. Overall, it is positive to see that many of the participants would like to learn more about climate change and the environment, whilst an even larger amount feel they are now more aware of their

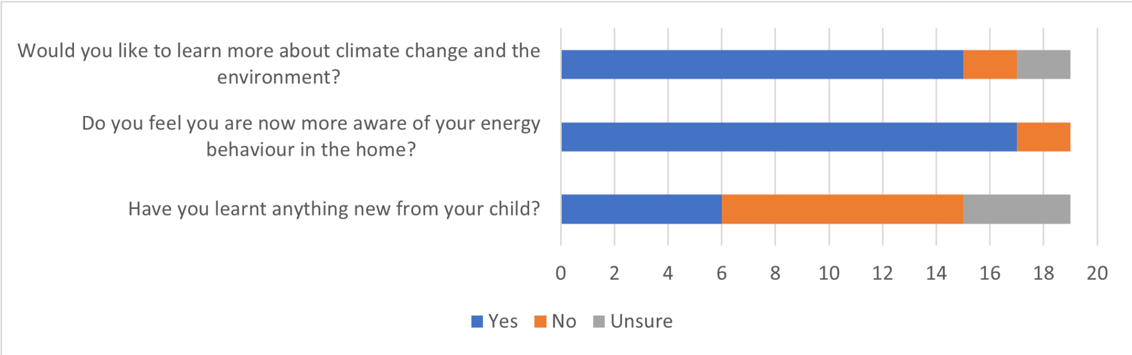


Figure 133: Final Section of Survey

energy behaviour in the home. This again is one of the main take-away's from the study. Interactions must have happened for knowledge to be passed on from the short cartoon videos on the website to the parents, who will see the positive effects that knowledge will have. Although, as 9/19 participants (47%) have stated, they may not have learnt anything new from their children, 6/19 participants (32%) have said they have. There are, however, some interesting imbalances in the results; 17 parents stated they are now more aware, but only 6 stated they learnt something from their child. Are they suggesting they have not been made more aware of their child, but from another source during the same time? This may also show that parents are not considering 'awareness' a learned aspect, maybe because it is not a fact or figure for example.

Other important aspects for analysis:

Feedback from the participant parents

The feedback from the parents included some positive and negative aspects, but overall was very constructive towards implementing a fourth study after this one. The ease of completing the online activities is mentioned, leading to boredom and then in-completion, but the complexity and length of the activities are also mentioned, leading to the same outcome. Age ranges are large for a single activity, crossing three separate key stages. As required in Study 2, separate work is important for these different ages and abilities, but this is not achievable at the scale of this intervention. Separate activities on the website (or even separate websites) would have been logistically impossible. This does bring up an interesting point; the age of the children taking part was not collected, meaning that results cannot be analysed with that in mind. It is clear, however, that the online activities did not suit all age ranges. The study could be summarised in the following feedback; "We have made as many changes as we can financially, if anything this has brought it to our table and we discuss it more." An additional layer of interest comes with their next sentence that says "The message sent to have been lost at school and seems distant to our children at primary level". This study has produced data that would suggest the same; that energy literacy is not available at schools and by implementing a sustainable national curriculum, it can have positive effects on occupant energy behaviour in the home.

The Price Cap Increase

The 'Energy Price Cap' increased on the 1st of April 2022 and affected around 22 million UK customers [Ofgem (2022)a]. The average household on default tariffs paying by direct debit saw an increase from £1277 to £1971, a £693 increase (54%). This was driven by an international increase in global gas prices over the previous year [Ofgem (2022)a].

This price increase led to 29 separate energy companies falling into administration, including Igloo Energy, who were the commercial partners for the LATENT Study and initially provided the participant pool.

This change sat within the deployment of the Kids4climate study, which started approximately 4 weeks before this rise and finished approximately 3 weeks after it. Financial constraints have always been a strong influencing factor on heating use within the home; this study aimed to understand if environmental concerns would be prevalent enough to become the main factor in reducing heating use, the abrupt and unprecedented step change occurred mid-way through the intervention, thus it is likely this would have been the primary influence on behaviour during this period.

Uptake of The Study

The final uptake (of a fully completed before and after survey and website use) was n=19 out of a possible 750 (2.5%). This is considerably lower than anticipated and has meant the data is somewhat small. Some possible reasons that were addressed in the third iteration of the study can be seen below:-

- Children didn't want to do more 'work' once they were home from school
- Parents didn't want to commit to a potentially long activity
- Rewards (£20 Amazon voucher) might not be enough.
- The game might not be interesting enough.
- Overall topic might not be interesting enough.
- Website did not promote repeated use.

The main difference between Study 2 (Energy in the Home) and Study 3 (Kids4Climate) was the location of learning; the first within the class was delivered by a teacher (a trusted source) during school time, and the second was delivered online via pre-recorded videos whilst in the child's own time (a low cost, but potentially less trusted and less engaging platform). Feedback from several of the participants mentioned how getting children to do extra 'work' at home was hard. This was expected, but not to this degree; it was hoped the game would be entertaining enough for continuous play.

Domestic Hot Water (DHW)
Domestic Hot Water is the second largest consumer of gas in the home after heating. It also often happens to use the boiler as the heating source in most homes that use a modern combination boiler. These requirements for taps/showers/baths etc are currently included within the data collected (overall gas consumption) and may be having an effect of an unknown amount. Although an unknown quantity, it was accounted for in the analysis using the 70/30 split, which is an average ratio over the entire year. It was important to represent this as the prior readings were taken during autumn/winter and the Kids4climate readings during winter/spring, thus, if looking at them individually would have had different heating to hot water ratios.

5.3.1 Summary

This study has revealed several positive and negative results and issues. Factors outside the control of this research have had a great effect on the overall success, but also a lack of uptake by both parents and children led to low numbers of results. The response rate may have been low for one or more of several reasons as discussed earlier, but these are intended to be incorporated into the design of Study 4.

The main point for comparison within this study was the shift to an online intervention from the school environment. Results suggest this did not work as effectively, with children not inclined to complete the activities repeatedly. The home environment, as supported by literature such as Taubvuma et al (2021) is not as ideal for learning as the school environment.

5.3.2 Limitations

Study 1 (LATENT) utilised the then Igloo Energy customer base to achieve a very high number of respondents; it was a well-established and trusted source that gave a potential monetary reward for taking part. These aspects are likely the reason it was so successful in returning a 19.2% response rate. This was one of the main reasons Study 3 (Kids4climate) returned to the now 'post-Igloo customer base'. However, it became apparent, that participation in Study 3 was very low. Several aspects may be reasons for this low participation.

The first is the closure of Igloo Energy. This meant that customers had to be moved to another provider against their will. This had likely caused some friction with the customers, thus lowering the trust and diminishing the relationship that had been built up. It may have also tarnished the University of Southampton's reputation from the customer's perspective. It also meant that customers may have been having financial worries due to the change of supplier, as well as any inconveniences caused by having to check meters often, losing access to the online Igloo Dashboard and smart meters etc.. These reasons may have led to a distaste to carry out more research for Igloo/Southampton or simply an impatience with anything to do with utilities, thus a lower uptake may have occurred. These reasons are being grouped under the term 'Trusted Persons' as discussed previously with children at school in Study 2. This aspect seems to be a key influence in the success of the intervention studies.

The location of learning may have also been an issue. It would not have been possible to target such a large potential participant group without moving the intervention online (especially with the ongoing COVID-19 situation), but in doing so, the ideal learning environment of a school classroom was lost. This was clear from the outset, with potential participants contacted to say that taking part would not be possible due to the home workload on their children. Many others may have ignored the call for participants. This could also be affected by how the study was promoted towards the customers; it may have potentially sounded like too much work for families to commit to. Or, as in the previous paragraph, had the bankruptcy of Igloo tarnished the University of Southampton so much so that people no longer wanted to take part in studies associated with it? Similarly, Igloo Energy offered £100 in a raffle to five of the participants who took part. This research does not have the funding for such incentives, thus people may not have been so inclined to take part. Several of these are beyond the control of this research, but will still need to have alternative solutions found in order to succeed with the next study.

From a study structure perspective, the development of the Kids4climate website has been very successful in a few ways; by transitioning online, the research was able to avoid any potential COVID-19 restrictions, target a national audience and lastly create resources and record data for future analysis. This website can now be utilised at any point in the future for other research studies or similar. Feedback from parents who took part in the survey showed that they had learnt a variety of knowledge through interacting with their children since using the website, thus it appears it succeeded in delivering a small education that would increase the energy literacy of children. Having said that, these aspects are inherent to the design of the study, and the performance of the data gathered has not been as successful; participant numbers were low, and the retention rate to complete the entirety of the intervention was even lower.

5.4 Study 4 Analysis

Phase 1 Analysis – Parental Energy Behaviour Baseline

Below are the results of the initial surveys of Study 4 'Eco Homes' compared between the two participant schools. The participant numbers are as follows: Walhampton n=56, Woodcot n=12. The graphs below show percentages to allow for visual comparison. As with the same comparison in Study 3, a Fisher's Exact test was carried out on each to find any relationships. Below each figure will be a short analysis of the results. With participant uptake lower than expected, descriptive analysis will make up the majority of this analysis section.

It can be seen from the figures below (134 to 142) that there is a significant difference between the two schools for three of the nine questions. The demographics of the two schools are very different, and this may be evident in these answers. For example Figure 134 shows 85% of Walhampton parents stated 'Extremely' or 'Very' compared to less than 50% of Woodcot participants for the question 'Are you concerned about climate change?'. This result falls in line with the research from Gadenne et al (2011) and Pothitou et al (2016), who support that better energy literacy levels are linked to better awareness and concern [Gadenne et al. (2011), Pothitou et al. (2016)] . It can be expected from the indices of deprivation for the two school locations that the far higher rates of education and qualifications mean that energy literacy is likely higher at Walhampton, the school that showed higher concern for climate change [Gov UK (2019)].
It must be noted that the participant numbers for Woodcot were around four times lower than those of Walhampton. Additionally, the low participant numbers n total (n = 56 + 12, totalling 68) mean that statistical power is low and this must be accounted for within the Fischer's Exact test scores.

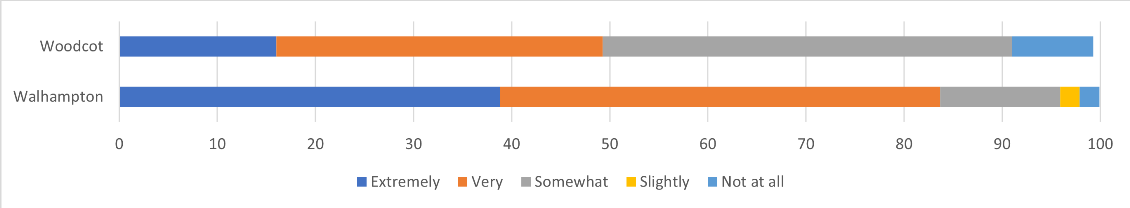


Figure 134: Study 4 'Eco Homes' Initial Survey Comparison - Walhampton + Woodcot Schools - How concerned are you about Climate Change? - Fisher Test (P=0.07175) No significant association

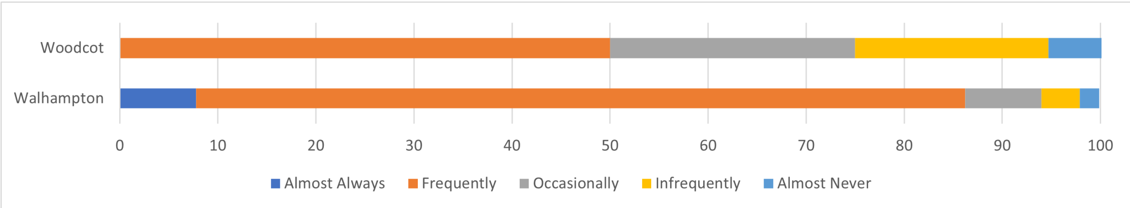


Figure 135: Study 4 'Eco Homes' Initial Survey Comparison - Walhampton + Woodcot Schools - Do you consider environmental impacts when you make decisions in your daily life? - Fisher Test (P=0.02966) Significant association

In Figure 135, it can be seen that no Woodcot parents stated 'Almost always' and 50% stated 'Frequently' to the question 'Do you consider environmental impacts when you make decisions in your daily life?', but for Walhampton, the response rate was 8% and 78% respectively. Adding to this, 8% of the respondents from Woodcot said 'Almost never', but only 2% from Walhampton stated that.

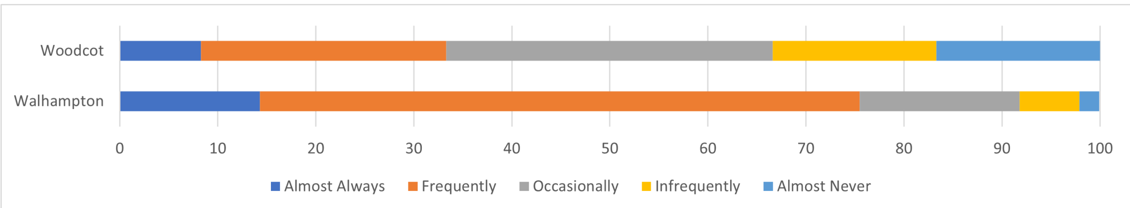


Figure 136: Study 4 'Eco Homes' Initial Survey Comparison - Walhampton + Woodcot Schools - Do you think about the environmental impacts when using your heating? - Fisher Test (0.03183) Significant association

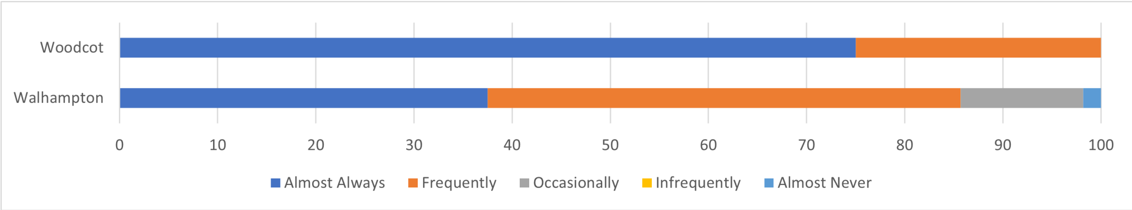


Figure 137: Study 4 'Eco Homes' Initial Survey Comparison - Walhampton + Woodcot Schools - Do you think about the financial cost impacts when using your heating? - Fisher Test (P=0.1549) No significant association

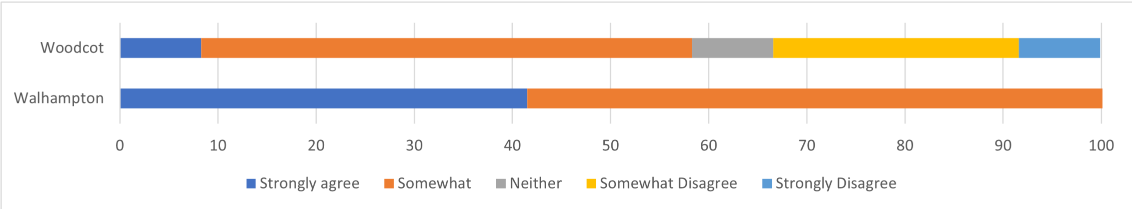


Figure 138: Study 4 'Eco Homes' Initial Survey Comparison - Walhampton + Woodcot Schools - Do you think your child or children are concerned about climate change? - Fisher Test (P=0.01815) Significant association

The different demographic groups are clearly evident in Figure 137, with 75% of Woodcot respondents stating financial concern influences their heating usage, but only 35% of Walhampton participants stated the same [Gov UK (2019)]. Interestingly, Figure 138 shows that five times more Walhampton participant parents think their child is concerned about climate change compared to Woodcot parents (42% compared to 8%). This may be because Walhampton is an independent school and does not have to strictly align with the National Curriculum, thus it can dedicate more time to alternative topics and content. For example, Walhampton is a Green Flag-awarded School (through Eco-Schools), but Woodcot does not have any environmental credentials and is required to follow the very limiting National Curriculum [Department for Education (2014)].

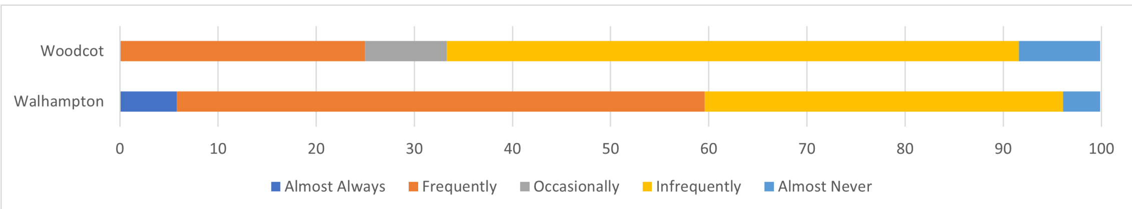


Figure 139: Study 4 'Eco Homes' Initial Survey Comparison - Walhampton + Woodcot Schools - Do you have discussions with your child or children about climate change or the environment? - Fisher Test (P=0.09399) No significant association

Similarly, Figure 138 shows that Walhampton respondents stated 'Frequently' or 'Almost always' 60% of the time for the question 'Do you have discussions with your child about the environment?' compared to Woodcot respondents, who had a far lower 25%. Walhampton does not follow either the literature, nor the results from Study 1, which both suggested discussions and influences from children are limited and negative if they do occur [Steemers and Yun (2009), Estiri and Zagheni (2019)].

Interestingly, 'Who starts the conversation?' (Figure 139 shows very similar results and has the weakest statistical difference. This may suggest that children of this age, no matter the financial or academic opportunities provided to them, do not initiate conversations about the environment with their parents. The reasons for this are unknown, other than that they may already not discuss school topics (such as maths) and learning about the environment at school may then put the knowledge in the same bracket.

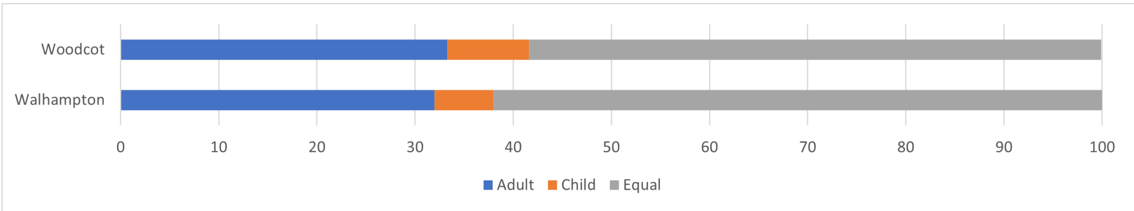


Figure 140: Study 4 'Eco Homes' Initial Survey Comparison - Walhampton + Woodcot Schools - Who starts the conversations about energy issues or the environment? - Fisher Test (P=1) No significant association

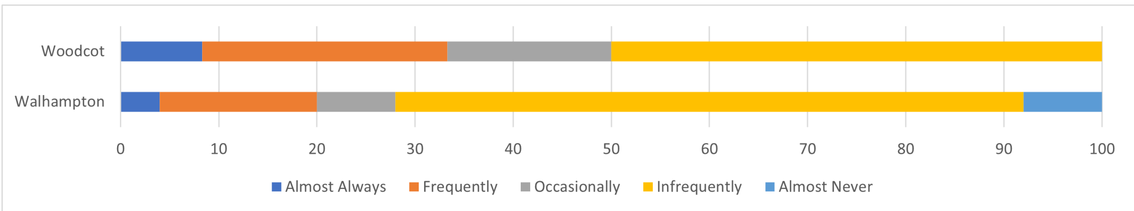


Figure 141: Study 4 'Eco Homes' Survey Comparison - Walhampton + Woodcot Schools - Do you think your child or children influence your energy usage decision-making in the home? - Fisher Test (P=0.453) No significant association

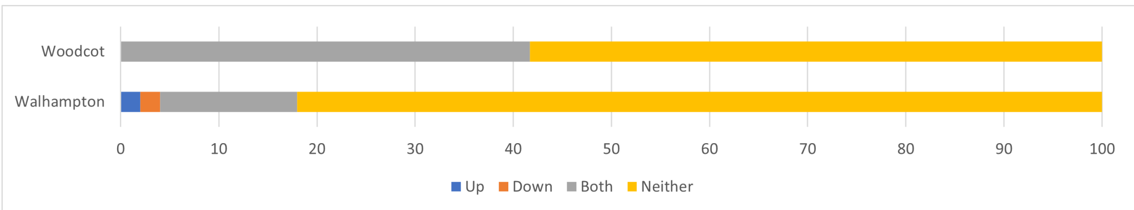


Figure 142: Study 4 'Eco Homes' Initial Survey Comparison - Walhampton + Woodcot Schools - Does your child ever ask you to turn the heating up or down? - Fisher Test (P=0.1331) No significant association

Phase 2 Analysis – Improving Energy Literacy Levels of Children

As per the Study 4 Process Diagram (Figure 28), the third comparison output states "Differences in results from Game 1 to Game 2 will show if energy literacy has been improved". This section will carry out those comparisons.

Study 4 School Lesson - Game 1 analysis

Five of the nine-item scores show lower medians or interquartile ranges from Walhampton pupils, with a sixth showing identical results. The only items scored higher by Walhampton were Cars, Fridges and Radiators. These are all items that have been included in past research that shows they may vary in use depending on other factors in the home. These could include Household Income, Household Floor Area or many other important factors.

The considerable difference in Game Console or Fridge scores between the two schools may be due to similar aspects as discussed above. It may be likely, given the demographic differences between the two schools, that ‘Appliance Deprivation’ may have played at least a small role in this. As aforementioned, in the UK, lack of access to a personal laptop or adequate device is consistently linked to worse home-learning opportunities; this study would be an ideal example of this [Digital Povery Alliance (2024)]. The children from Walhampton school would have had easy access to devices to complete this work, whereas those from Woodcote may not have. All children must have access to knowledge and information, and promoting a digital learning environment may not be the best way forward.

The ‘Car’, which is the central item of the list of nine items, shows a different pattern to the rest of the results. As it is the central item, it can be scored equally higher or lower by +/-4 places. Both schools recorded a lowest score of -4 and a highest of +4, the vast majority of Walhampton (red) students scored the item as +2 to +4, with three ‘minus score’ outliers being shown in the box plot, whereas Woodcot (blue) shows the entire quartile range scored lower (-1 to +2). This variability difference is the largest for a single year between the two schools and may represent the stark contrasts between the demographic areas in terms of the Indices of Deprivation [Gov UK (2019)].

It can be seen in Figure 143 above, taken from the 2021 Census, that Gosport, the location of Woodcot Primary School, has three times as many households with access to only one car, whereas Lymington Town, the location of Walhampton Prep School, shows twice the number of households with 2 cars and almost 4 times as many with 3+ cars.

Number of Cars Per household	Lymington Town (Wal)	Gosport (Wood)
0	12.5	36
1	41.7	44.7
2	31	15.4
3+	14.9	3.8

Figure 143: Table showing number of cars per household. Taken from ONS, "Census Map of LAD + Car Ownership," 2021

With over 80% of Gosport households having access to only one car at the most (compared to Lymington, with 45% of the households having at least 2), the results shown in the boxplot could perhaps represent a difference in opinion that may stem from these differences in daily life. Whilst students from both schools have overestimated the energy consumed from car usage, the Walhampton students, from far more affluent households, have recorded higher levels of over-estimation than the students from the less affluent school area (Gosport), in line with the ideas put forward by Hansen and Jacobson (2018) that "practices are shared and reproduced within the family" - with the Walhampton families likely driving more often [Hansen and Jacobsen (2020)].

This could be looked at from several perspectives; the first is that Walhampton children know their daily car use is high, they drive to school each day, and likely live in more rural areas thus driving more often. A second perspective is that Woodcot children know their car use is low, they may not own a car at all, or walk or use public transport daily. It could also be likely that both sets of students are simply accustomed to the daily transport behaviours that they neither know of nor understand other ways of transport or the energy consumed by different these different ways.

Differences in lifestyles between the two participant schools may be responsible for more than differences in just car ownership and perceived energy consumption. Games Console sees the largest difference where Walhampton scored lower than Woodcot. The median score for Walhampton is perfectly correct with a score of 0, whereas Woodcot's median is on +2. This may be an offshoot of the aforementioned appliance deprivation issues, moving from white goods to more leisure-time devices [Digital Povery Alliance (2024)]. Game console ownership in the UK is around 5 per cent points lower in low-income than in high-income homes [Statista (2023)], thus if the two participant locations follow this national average, there will be fewer game consoles in homes of Woodcot students than those of Walhampton students. It could then be assumed from the boxplot data that Woodcot children may have less knowledge of the item and thus have overestimated how much energy it would use each day.

Study 4 School Lesson - Game 2 analysis

Four of the Game 2 items were pairs: cycling and driving, and then showering and bathing. These were deliberately chosen so that children could discuss the direct comparison between the two. After the lesson discussing energy in the home, it was expected that the students would understand that a bicycle uses no energy compared to a car and that having a shower uses less water, which in turn means using less energy.

Discussing Cycling and driving first, it appears from the boxplot of game two, that Walhampton pupils by far had this as the most correctly placed behaviour. All, but four points are placed on 0, showing correct placement. The outliers are +1, +2, +3 and +6, respectively. This is not the case for Woodcot, which sees a larger spread more similar to other behaviours on the graph. It could be presumed that the children at Walhampton may have simply been told that cycling is the lowest energy consumer by their teacher, but the study took place in 8 separate classes taught by 8 different teachers, none of whom were told to do so. From the topics covered in the lesson, discussions may have taken place based on fuels such as petrol, gas (and electricity), thus this human-powered device would naturally be placed towards the bottom of the ranking.

Its partner, Driving, has been over-estimated by both schools. This is the same situation as looking at the car as an item in game 1. The item (car) and behaviour (driving) both see medians of at least +1 or higher. The quartile ranges are significantly higher than the S-Curve that would be expected or has been produced by the results. Interestingly, it is Woodcot (blue) that this time has placed driving higher, compared to Walhampton when it was an item in Game 1.

As previously discussed, the two sets of children likely have very different experiences and knowledge when it comes to vehicular travel. This would also include daily travel to and from the school itself. Walhampton Prep is located approximately 1 mile away from the town of Lymington. It is inaccessible by foot with the school running a small bus service (8 minibuses), but the majority of students arrive and leave the school by car. This is a stark contrast to Woodcot Primary, which is located within a housing estate and sees almost all students arrive by foot. This lifestyle difference may explain the contrast in results between the schools. The change in results between Game 1 and Game 2 may be explained by the different ratios of age groups that took part. Woodcot included years 1 and 2 in the intervention, whereas Walhampton did not, thus when compared, the average age of pupils would be higher at Walhampton. Younger children may be considered less informed as they have received less formal education at the time of the intervention.

This still does not explain the change between games 1 and 2 – Walhampton initially placed the Car far higher than Woodcot, but then in Game 2, Woodcot placed Driving higher than Walhampton. This may not be due to inherent or learned knowledge of the item/behaviour, but more to do with the relative scales of the two games. Although there are 2 matching topics between the two games, there are 7 that do not match. The children may have thought other items were more or less energy-intensive, thus these affected the placement of Driving. The inclusion of behaviours such as Eating Meat and Leaving Windows Open, which are more complicated concepts to understand, may have led to more well-understood behaviours being more often incorrectly placed.

Showering and Bathing are also two different behaviours that reach the same outcome by using very different levels of energy (and water). The topics of water usage, wastage and domestic hot water (DHW) were all discussed during the lesson in the hopes that a distinction between the two behaviours was realised by the children. From the results, Showering has a larger variability for Woodcot children than for Walhampton, with the median at +2, the latter's median landing on 0. Bathing's median is also on 0 for Walhampton, but this time Woodcot's median is below 0 at -1. Walhampton children scoring both medians correctly suggests that they indeed saw and understood the difference in energy consumption between the two methods of washing.

As aforementioned, driving does not fit the expected S-Curve that should be produced with a ranking style game and has been discussed above. The second behaviour that does not seem to match the pattern is Stand By – this refers to leaving items, devices and other technologies in the home on standby, rather than turning them off at the main power switch or plug socket on the wall.

<u>Study 4 School Sticker Game Results regarding Year Groups</u>

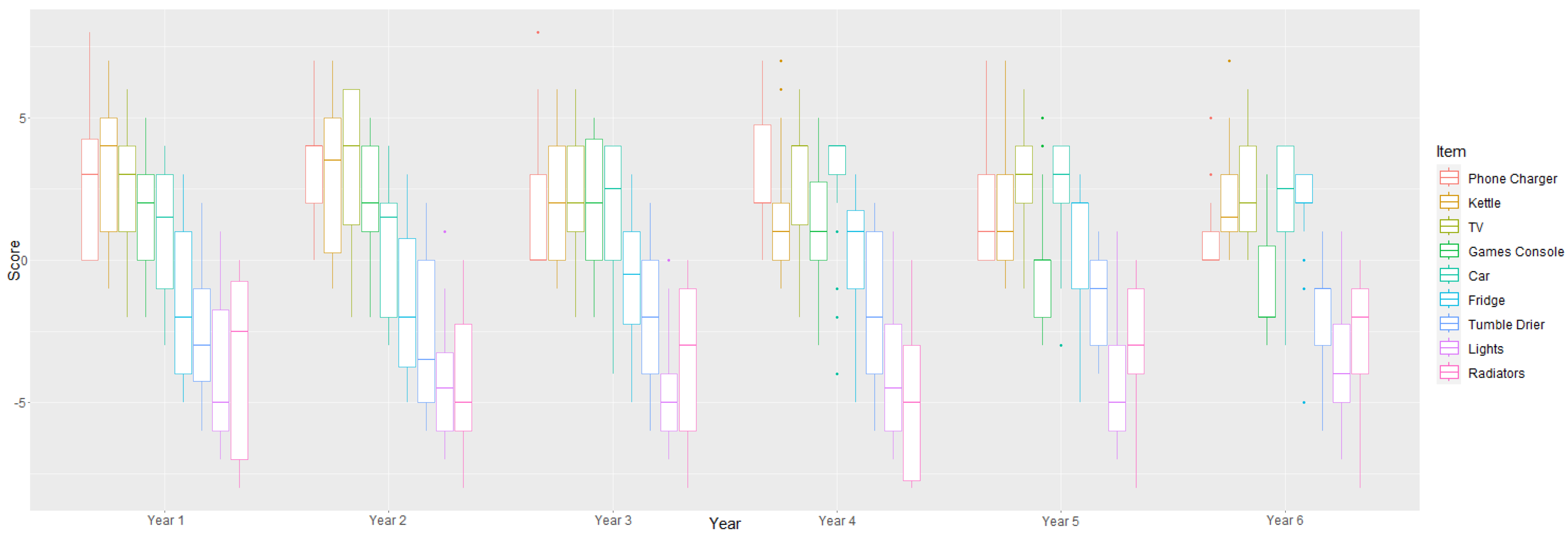


Figure 144: Study 4 School Sticker Game - Boxplot of Game 1 Variability By Year Group - Both Schools

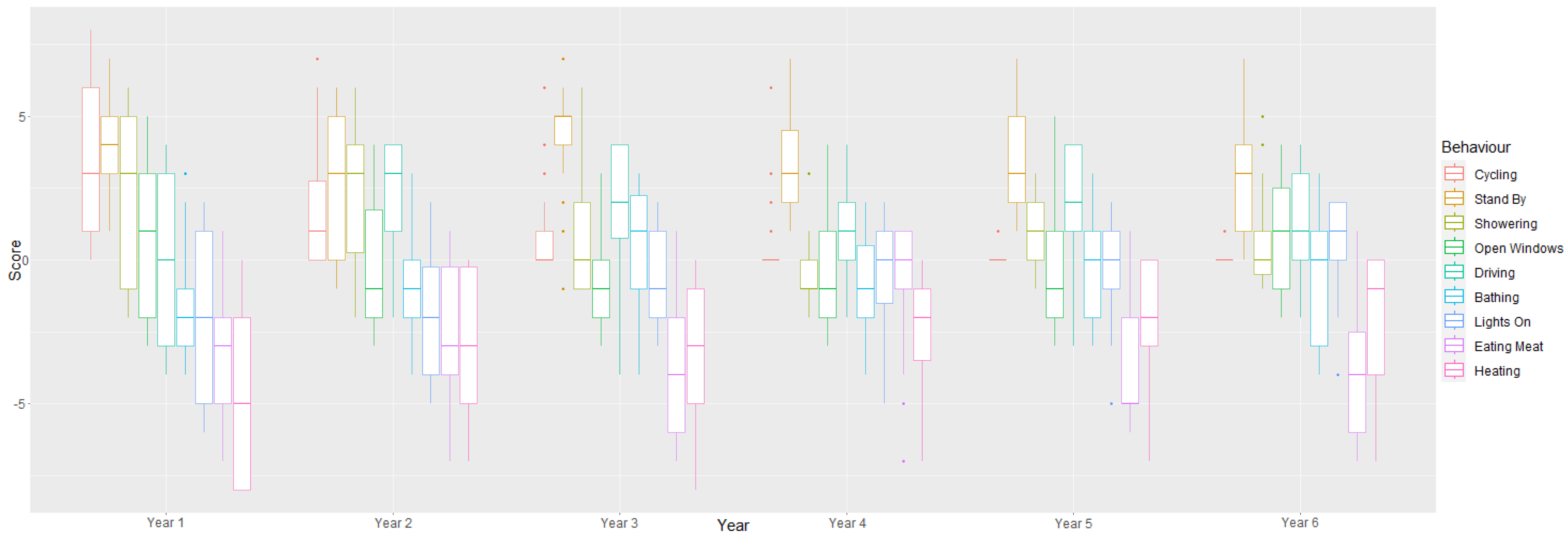


Figure 145: Study 4 School Sticker Game - Boxplot of Game 2 Variability By Year Group - Both Schools

The above Figures (144 and 145) show the results of the class-based sticker games divided into year groups. Patterns can be seen from these regarding which age group's opinions differ. It is expected that as children get older, their answers may become closer to correct (0), but this is not observed.

The below box plots (Figures 146, 147 and 148) show only the items that displayed interesting patterns in Figure 144 It can be seen that these items swap in placements as the children's age groups increase, with younger children thinking the opposite of older children.

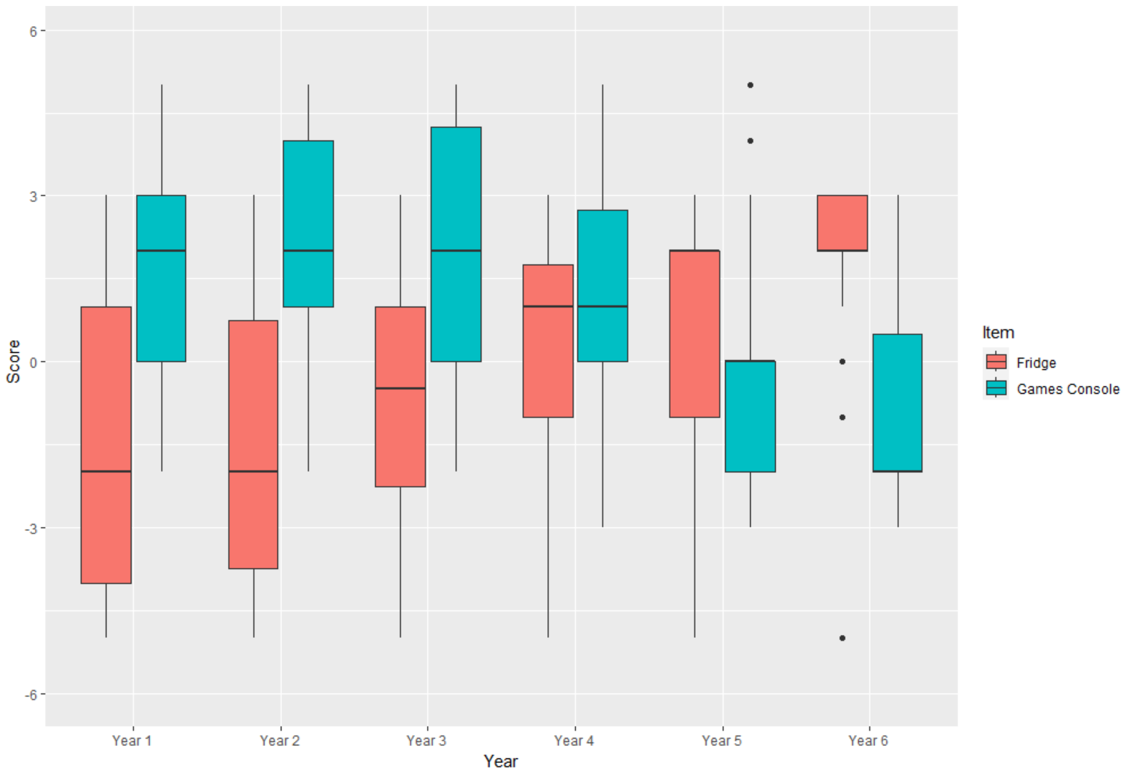


Figure 146: Study 4 School Sticker Game - Boxplot of Fridge and Games Console - Game 1 all Children

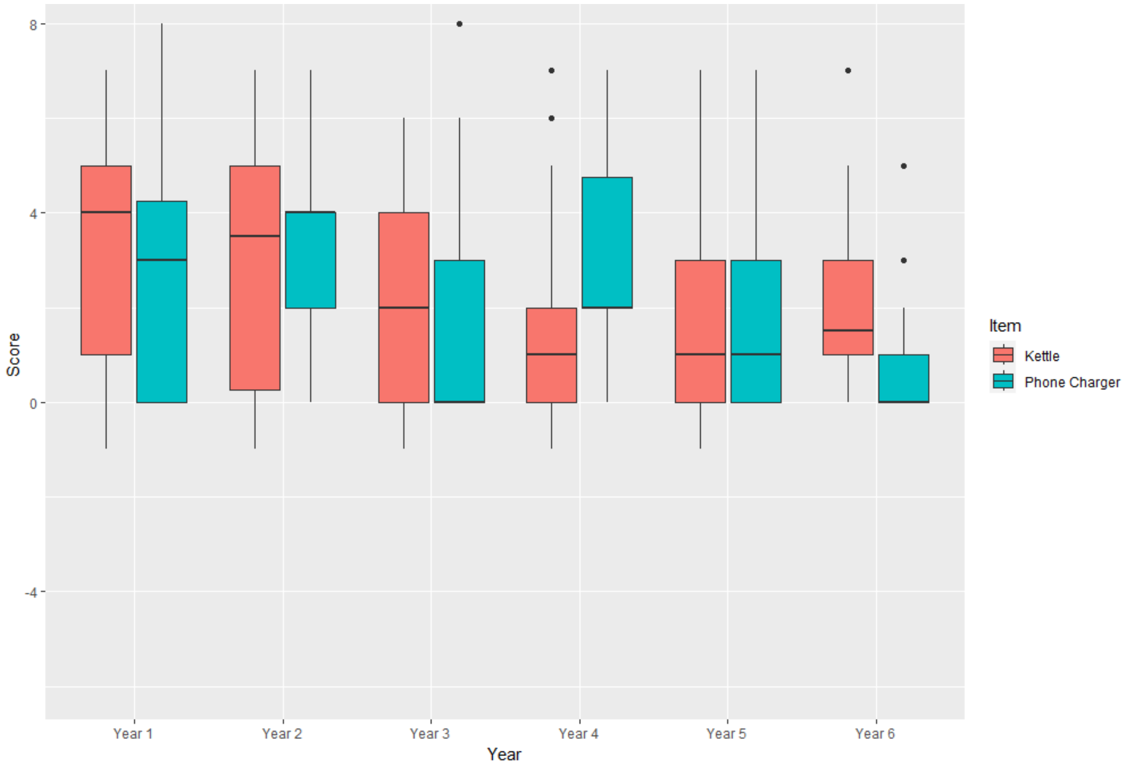


Figure 147: Study 4 School Sticker Game - Boxplot of Kettle and Phone Charger - Game 1 all Children

Figure 148: Study 4 School Sticker Game - Boxplot of Lights and Driving - Game 2 all Children

It can be seen from Figure 148 above, that game 2 also had some interesting results. Lights and Driving initially have a large variability with the younger children, but as they get older, the children start putting the behaviours more correctly, until the year 6s are only slightly overestimating them.

The two games - one at the start of the eco lesson and one at the end - were positioned so as to record any improvements in energy literacy levels. In the second game, the Woodcot children scored 20.1% more accurately (an average of 0.5 places closer to correct overall) than in the first game. Interestingly, the Walhampton children saw a larger increase of 44.8% (an average of 1.0 places closer to correct overall). The true reasons for this are unknown, but there are several factors that can be discussed. Within Walhampton, a single teacher taught the lesson four times (to two year-five classes and two year-six classes), it can be presumed the teacher was well-versed in the contents and delivery by the end of the day. For this reason, the lessons may have become more streamlined, with key issues that arose during the first being fixed and so on and so forth. Prompting of topics for discussion may have been more appropriate and overly the level of education higher. In stark contrast, Woodcot teachers taught only one lesson to their class, they would not have been so versed in the content and delivery and thus the level of education may have been lower.

Phase 3 Analysis – Opportunity for Inter-Generational Interaction

This Phase included the home sticker games that were completed by the adults with the children. N=41 participant parents played the game. It was identical to the sticker game played at home, the children had seen the answers and should have been able to challenge the parents to beat their scores. It also allows for a direct comparison to be made between the energy literacy levels of children and adults within the participant groups.

Within Game 1, (Figure 84) it can be seen that the main differences between the adults and children are the items TV, Games Console, Tumble Drier and Radiators. The adults respectively scored the first two of these two lower than the children, then the last two of these higher than the children. The pattern and choice of items in the pattern suggest that the items children are familiar with (TV and games console) were overestimated in terms of energy consumption because they are used more often than other items. The same can be said with the adults (tumble drier and radiators). A child will sparsely be seen using the tumble drier compared to an adult. Similarly, radiators have a link with parents - the financial cost and physical bill they receive each month.

Game 2 shows a similar range of answers, but it seems the adults have learnt from the first game; heating is far more correct this time, as is lighting, both of which are two of the largest consumers in a home. Interestingly the addition of 'eating meat' did not surprise the adults and it was relatively correct, especially when compared to the children's response. This again is likely to do with adults being far more involved with food shopping and preparation compared to children. At the other end of the spectrum, children once again overestimated behaviours they are familiar with - leaving items on standby and showering are two such behaviours,

There was an additional short survey linked via a QR code on the instruction sheet for this home energy game. The two following Figures (and) show the results of the question asked and the two lists following them show the written responses from the parents.

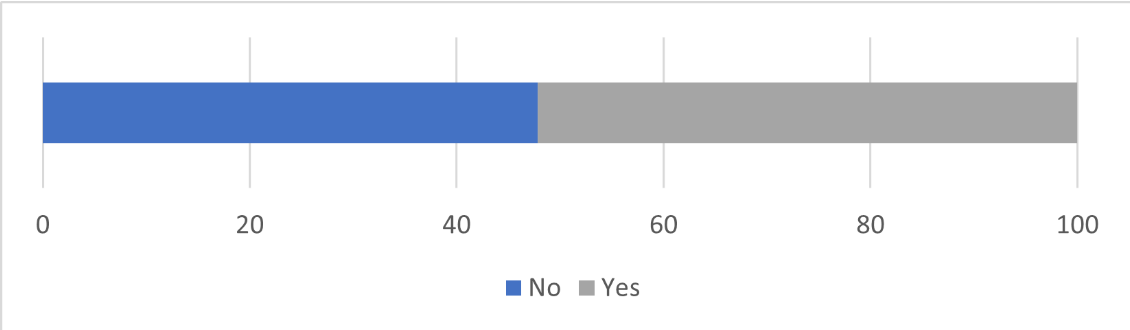


Figure 149: Study 4 Home Sticker Game 1 - Did your child discuss energy issues related to any items whilst you played? (n=23)

If so, what was discussed?

- Mobile phone charger, kettle car fridge, lights
- That we shouldn't leave lights on!
- Meat and that he should get eco points for being vegetarian. And bathing!
- Understood the useable and how you could reduce it
- TV, Game Consoles, tumble dryers, showers vs baths, and leaving the lights on
- We thought games consoles would be lower than the TV.
- Surprised at how high the lights were and how important it is we keep them off when not using.
- Leaving lights on and how things like a fridge you have on all the time whereas a kettle or tumble dryer you only use at certain times
- That items that heat consume the most electricity

- Turning off lights and the environment
- Temperature of the thermostat, we checked ours
- The placement of the kettle which I would have placed higher in terms of energy use

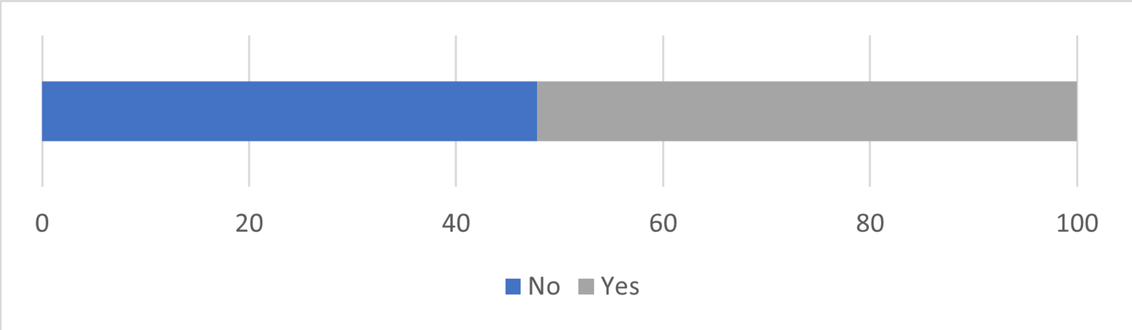


Figure 150: Study 4 Home Sticker Game 2 - Did your child discuss energy issues related to any behaviours whilst you played? (n=22)

If so, what was discussed?

- Leaky windows
- How eating meat was really bad for the planet
- He said he would have a shower rather than a bath, he was surprised that driving 5 miles used as much as a bath. He said he now understood why I keep on at him to turn the lights off and why I won't put the heating on. He was not keen to hive up meat.
- We need to eat less meat!
- Having a shower is better than a bath
- Importance of switching this off
- Eating meat and how high it was.
- Again, the importance of keeping lights off
- How a shower was better than a bath, and the effect of deforestation on intensive farming
- Having a shower instead of a bath to save energy
- The many environmental consequences of eating meat

Although both of the yes/no questions about discussing items and behaviours whilst playing the game are essentially 50/50 in their answers and so show very little positive or negative outcomes, the open ext input questions show that many different aspects of energy literacy were discussed and that interaction did indeed take place.

In the responses to game 1 Items, turning off lights was mentioned several times, along with electrical items - again, two things that children are familiar with in their daily lives. This already existing familiarity with such items and behaviours was one of the main reasons other aspects, such as heating and diet, were discussed. It is important to fill the gaps of knowledge and not just reiterate things heard before.

In the second game responses (behaviours), it can be seen that the inclusion of real-life options and decisions (cycling to driving, showering to bathing) has been understood, with multiple children suggesting choosing the least energy-intensive option more often. This suggests not only that they have learnt from the school activity, but that they have passed this knowledge on in an inter-generational interaction, as this research aimed to achieve.

Phase 4 Analysis – Reassessing Opportunity for Inter-Generational Interaction

As per the Study 4 Process Diagram (Figure 28), the first comparison output is to measure the differences (of both participants and control groups) between the initial survey completed before the intervention and the final survey completed after the school and home interventions (but before the longitudinal aspect). This section will carry out those comparisons.

Below are the results compared between the initial and final surveys of Study 4 Eco Homes. The participant numbers are as follows: Initial n=57, Final n=28. The graphs below show percentages to allow for visual comparison. As with the same comparison in Study 3, a Fisher's Exact test was carried out on each to find any relationships.

Study 4 survey results show three out of nine (33%) questions show significant associations. Unfortunately, they are not all showing the positive transition the study would need to succeed. Figure 151 shows a significant decrease in concern for climate change, the opposite of the intended result of the study.

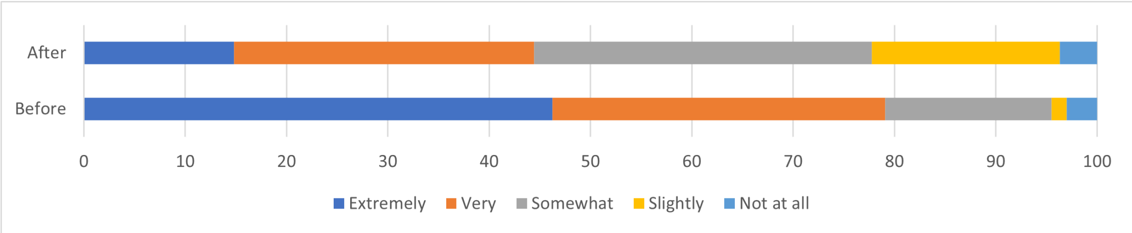


Figure 151: Study 4 'Eco Homes' Survey Comparison - Initial + Final - How concerned are you about Climate Change? - Fisher Test (P=0.001582) Significant association

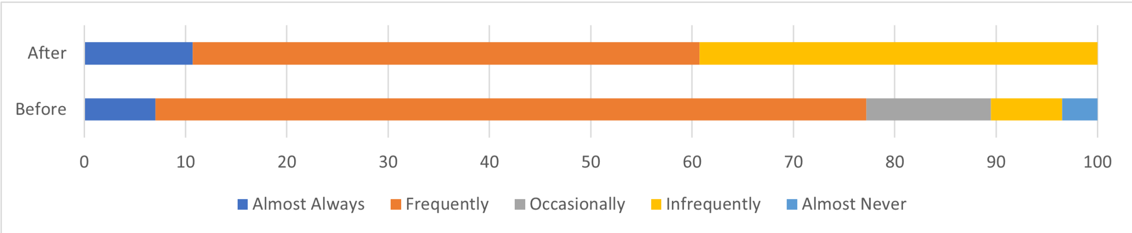


Figure 152: Study 4 'Eco Homes' Survey Comparison - Initial + Final - Do you consider environmental impacts when you make decisions in your daily life? - Fisher Test (P=0.001283) Significant association

Similarly, both 'environmental concern when making decisions' (Figure 152) show a significant negative change in responses. This would suggest the study is not effectively improving occupant energy behaviour, this could be through the interactions failing, or the interactions succeeding, but the knowledge passed on is not being influential enough.

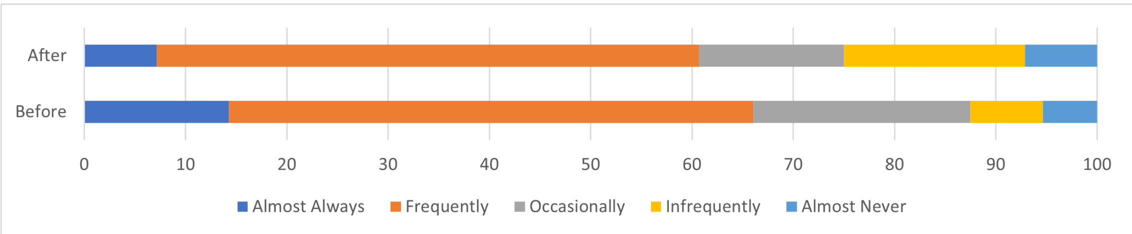


Figure 153: Study 4 'Eco Homes' Survey Comparison - Initial + Final - Do you think about the environmental impacts when using your heating? - Fisher Test (P=0.512) No significant association

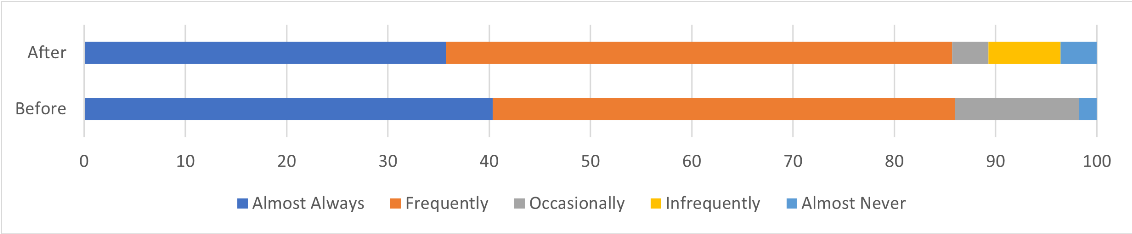


Figure 154: Study 4 'Eco Homes' Survey Comparison - Initial + Final - Do you think about the financial cost impacts when using your heating? - Fisher Test (P=0.2094) No significant association

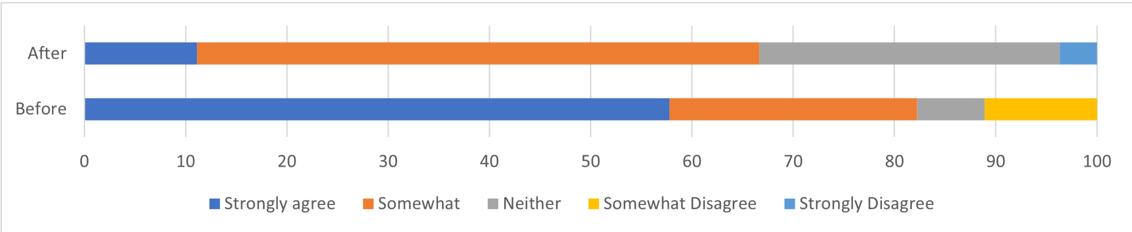


Figure 155: Study 4 'Eco Homes' Survey Comparison - Initial + Final - Do you think your child or children are concerned about climate change? - Fisher Test (P=0.00001326) Significant association

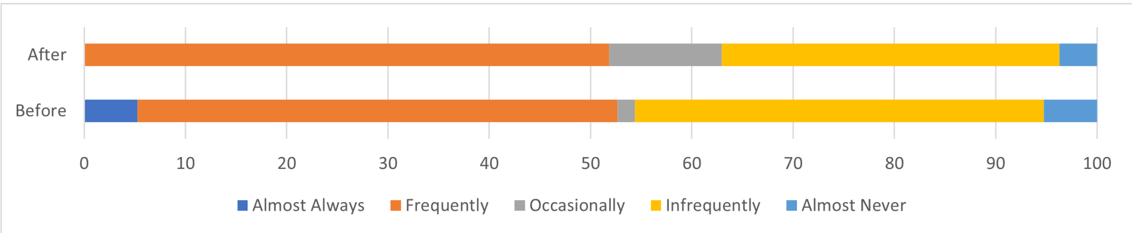


Figure 156: Study 4 'Eco Homes' Survey Comparison - Initial + Final - Do you have discussions with your child or children about climate change or the environment? - Fisher Test (P=0.3093) No significant association

One of the most important measures is the question 'Do you think your child is concerned about climate change?' (Figure 155 sees one of the largest negative changes, with 'strongly agree' dropping from 55% to 12%. This is not the outcome desired for the study. Similarly, an equally important measurement for this research was the question 'Who starts the discussions?' (Figure 156) which, although not as large, has also seen a negative change from the initial survey to the final survey.

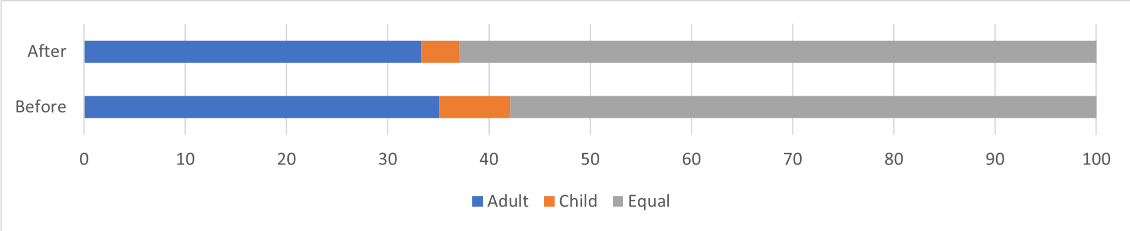


Figure 157: Study 4 'Eco Homes' Survey Comparison - Initial + Final - Who starts the conversations about energy issues or the environment? - Fisher Test (P=1) No significant association

Figure 157 has seen a positive change, although very small. The number of adults initiating the conversation has reduced from 35% to 33%. Unfortunately, the number of children initiating has also reduced from 7% to 4%. The reported number of 'equal' has increased from 58% to 63%, which is a positive change, even if very small.

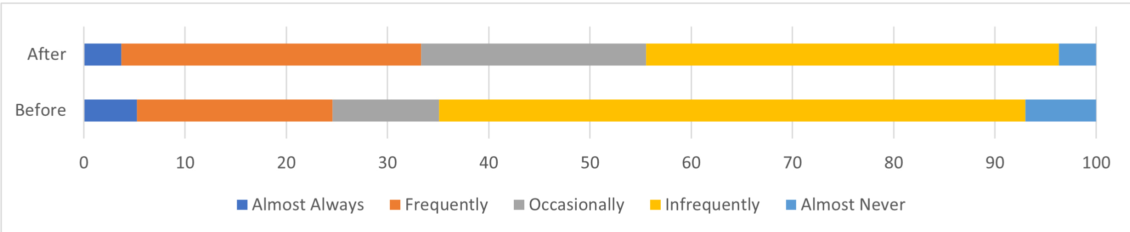


Figure 158: Study 4 'Eco Homes' Survey Comparison - Initial + Final - Do you think your child or children influence your energy usage decision-making in the home? - Fisher Test (P=0.3985) No significant association

'Does your child influence your energy decision-making in the home?' (Figure 158) has not seen a significant change and appears to have changed only slightly. 'frequently' and 'occasionally' have increased in reported number, but it is not possible to understand if this is positive or negative from this question. If the children are influencing greater energy consumption then this study has not been successful, but if the children are promoting lesser energy consumption then this is a good indicator of success for the study.

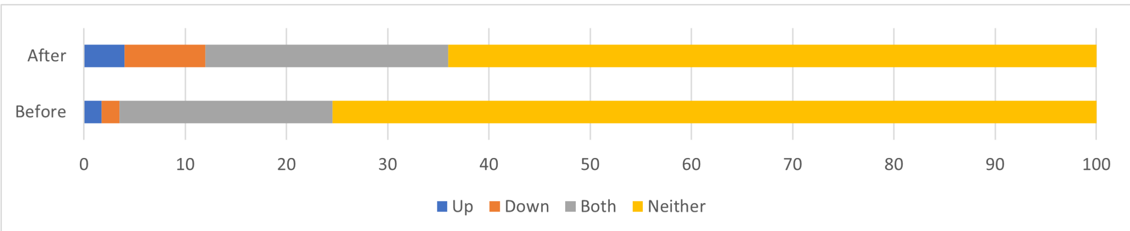


Figure 159: Study 4 'Eco Homes' Survey Comparison - Initial + Final - Does your child ever ask you to turn the heating up or down? - Fisher Test (P=0.3335) No significant association

Another small yet positive measurement of success can be seen in Figure 159 - 'Does your child ask to change the heating?'. Although 'up' has seen an increase from 2% to 4%, 'down' has seen a jump from 2% up to 8%, twice as large as 'up'. The reported answer 'neither' has also seen a reduction from 75% to 64%, suggesting that children post-intervention are influencing their parent's heating directly. As heating is the largest energy consumer in the home, these results are very positive for the success of the study.

In summary, these responses have not suggested the same level of success as the responses in Study 2 and Study 3, with very few positives coming from the intervention. There was very little uptake for the final survey compared to the initial; this may have affected the results. It would have shown greater depth to analyse these with schools divided on the same graphs.

Control to Intervention Groups Analysis

As per the Study 4 Process Diagram (Figure 28), the fourth comparison output is to measure the differences between the participants and control groups, specifically the initial survey completed before the intervention and the final survey completed after the school and home interventions (but before the longitudinal aspect). This section will carry out those comparisons.

Table 15 below shows the P-values from a Fisher's Exact test that was completed on the survey results from Study 4. The results were initially split between 'control' and 'intervention' groups before relationships were assessed between each group's initial and final surveys.

Table 15: Fisher's Exact P-Value Results comparing the Initial and Final Study 4 Surveys - Split between Control and Intervention Groups.

Survey Question	Difference between Inital and Final Survey results (Fisher Test P-Value)	
	Control Group	Intervention Group
Do you consider environmental impacts when you make decisions in your daily life?	0.01486*	0.2184
Do you think about the environmental impacts when using your heating?	0.8598	0.8311
Do you think about the financial cost impacts when using your heating?	1	0.5029
Do you have discussions with your child or children about climate change or the environment?	0.6854	0.1892
Do you think your child or children influence your energy usage decision making in the home?	0.1881	0.9585
How concerned are you about climate change?	0.06707	0.5122
Do you think your child or children are concerned about climate change?	0.0452*	0.09685
Who starts the conversations about energy issues or the environment?	0.1528	0.74
Does your child ever ask you to turn the heating up or down?	0.2213	0.2236

* indicates $p < 0.05$

It can be seen that there is no significant difference for any of the nine questions in the Intervention Group, and only two questions show a significant change within the Control Group. Analysing the first of these, 'Do you consider environmental impacts when you make decisions in your daily life?', it is interesting that the control group has seen a change and the intervention group has not; one would expect the opposite outcome. However, when the individual results are interrogated (see Figure 161 below), it can be seen that the control group has seen a negative change between the initial and final survey; 'Almost always' sees little change, but 'Frequently' sees a large decrease of 29%, whereas 'Occasionally' sees a large increase of 47%. This is a significant change in the negative direction, suggesting that during the period of the study, consideration of environmental impacts declined. This may have to do with the timing of the study- coming out of winter and into spring, thus families may have been starting to use heating less and worrying about the impacts of it less too.

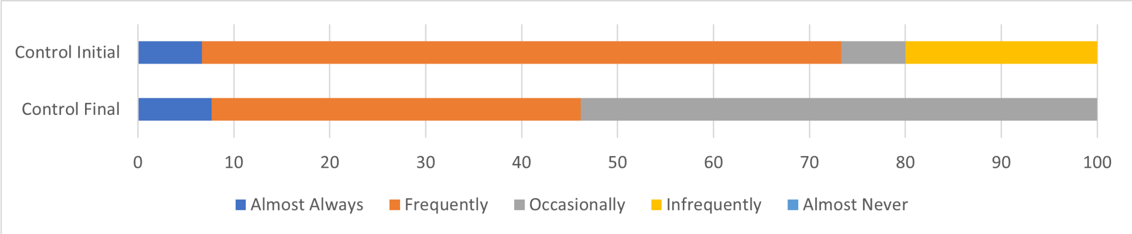


Figure 160: Study 4 Control Group Survey Results - Initial to Final - 'Do you consider environmental impacts when you make decisions in your daily life?' (%)

The second question with a significant difference is, "Do you think your child or children are concerned about climate change?". Similarly, this difference is in the negative direction again. Figure 161 below shows the two sets of results from the survey for this question. 'Strongly agree decreases from 33% to zero responses, 'Somewhat agree' and 'Somewhat disagree' stay at similar levels, 'Neither' decreases from 31% to 7% and finally 'Strongly Disagree' increases from 0% to 8%.

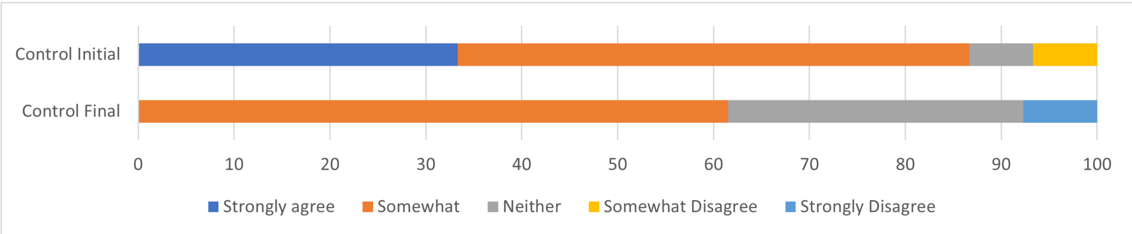


Figure 161: Study 4 Control Group Survey Results - Initial to Final - 'Do you think your child or children are concerned about climate change?' (%)

The intervention group saw no significant difference between the initial and the final surveys. Although this is not the ideal outcome, the group has not seen the negative change that the control group has experienced. For example in the same two questions that saw a negative change in the control group, the intervention group saw answers maintaining their levels of positive responses. For the initial survey question 'Do you consider environmental impacts when you make decisions in your daily life?', the largest response was Frequently at 71% (over seven times greater than the next largest response) and this only reduced to a majority of 61% in the final survey (over twice the response of the next largest). Similarly, 'Do you think your child or children are concerned about climate change?' also sees very low levels of change between the two surveys. The results can be seen below in Figures 162 and 163.

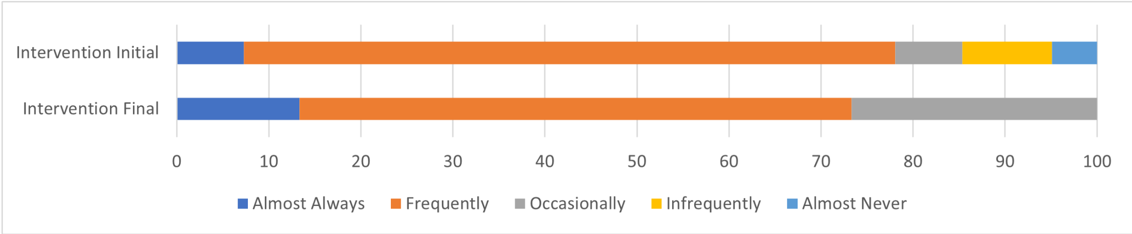


Figure 162: Study 4 Intervention Group Survey Results - Initial to Final - 'Do you consider environmental impacts when you make decisions in your daily life?' (%)

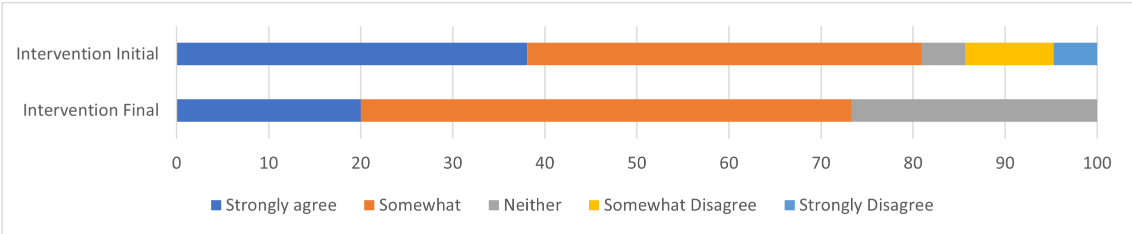


Figure 163: Study 4 Intervention Group Survey Results - Initial to Final - 'Do you think your child or children are concerned about climate change?' (%)

The intervention may be the reason behind this retained positive response rate. Both control and intervention groups were equally affected by the Energy Price Cap; at the time of the study, it was decreasing in cost from the high it reached in winter 2022. The relatively high prices may have still been influencing occupant behaviour in the home, but as both groups were affected and both groups are a mixture between the two schools (and their catchment areas), this external variable has been accounted for as much as possible.

Phase 5 Analysis – Additional Longitudinal Interaction and Assessment

As per the Study 4 Process Diagram (Figure 28), the second comparison output is to measure the differences (of both participants and control groups) between the phase 4 final survey completed before the intervention and the longitudinal survey completed after all other parts. Game scores within the two phases will also be compared. This section will carry out those comparisons.

The reported number of longitudinal card games played was n=3. All of these were Woodcot School parents, this is a very low number relative to the almost 400 sets of cards that were given out (0.75%). This does however, suggest that a longitudinal activity may not have been suited to this study, or that simply too long had passed between the two phases. This may be because of lack of engagment or lack of benefit from the study, as suggested by Howe et al (2013) [Howe et al. (2013)]. Figures 101 and 102 show the inclusion of these three parents into the game score variability graphs, but little can be drawn from such a low participant number.

In terms of levels of surprise from items and behaviours, Radiators was chosen by 2/3 (66%) as a high surprise in game 1, and games-console was chosen the same number of times (twice) as a low surprise item. Having analysed the home sticker game, the underestimating of radiators and over-estimating of game consoles does not seem to fit the pattern of familiarity that was seen before. For game 2, having a shower was stated both as a surprisingly high-energy consumer and a surprisingly low-energy consumer, and no other patterns emerged.

When asked if and what the children discussed energy when playing the two games, respondents mentioned "the energy used for different things" and "how drafts in the home are caused by gaps in windows and doors that need replacing, how we let heat out of those gaps when heating the house". Both of these are very valid points, and it is promising for the success of the study to see two aspects like this being discussed between generations.

As aforementioned, with a participant rate of 3, there is no statistical power within these results, and the points discussed must have this caveat noted.

5.4.1 Limitations

This study aims to address the negative aspects of the previous Studies. Instead of using the post-Igloo Customer base a second time, the study returned to the school environment, where there is a trusted source delivering the lessons and children can be immersed with others around them also learning the same content. Children can work together and learn from one another in a time and place in which learning is strongly promoted, not having to give up their free time at home to do more learning. A physical take-home activity was provided during the school day that children reported being excited about and wanted to play with their parents. Reminders, incentives and rewards were delivered by teachers to increase participation. Then as with Study 2, some children enjoyed the topic and rippled over to other subjects. This was most common in the year 3 classes at Walhamapton, in which the teacher reported expanding the single-hour lesson to over 6 in total covering other parts of the curriculum.

The school environment also allows for almost instant oral feedback from children (and teachers), this is important feedback and was missing from Study 3. Gaining an insight into what the children have learnt from the lessons is important to establish whether energy literacy has improved. The added aspect of a physical take-home activity not only acts as a reminder once at home, unlike the website but also is far more tactile and enjoyable than using a device. The decks of cards can also be kept and act as a normal deck of cards, potentially promoting energy discussions between future groups of people when they are re-used.

The Energy Price Cap was unchanged during the intervention; it increased in October 2022 but was settling until April 2023, providing 6 months of relative consistency for people in the UK. This meant that when the intervention took place, occupants had several months to get used to increased prices and would potentially have found a new habitual routine. Study 2 saw the shock as the cap increased and occupants largely decreased how much heating they used as they were unaware of how much it would cost them, leading to a drop that can't be accounted for within the scope of this research.

The aim was to use 2 schools for this intervention. This was a limiting factor when compared to Study 3's use of the post-Igloo customer base of 26,000, but the uptake from that study was so low that it will not be used again. The resulting data from the study must be powerful enough for a thorough investigation, The final survey was very similar to those that have come before it within studies 1-3, the emphasis was changed slightly to research more on the interactions, than the final change in behaviour and energy reduction to fall in line with the evolution of this research. All three of the previous versions were completed online, thus this one will follow suit. This survey was accessed via a QR code provided within the sticker game and the second within the Deck of cards.

The longitudinal aspect of this study was not as successful as intended. Although the limited data did suggest it was successful in terms of initiating inter-generational interactions, the significantly low response rate means this data is questionable and this phase of the intervention may not have added to the overall success. In terms of input to output, this aspect required large amounts of time and capital. Decks of cards were professionally designed and printed, which would not have been possible without the New Things grant. Talks regarding this research are currently happening with Portsmouth City Council, which runs a large number of schools in the city/county - they are interested in joining potential studies in this area and have shown enthusiasm to take part in an intervention similar to Study 4.

5.4.2 Summary

Study 4 was by far the largest completed for this research. Not only were two schools involved, but the phases incorporated substantial amounts of content and preparation. To add to this, a fifth phase was introduced, and additional data gathering was attempted.

For example, creating quantitative data on the levels of improvement from the energy literacy levels of both children in the lesson) and parents (at home). A control group was utilised to avoid external issues with the energy price cap, and feedback from teachers during Study 1 meant all of this had to happen in a single lesson rather than an 'eco day'.

The two schools produced contrasting results that have been discussed throughout this section, with significant differences measured on several initial and final survey questions. Many variables are different between the two schools (indices of deprivation, car ownership, average household income etc), and these may have led to the difference in results. For example, Walhampton children scored cars as far larger energy users than Woodcot children, likely because they have a different daily relationship with cars (12% of the Walhampton area only own one car, compared to 36% of Woodcot's local area).

The two eco-sticker games at the start and end of the intervention lesson showed that children improved their energy literacy levels in terms of energy-related behaviours in the home. Analysis between year groups showed a change in the familiarity of items and behaviours as children aged and started using their homes differently, for example, the fridge and games console swap in position perfectly as the children age (Figure 146).
The surveys completed by the parents at the start and end of the intervention gave mixed results overall, but when split between the intervention and control group, they showed that the control group reported changes to their behaviours in a negative direction, whereas the intervention group reported maintained high levels of positive results.

Feedback through open-text questions showed that a variety of energy aspects were discussed during the interactions that took place, and that lessons were learned by the parents. Additionally to this, changes were reported by the parents to have been made because of the interactions.

Unfortunately, the additional Phase 5 Longitudinal Interaction and Assessment did not reach a sufficient number of participants responding - a total of 5 participant families reported taking part, but only three of these completed the online survey in its entirety. This intervention likely took place too long after the initial lesson, thus, any motivation for the topic had disappeared. The 'Eco day' that took place during Study 2 seemed to create a longer interest in the subject than the single lesson in this study.

Overall, this study, which was a large scale classroom based method, showed both positive and negative aspects throughout its 5 phases. In phase 2, the games before and after the eco lesson, that were in place to test whether energy literacy was improved, increased in accuracy by 20.1%, with Walhampton improving even more than this average to 44.8%, suggesting that energy literacy can be improved within the classroom. Within phase 3, 45% of those who played the home activity game reported their child discussing environmental themes with them (although participant levels were low). However, the results from the phase 4 survey suggested that parental views on the climate, their energy behaviour and the impact from their children (and game based interactions) did not improve or change in the direction initially hoped. Parents reported a negative change in those aforementioned points. Phase 5, the longitudinal aspect also only reported an uptake of n=3, suggesting there may be other influences that affect follow-up style interactions and meaning the results were unsubstantial.

6 Comparisons between the Studies

Table 16: Key pieces of data in the 4 Studies (* highlights limits of the studies)

	Study 1	Study 2	Study 3	Study 4
Name	LATENT	Energy in the home	Kids4climate	Eco Homes
Population Size	26,000	200	5,000	400
Sample Size	5000	50	17 completed all aspects*	3-361*
Response Rate	19.2%	25%	0.34%*	0.75% - 90%*
Sample Location	UK	Gosport (Hampshire)	UK	Gosport + Lymington (Hampshire)
Participants	High Income	Low Income	High Income	Low + High Income
Mode	Online	In Person + Online	Online	In Person + Online
Survey Data	Quantitative + Qualitative	Quantitative + Qualitative	Quantitative + Qualitative	Quantitative + Qualitative
Participants Age	Adults	Adults + Children	Adults + Children	Adults + Children
Trusted Person	Igloo Energy + University of Southampton	School Teacher	None*	School Teacher
Energy Price Cap	Prior to Increases	Prior to Increases	During Increases*	Post Increases
Study Location	Home	School	Home	School
Initiated Interactions	NA*	Yes	Yes	Yes

The four studies undertaken each have areas that have worked well to encourage intergenerational interactions in the home, but similarly, they each have had some areas that did not work and could be improved. The above Table 16 describes key differences between the 4 studies:

It can be seen from Table 16 that cells have been highlighted with an asterisk; these represent negative aspects of the studies. It can be seen from this that response rate and overall uptake are issues with Studies 3 and 4. Study 3 also did not utilise a trusted person due to its inherent virtual location.

Figure 164 shows the studies within a 'Didactic triangle' similar to the one put forth by Thunborg (2012). It clearly shows that each aspect is connected to the other two. Andersson (2024) then expanded upon it with Society and World levels added. The graphic has been expanded upon again, taking the School and replicating it for the home, where the three points have been altered to represent the same learning experiences that occur. It can be seen that each of the studies (labelled S1-S4) is in a slightly different place within the triangles. Studies that are there twice have aspects in the home and in the school. This visually shows how much of each element was included in each study. For example, Study 4 delivered less topic content than Study 2, but both occurred in the school and involved teachers and students[Thunborg (2012)][Andersson (2024)].

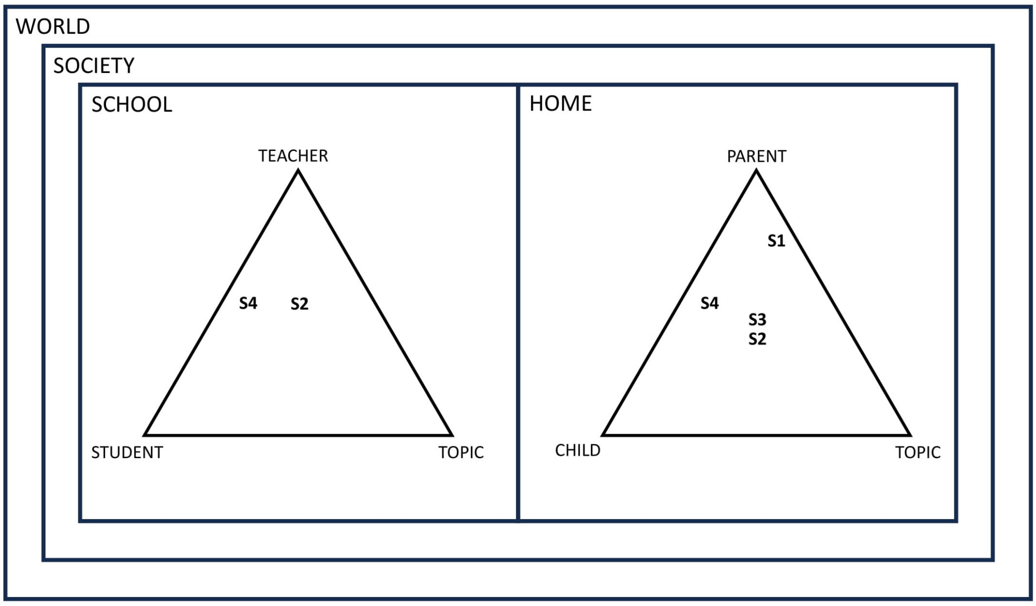


Figure 164: Didactic Triangle of Studies

6.1 Phase 1 Comparisons

Phase 1 took place in three of the four studies (missing Study 2). It was aiming to establish a parental energy behaviour baseline - how people currently behave in their homes in terms of the influences, decisions and behaviours that affect energy consumption. Of course, emphasis was on the aspect of inter-generational influence in the home. Are children currently having any effects on energy consumption, and if so, in what ways? It is well established that having dependents as a whole (both young and old), will increase energy consumption simply due to behavioural decisions such as longer heating periods and now high levels of device usage [Pais-Magalhães et al. (2022), Estiri and Zagheni (2019), Kane et al. (2015)], but the aim was to find if any positive influences are coming from intergenerational sources.

Starting with participant numbers, Study 1 was by far the most successful by utilising the existing LATENT participant pool at 26,000 potential respondents and a completion number of circa 5000 surveys (19%). This is far larger than Study 3 (5000 in pool and 63 completed - 1.26%) and slightly higher than Study 4 (500 in pool and 66 returned - 13.2%). The lack of uptake, especially within Study 3, has meant that results have not been as statistically powerful as originally desired, and thus confidence in any outcomes is lessened.

This is particularly interesting as literature and analysis looked at 'trusted sources' [Lawson et al. (2018)] - this is a prior link, physical or opinionated, that suggests trust in the person or group will lead to better pick up rates, in this case, the University of Southampton and the company Igloo Energy were trusted and thus may have had a positive affect on uptake of the survey. It was expected that leveraging the same population for a second study (Study 3 Kids4climate) would have led to similar levels of uptake, as the same trusted sources were used. However, this did not seem to have as much of a positive effect as hoped (a drop from 19% to 1.26%). From the feedback gathered in Phase 4 of Study 3, several parents mentioned that time was a considerable factor in the completion of the home activity. This is in line with literature that suggested time at home was precious and distractions or hobbies led to less time to be devoted to an online learning game, such as in this study [Tabvuma et al. (2021), Todd (2020)].

There were many reasons for choosing to complete Study 3 online, COVID-19 and international lockdowns being just the most influential of a few. The second most influential was the ability it brought to increase the participation pool numbers from a single school in a local area to of a national or even international audience in the future. This, as aforementioned, did not turn out to be the case, with Study 4 actually being more successful in terms of achieving participation with just two schools than Study 3 using the LATENT participant pool.

The surveys used within the three different studies for Phase 1 were almost identical in how they were laid out, utilised and the questions they asked. However, Study 3 also attempted to gather information about current energy consumption by taking gas and electricity meter readings. This not only may have affected uptake, as this may have been considered an annoyance, but also did not work in measuring energy consumption before and after the intervention because of external factors also affecting how occupants were using their homes. The price cap increase that followed the Russian invasion of Ukraine occurred during the intervention and meant that any decreases in consumption seen could not be considered the effect of the intervention alone, but rather the effect of the financial pressures of the energy price cap. This attempt to quantify a measure of success was then removed for Study 4, and less emphasis was put on heating during the eco lessons and more on holistic sustainability in the home and daily behaviours.

6.2 Phase 2 Comparisons

Phase 2 aimed to improve the energy literacy levels of children; in Studies 2 and 4 within the classroom environment, and in Study 3 within the virtual online environment. Lessons were developed based on the National Curriculum, covering themes that were required for the age groups used, whilst introducing new information and knowledge about energy and sustainability that was not included [Department for Education (2014)]. These were then delivered either in the classroom by a teacher or through animated videos on the Kids4climate website at home.

Measuring Energy Literacy Levels

The two school-based interventions tested the existing energy literacy levels of the children in two different ways. The first used questions used by the teachers at the start of each topic throughout the lesson. For the younger children, the class teacher wrote their answers on the board. The older children were put in groups and allowed to discuss their thoughts. The lessons were then delivered, and the same questions were discussed at the end of the lessons. These oral results were then fed back into this research. This worked well in that the teachers suggested that the lessons were successful in teaching the content, but did not provide any numerical or quantifiable before-and-after readings.

The lessons then moved online for Study 3, and a test to measure energy literacy before and after the intervention was not included due to budgetary and time constraints during the creation of the website. This is now considered a large mistake, and gathering data on the success of a website to teach environmental knowledge would have benefited the research.

The second school based survey improved upon this and the first, with the addition of a small energy game to the lessons that the children completed upon entering the lesson and then again at the end. The game asked the same questions in a slightly different setting to mitigate cheating from simply remembering the order, and also allowed the teacher to go through the correct answers (to the first game) if they so wished, without reducing the effectiveness of the second game. These were collected by the two schools, and it was then possible to grade the accuracy of the results. It was found the second game had an average improved accuracy of over 20% compared to the first, suggesting that the lesson did deliver knowledge well enough to improve the energy literacy levels of the children.

Comparing the three Studies that delivered content, it is clear that Study 4 was the most successful at measuring and quantifying the process of aiming to improve the energy literacy levels of the children. This was also based on a shortened lesson, which will be discussed in the next section.

The lesson content

As aforementioned, the content of the lessons was developed with a teacher from Woodcot Primary School and was intended to not only cover the minimum requirements of the National Curriculum [Department for Education (2014)], but also cover knowledge that would be helpful in promoting better energy behaviours and decisions in the home. With the NC not covering any sustainability or energy topics until the GCSE level, it was important to cover the basics of climate change and energy, but also to cover more niche or sensitive themes, such as why it is important and what is happening to the world. These had to be delivered in a way that created enough concern without causing alarm [Groundwork (2021), Long (2012), Boyd et al. (2024)].

Many resources were used in the creation of the final content in the lessons, but it became apparent quickly that the children would need to learn some science (such as the difference between primary and secondary energy) that would normally be taught to children older than those used in the interventions. And that the climate science taught traditionally about nature and animals, for example, would not contain the necessary knowledge [Léger-Goodes et al. (2022)]. Many of the resources can be seen in the methodology or appendix of this document. This decision to teach more detailed and higher key stage information was a novel approach that has seemed to pay off, with many resources now created that could easily be utilised within primary schools around the country to add further benefit to any eco lessons that are taught. It was also apparent from the feedback from the teachers in Study 2 and the energy games in Study 4 that children were taking this knowledge on board and their energy literacy levels were improving, further supporting the idea of the success of the content and potentially showing that the NC, in its current format, is unfit to teach a thorough energy education to primary-aged children.

The lessons aforementioned were created for an Eco-Day at Woodcot School in study 2. This was four lessons long, totalling four hours of content, which had to be drastically reduced for use on the Kids4climate website in Study 3. Each lesson was divided to suit the activities that happen in each area of a typical house - discussing fossil fuels on the drive, food in the kitchen, etc... The videos were all under 5 minutes long, yet delivered the same core information as previously; however, the activities, experiments and group content were of course missing, as was the trusted person to deliver the content. In line with the literature, feedback from the parental survey at the end of this study found that the children were not as involved with the content as anticipated [Vaccani et al. (2016), Deslauriers et al. (2019)]. to add to this, although the website had gone through several iterations and had been tested on several children, there were still issues reported with children and parents not being able to use the website, or not knowing what to do or that it was a daily tracking game, again in line with literature [Todd (2020)].

Returning to the school environment for Study 4, but reacting to the feedback from the previous two studies, this content was to be delivered in one single lesson (ideally an hour) in a format that included a test before and after intervention to test the success of the teaching. The content was again streamlined from the original lessons into a single one, and only the very core information was kept. Although this was time-consuming, outputs have now been created for single lessons, a day of lessons and an online alternative, including all experiments, group activities and hands-on content. This could easily be adapted and used within future updates to local or national school initiatives.

Online vs In-person The largest difference between the studies was the change from in-person to online for phase 2 of each study. The actual content aside, the delivery is of vital importance to the success of the method. As aforementioned, there was a driving force out of the researcher's control that meant the change had to occur; the outbreak of COVID-19 and the closures of schools that followed this, in line with a lockdown across the UK, meant that all learning was moved to an online and home-based realm. It was shown in the previous paragraphs that the classroom-based teaching worked well, with knowledge being passed from a trusted person to children effectively and Study 3 provided quantifiable proof that this occurred.

The literature suggested that the classroom offers several benefits, from a routine working schedule (Tabvuma et al, 2021), to horizontal learning (Wenger, 1991), and importantly, the trusted person delivering the lesson [Lawson et al. (2018), Jiwa et al. (2011), Tabvuma et al. (2021)]. These all may have been apparent reasons for the success of the in-person lesson when compared to the online lessons. Time has been mentioned already in this chapter as one of the reasons the website was not utilised or completed, which also falls in line with literature regarding negative aspects of home working - specifically the unstructured time, along with overuse of behaviours considered leisure activities in the home, and this may well have been apparent during the study [Panek (2014)].

6.3 Phase 3 Comparisons

The take-home activities evolved as the studies progressed. Study 3 took the same game from Study 2 and moved it online, with rewards and competitive aspects added. Then Study 4 saw a greater change, with a sticker activity identical to the one they used in phase 2, to play with the parent or carer - this was also intended to assess the parent's energy literacy levels during the interaction. This multi-layer approach was likely too complicated and not ironed out enough to work to the full intentions, but was intended to be played directly with parent and child to maximise the interaction and time duration.

In Study 2, the take-home activity was a 'Snakes and Ladders' inspired energy detective game, similar to that put forward by Varaden (2018) - utilising the children to gather information during an activity that they find interesting themselves [Varaden et al. (2018)]. In the case of this research, the data they were finding was not the important aspect, but the interactions they would have needed to have with a parent or carer to achieve all aspects of the game. The game was designed and intended to be at a level of complexity where a child could do the majority by themselves, but a parent would be required to answer questions that may arise or help with reading, leading to interactions. Approximately a third (60%) of the parents who responded stated they played the game with their child, suggesting the level was potentially slightly too easy, maybe for the older children. Questions about aspects of the environment and energy also arose in 40% of those who responded, suggesting that the game did work as intended, although to a small degree.

The same ideas and themes were designed into the online version for Study 3, but this gathered such low levels of participant participation that the data were far less usable for interrogation. First, the snakes and ladders aspect was removed from the game as it had to be played through the Kids4Climate website. It was instead a section drawing of a home, and the user could click on different rooms and be given different tasks to complete and data to gather. The main difference between the previous version and this one, apart from the online presence, was that this game was to be repeated for the entire duration of the study (3 months). Children could work their way up the leader board and levels, winning rewards for the more data they gathered. This differed from the single play of the game in Study 2. However, it is clear from the scores and the parental feedback that very few children played the game as intended, and many of them simply did it once. This could be for many reasons, likely similar to those put forward in the literature and above paragraphs - the feeling of working during home time [Panek (2014)], an apparent complicated online system creating boredom and frustration [Lamie (2005)] and simply an unpreferred location to work [Kemp and Grieve (2014), Tang et al. (2020)]. In comparison to the in-school version, this did not work as effectively, and this was the reason to return to the classroom for Study 4.

It was hoped that participation would be higher than in the previous two studies for the second iteration of the school-based Study 4. Using two schools would now mean the potential participant pool would be almost doubled, and that the in-class based learning for Phase 2 was guaranteed to happen with more children. However, the take-home activity was still an unknown in terms of participant numbers. A total of n=41 parental participants played the game and returned their scores through the feedback link. More may have completed the game, but not responded, or may have responded too late to be included. This is around 10% of participants from the nearly 500 student families available, better than the rate of return from the online study. Feedback from the parents also suggested that they had indeed learnt some information from their children (or the game) - with parents mentioning they had learnt about improving their behaviour with heating, driving, lighting and walking more to help reduce their energy consumption. Then, when asked what changed they had made, they responded with mentioning heating, showering rather than bathing, and one even mentioned sea level rise. These are very positive outcomes that were not seen in the feedback from Study 3.

It seems apparent from this brief comparison that the in-class version of the take-home activity created more successful interactions with parents, successful being passed on what they had learnt during the lessons during the interaction, and even taking the positive outcomes further with parents stating changes they had made in terms of their energy behaviour and decision making.

6.4 Phase 4 Comparisons

- Study 2 was a yes/no answer - bad choice, but no qualtrics then - Study 1, 3 and 4 had Likert scales and are comparable - Need actually to compare them?
The surveys for Phase 4 also saw an evolution from Study two through to Study 4. They initially started as simple yes-no questions that were based on the LATENT survey questions, but then, for Studies 3 and 4, they were Likert-style questions. The reason for the choice of yes-no was to keep the survey fast and simple [Rivera-Garrido et al. (2022), Dolnicar et al. (2011)]. This does not seem to have been the case, with a lower percentage of respondents completing the phase 4 survey in Study 2 than in Studies 3 and 4, which were Likert-style questions. The surveys for Phase 4 of Studies 3 and 4 would have taken longer to complete, due to the more sophisticated questions, larger total number of questions, and the additional aspects, such as adding their game scores for Study 4. Yet this did not seem to hinder the uptake compared to Study 2's simple survey. The research may have missed out on potentially interesting findings by not using a Likert-style survey in this case.

It must be noted that participant numbers were low across all three Phase 4 sections. This is probably due to larger and more influential reasons than the structure of the survey itself. As mentioned earlier, distractions in the home and lack of time can cause even adults to reduce motivation in external aspects such as surveys [Tabvuma et al. (2021), Todd (2020)].
There were still positives to be seen in line with the main aims of the research however. All three studies did have (to varying degrees) some examples and feedback from parents on how the lessons and take-home activities had caused interactions on energy in the home. Of those who responded (n=18), 89% of children asked their parents to do things differently in the home, and then 89% of parents said 'they will continue with these changes'. Comparing this to the baseline from the LATENT survey, which showed that children rarely influence the use of heating in the home, seldom asking for it to be altered either higher or lower and also, only 'occasionally' or 'almost never' influence energy decisions according to the answers from the respondents (n=5000).

Even within Study 3, which could be considered the least successful, especially in terms of participant uptake, saw positive results for the research within phase 4. Of the 19 households, 16 of them saw a decrease in how much gas they were consuming (corrected for HDDs) before the intervention compared to the end of it (ranging from 13% at the lowest to 62% at the most). Of course external influences were also at play here; thus, just looking at the survey results, the written feedback results were promising on the whole, with families not only having discussions about the environment, but there was also a

transfer of knowledge from younger to older that was then acted upon with a behavioural change. The majority of the adult participants have stated that they intend to maintain these changes for the foreseeable future; again, a very positive outcome.
Study 4's phase 4 did not show the positive changes the intervention was aiming for, however. Many of the questions produced results trending in the negative direction when compared to the survey in phase 1 of this study. The questions and style of the survey were very similar to those of the same phase in Study 3, but with different participant pools. The survey structure and format were well established by this point, using an online format accessible from a mobile phone simply by photographing a QR code provided. This was an improvement on the survey of Studies 2 and 3, which was provided via a link in an email post the intervention, which may have caused some participants to miss it.

The ideal study from what has been learnt
This short section will discuss the potential for a new study taking all the lessons learnt from the four studies completed within this research.

Firstly, the study would take place in the school environment. The idea of a 'trusted person', along with the expected routines and learning that takes place in a school, was far more successful than delivering the intervention online. The only drawbacks to this are schools finding the time and resources to allow such an intervention to take place.

There appeared to be few large differences between the schools. One may have expected the high-income families of Walhampton to be able to make larger savings as they are more likely to be over-consumers, whereas the opposite is true of the Woodcot School families. Both schools appeared to show successful inter-generational interactions taking place, and both also saw behavioural changes from parents. Both state and independent schools have their benefits and drawbacks, but neither should be dismissed.

Within the school, a substantial duration of intervention would be aimed for - an Eco day. This logistically benefited by allowing for ongoing experiments to be visited by different classes at different times, but also meant that all children were discussing the lessons on the same day, potentially increasing learning time through horizontal learning. The longer intervention seemed to have longer-lasting effects on the children; they continued to discuss and wanted to incorporate more energy literacy topics into other lessons. Again, the largest issue with this is the time and resources taken away from the already very busy school environment.

It can be seen in Figure 207 that this teacher encouraged the students and parents to play the game with a 'raffle'. This was not suggested as part of this research, but this class produced larger amounts of data than others. Rewards, therefore, could be introduced to the intervention, for children and families as they take part. These could be stickers that are collected for completing different tasks in the home, for example.

A physical take-home activity that encourages interaction worked more effectively than the online intervention during the studies in this research. In Study 1, children played against their parents in a Snakes and ladders style game, working well (especially when considering the input required). Study 2 put children competing against other children virtually, but this was not as successful. Study 3 had the parents playing a game that the children had already played; they were not directly playing against each other like in Study 1. This appears to have worked well, but could only be completed once and did not incorporate the 'energy detective game' style that Studies 1 and 2 did. The longitudinal aspect did not perform well in terms of uptake, likely because it was initiated too late after the initial intervention and interest had been lost.

In terms of data gathered, surveys before and after the intervention worked well. The use of Likert scale questions combined with open-text questions allowed for good comparisons and feedback from the parents. If the meter reading from Study 3 and the Control Group aspect from Study 4 was also introduced, there may be a quantifiable measurement of success to go alongside the surveys.

6.5 Summary

In summary, Study 1 allowed for an extensive baseline to be created for this thesis, as well as to undertake statistical analyses that were far larger and more thorough than any other studies. However as it was an existing study, it could not be altered to the extent that would have allowed for more specific research into inter-generational influences in the home. It was also entirely answered by one of the main occupants, thus lacking any input from others in the home who may have different behaviour habits or similar.

In regards to Study 2, external factors (namely COVID-19) played a factor during the inception of the intervention, meaning content for lessons and take-home activities had to meet the requirements of the online realm as well as the in-person school environment. Fortunately, the Eco Day took place once schools had returned. Survey results were very positive, with high numbers of parents reporting their children played the game, discussed energy and behaviour in the home and taught them improved energy decision-making. This led to changes that they reported they would maintain.

Several negative aspects also arose, namely the older classes (years 5 and 6) not having enough flexibility and time in their schedules to complete the entire eco day. Therefore it was split over several lessons and likely did not have the same impact. The take-home energy detective game was also reported to be too complicated for some of the youngest children, but results from it showed many tried to play it. The data gathered by the game was not inherent to the success of the study, thus the lack of accuracy and high levels of human errors were expected.

Study 3 'Kids4climate' was the first fully online intervention. This was chosen as the method for several reasons: the large potential participant base it could achieve, the potential resurgence of COVID-19 and the idea that a successful website intervention may lead to the development of an app or similar output that can then be used for outreach or other external interventions. Unfortunately, uptake was low. This may have been to do with the closure of Igloo Energy and a lack of trust for aspects attached to them, such as the LATENT study and this study. Equally likely reasons may have been to do with both adults and children deciding not to take part because of reasons such as time constraints. It became apparent that children did not complete the website many times, potentially because of the lack of a 'trusted person' (a teacher) a distracting environment (home) or the lack of schedule at home (schools are organised to reward work with play throughout the day) or finally, the sub-conscious belief that activities such as this are homework and thus negatively perceived. Results from parents were very similar to those of Study 1, again showing from their written feedback that dissemination of knowledge occurred through inter-generational influences. A key addition to this study was the inclusion of gas meter readings, allowing for a quantitative data comparison of the period before the study to the period during the intervention. Unfortunately, the outbreak of war in Ukraine led to British gas prices becoming turbulent and the Energy Price Cap was increased in the middle of the intervention time frame, meaning participating families likely altered their energy behaviour, mitigating any changes that might have been apparent due to the intervention.

Study 4 Eco Homes returned to the in-person school classroom environment following the low uptake and feedback from Study 3. It also increased from one to two participating schools. This allowed for greater numbers and the inclusion of a control group (this mitigates any external factors causing issues). The study produced a large set of results for each phase, including the additional Phase 5 Longitudinal Assessment. The two eco-sticker games at the start and end of the intervention lesson showed that children improved their energy literacy levels in terms of energy-related behaviours in the home. The surveys completed by the parents at the start and end of the intervention showed that the control group reported changes to their behaviours in a negative direction, whereas the intervention group reported maintained high levels of positive results.

Feedback through open-text questions showed that a variety of energy aspects were discussed during the interactions that took place, and that lessons were learned by the parents. Additionally to this, changes were reported by the parents to have been made because of the interactions. Unfortunately, only a total of 3 participant families completed the additional Phase 5 Longitudinal Interaction and Assessment. This intervention likely took place too long after the initial lesson, thus, any motivation for the topic had disappeared. The 'Eco day' that took place during Study 2 seemed to create a longer interest in the subject than the single lesson in this study.

Overall, this study, although with disappointingly low participant uptake, has shown to a small degree that inter-generational interactions on energy in the home can be encouraged through an in-person school-based intervention and that parents may have the potential to learn and occasionally even improve their behaviour based on the knowledge they have learnt in these interactions.

7 Conclusions

This research aimed to develop and test methods of initiating energy interactions between generations in the home. This has been carried out by developing 4 studies (one to ascertain a baseline and three following full studies), each a variation or expansion of the previous, that have each had differing methods of improving children's energy literacy levels, and then creating opportunities for inter-generational interaction to take place within the home environment. Feedback was then gathered from teachers, children, and parents on levels of interaction and whether what they had learnt during the interventions had led to them changing behaviour for the betterment of the environment.

Initially, a significant literature review of relevant topics was carried out. This was vital as it showed there were only small amounts of existing research into the role of children as agents of change in improving parents' behaviour in the home. Several papers, notably by Fell (2014) and Lawson (2018 and 2019), have looked into the area and found some results that show it is promising. It also indicated that children of all ages, but particularly primary age, currently learn little to nothing about climate change / environmental awareness within school (in the UK) - the phrase 'climate change' appears only once in the entire UK National Curriculum [Department for Education (2014)]. There was also little research into the exchange of knowledge between generations, thus, this work has an aspect of originality to it. The literature review also covered the many aspects that influence energy behaviour in the home, from thermal comfort to social norms, but mainly showing that education and awareness are equally important.

Research continued into the methods that were used throughout the four Studies in this research, looking at the validity of questionnaires, teaching methods (particularly within the less effective online realm), how to achieve good participant completion and how best to analyse results. Results from the four studies were collated and presented. Starting with Study 1 - the LATENT Study, the additional questions added for this research were to ascertain the current state of inter-generational influence in the home between children and parents and also attempt to find a baseline for future comparisons. The opportunity also allowed for the elderly generation to be included in the study, which made for an interesting comparison.

As expected, the survey showed that (in the parents who completed it) children rarely influence the use of heating in the home; seldom asking for it to be altered either higher or lower and also, only 'occasionally' or 'almost never' influence energy decisions. This is a stark contrast to the elderly, who are far more likely to ask for heating increases and influence energy decisions 'almost every day'. This was found to be almost entirely because of health and comfort reasons for the elderly; there was no mention of environmental concern from either generation. Interestingly, there was no relationship between the different house type groups (with children, with elderly, with both, with neither) and their set thermostat temperature, nor their heating strategies. When looking at discussions between generations, both groups with children recalled discussing environmental issues, with no participant group choosing ‘almost never’. However, when asked who initiates the discussion, most of both groups chose ‘Adult’. This would suggest the conversations are one-sided and the children do not currently have enough awareness to be concerned or put other factors first. The overall results from LATENT would confirm the findings of the literature research; that at the moment, there are very few inter-generational interactions about the environment, that levels of ‘energy literacy’ among children (and potentially parents) are low and finally that these missed interactions are a wasted opportunity to improve adult energy behaviour in the home.

Moving on to Study 2, the aim was to develop and test an ‘in person, classroom’ based intervention intended to improve energy literacy levels and promote interaction between generations. The method of promoting interaction was a game encouraging inter-generational discussions between the child and parent in the hopes that by acting as agents of change, the children would transfer awareness, knowledge and better behaviour to their parents. From the feedback from teachers, children, and parents, it would seem the lessons worked well - oral questions before and after the individual sections seemed to show the children were learning the intended content. Enjoyment was had by the children as they learnt the basics of climate change, which they then took home to their parents, of whom 100% said they had since discussed saving the planet and used the phrase ‘climate change’. It must be noted that the response rate was very low for this final survey. This 100% rate does seem to show however, that the intervention, at least in the short term, was successful in both improving their energy literacy and promoting inter-generational discussions. Finally, of the surveys returned, 89% of children asked their parents to do things differently in the home, and then 89% of parents said ‘they will continue with these changes’. This shows that there is potential merit in this research and that inter-generational interaction can have positive influences on occupant energy behaviour in the home.

The third study included in this thesis was the Kids4Climate intervention that occurred during the winter and spring of 2022. After significant effort and time in website development and several iterations of ethical approval, the study started in February and finished in April 2022. Although slightly later than initially planned, the weather was cool and participants were still using their heating, the largest consumer of energy in the home and a key part of the teaching. Of the 750 LATENT participants contacted, 150 confirmed they would take part and signed consent forms. Unfortunately, when the initial surveys were released, this dropped to around 60, and by the time the study closed, only 19 participant families had fully completed all aspects of the intervention. This low uptake has been detrimental to producing reliable results and data for thorough interrogation.

The data, although small, does show some promising results. Of the 19 households, 16 of them saw a decrease in how much gas they were consuming (corrected for HDDs) before the intervention compared to the end of it (ranging from 13% at the lowest to 62% at the most). On the surface, this would seem an ideal outcome, but a national Price Cap Increase on the cost of utilities also occurred during the intervention period, with the average household seeing an increase of £600 to their annual bills. Although this is currently outside the scope of this investigation, it can be said with some certainty that it has had an effect on heating behaviour in the home. This, therefore, was addressed in Study 4 by introducing control groups and removing the metric of gas consumption.

The survey results in Study 3 had both positive and negative results from the 5-point scale questions, but the written feedback results were promising on the whole, with families not only having discussions about the environment but there was also a transfer of knowledge recorded, by the parents, from younger to older that was then acted upon with a behavioural change according to the open text feedback questions. The majority of the adult participants have stated that they intend to maintain these changes for the foreseeable future; again, a very positive outcome.

Study 4 Eco Homes, encompassed all that had been learned from the three studies before it. It combined the positive Study 2 School learning environment (this time utilising two schools) with home-based games that enabled the transfer of knowledge whilst testing the adults' current energy literacy levels. An additional longitudinal aspect has been developed that provides a physical, tactile and repeatable game - a deck of playing cards. With feedback from teachers in Study 2, the Eco Day was reduced to a single one-hour lesson about energy in the home to mitigate any loss in normal teaching time. Within this lesson, children's energy literacy levels were tested at the start and end to confirm levels had been improved - the children scored over 20% better in the second.

The parents then completed the same sticker game at home and recorded their results in an online survey. This was the proposed intervention to promote inter-generational interaction on energy. The feedback from parents shows that discussions were had on many different topics that were previously taught in the classroom lesson. Upon examining the results, it has become apparent that adults and children differ in their thoughts about what consumes the most energy in the home, mainly based on what they use often or have a familiarity with. For example, children overestimated device consumption and underestimated heating and food consumption - the parents the opposite.

The longitudinal aspect returned a disappointing level of responses with only three participant families fully completing the game and feedback survey, all from one of the two schools. The open text questions were answered very positively still in regards to the study, with parents again stating that discussions were held about important energy topics whilst playing the game.

How the studies differed

The main aim was to develop and test methods of initiating energy interactions between generations in the home. Three different methods were tested through this research. The first utilising a small primary school in Lee-on-the-Solent. An Eco-Day was ran at the school teaching all the children environment based lessons and providing them with an activity to complete in the hoe that following evening. Parents were then provided with a survey to fill out asking them about any feedback they had from the experience. This included any discussions with their child about the topics covered, whether they played the activity with their child and if this led to them learning anything they may take forward in terms of energy behaviours or decisions in the home.

The second method was completely online, with a pre survey sent to parents taken from the LATENT participant pool. This gathered information on current inter-generational and general energy influences in the home as well as taking their gas and electricity reading between set periods. An online intervention then took place; children of the parents were given access to the Kids4Climate website; an interactive website with short videos and a game based around energy in the home. The children could use this to log their behaviour during the intervention period before a final survey was completed asking the parents once again about energy in the home and if their children were now influencing their decisions. These were two very different methods of delivering the same content and the same surveys. Both had their individual positives and negatives; namely that participation uptake in the online realm was far harder to achieve.

The third method returned to the in-person classroom-based methodology, but added several new aspects. Scale was increased from one school to two, the eco day was reduced to a single eco lesson, ways of measuring energy literacy levels of children (and adults) were introduced and a longitudinal additional short intervention was tested after the initial. It was found that the lessons were successful in improving the energy literacy levels of children, but uptake of participants again hindered the home activity, whilst the longitudinal aspect derived little to no results. The three methods, although delivering the same content, did so in different ways, with different interactions promoted differently in the home.

7.1 Answering the Research Questions

1. How do occupants currently behave (in terms of energy) in the home?
This question was answered by Phase 1 of each of the four studies. It was referred to during this thesis as the 'energy behaviour baseline', that is, the results collected during this phase were used as comparisons for measures of success throughout the four studies. Study 1 LATENT gathered a large collection of data answering this research question before the subsequent three studies collected smaller but equally valid data sets to answer this.

It was found repeatedly throughout the literature and the studies that other influences, such as finances and thermal comfort, are the main drivers behind energy decisions and behaviour in the home. It was found in LATENT that although the majority of people were concerned about climate change, which also happened to be the highest qualified people too, this did not translate into particularly better energy decisions in the home, potentially because of the Value Added Gap or Rebound Effect. In Study 3, under 20% of participants said environmental concern influences heating use, but over 65% said financial cost impacts do. A similar number answered the same for both of these questions in Study 4, suggesting that environmental concern is not one of the main driving factors - an aspect that this study could aim to change in a positive way.

2. What are the current levels of inter-generational influences on energy in the home?
This question was also answered by Phase 1 of each of the four studies. Study 1 LATENT asked four specific questions that were then also asked in all of the subsequent studies. Following on from the previous paragraph on influences in the home, if other generations were mentioned, it was that children appear to be negative influencers, requiring more energy to satiate their apparent need for technology and other electricity consuming goods. This is on top of the proven requirement that feeding, washing and heating more bodies in the home will of course require more energy. This was expected following the themes discussed in the literature review and shows there is a potential to turn children into positive influencers of energy in the home.

3. What are the current energy literacy levels of occupants and children?
This research question was answered during Phase 2 of each study. The level at which this question was answered varied between studies, however, Study 1 did not answer this

question in any way. In Study 2, informal posters and discussions were created either by the teachers (youngest students), groups of students (Years 3 and 4) or individually in note form (Years 5 and 6). This was then feedback verbally for analysis in this thesis. In Study 3, there was no way of directly assessing the current levels of energy literacy among the participating children. Finally, Study 4 used a game at the start of the Eco-lesson to assess the current energy literacy levels of the participating children. It was found that before the lesson, compared to after the lesson, children's accuracy within the game improved by over 20%. The facts and knowledge about sustainability and energy were basic to an adult, but generally not taught to children of this young age. It could be said from this 20% jump that the children initial energy literacy levels were not high. This falls in line with the literature, which found the National Curriculum does little to teach children about sustainability, and if children are taught topics such as these, it is often from teachers going above and beyond.

4. What topics and knowledge would be best to teach children (and parents)?
This research question was initially answered through literature research, but was added to when developing the Study 2 lessons with teachers from Woodcot School. It was then built on again when developing the lesson and content for Study 3 with teachers from both schools. They were able to recommend real-life experience-backed ideas and feedback that helped streamline the lesson effectively.

Almost all of the knowledge taught in the lessons and website was about topics and themes not touched upon in the National Curriculum. Literature suggests that children should be taught more about the planet and its wildlife when learning about sustainability in order to mitigate any chances of eco-anxiety appearing. However, in order to have the children at the required level of energy literacy so that they could have a positive effect in the home, some heavier and more complicated knowledge had to be included within the lessons. Experiments about the greenhouse effect, activities demonstrating how power stations worked compared to primary energy generation, embodied carbon and the effects of a warming planet were all discussed to a good level. This originality was one of the highest value takeaways from the research, with content now created that delivers a far better environmental education than has been seen in the National Curriculum in the past. It is important to note that the children not only left the lessons with higher levels of energy literacy, but some classes continued the learning in other lessons, and there was little to no signs of climate or eco-anxiety reported.

5. How should this knowledge be delivered?
This research question was also answered in the same way as the previous; it was answered through literature research and improved upon by teachers from Woodcot and Walhamp-

ton School. The two main methods tested were in-person vs online delivery. In person, within the classroom environment was tested in Studies 2 and 3, whilst Study 3 was based online. It was found that the online delivery system led to fatigue and boredom far faster than the classroom based delivery, in line with the literature that said a classroom has many benefits. Participation was also guaranteed in the school environments, with almost 15 classes in total completing the lessons over the two studies. Where as participation online (and thus in the home) was not only not guaranteed, but considered negative, like homework, in the feedback from Study 3 participating parents. In conclusion, the in-person classroom-based teaching intervention appeared to be a better delivery system.

6. How should interactions be triggered in the home?
The three studies that included home-based Phase 3 each tested a slightly different method of triggering interactions in the home. Study 2 used a simple Snakes and ladders style game that was played between adults and children, culminating in a detective-style search around their house to answer question cards about energy in the home. Study 3 continued online, shifting the competition to other children through the inclusion of a leaderboard for all children who participated. This version could also be repeated daily to create a larger set of data and allow the children to notice patterns (and potentially attempt to improve them). Study 4 returned to a physical game; initially, the children took home a sticker game, before the longitudinal Phase 5 aspect happened, and a deck of cards was provided to every participating child. This was the eco card game - the same game as the stickers but in card form, allowing for additional playthroughs and providing a physical time that may trigger similar energy interactions in the future.

As with question 5 above, the differences between the three studies' home interaction was affected by the same negatives - Study 3 children had distractions and hobbies which took priority over the intervention. This is to be expected from the literature, which states that home time is leisure time and thus harder to learn or complete tasks. Where as the children that were completing it for school not only had potential rewards in place for completion, but also had physical and tactile activities. The games were single one-off play through, rather than the continued recording attempted within the online activity - this appeared to be a vital part of the comparison, as study fatigue was fast to arise for the online children. The difficulty of the games was a time-consuming process to perfect; fun had to be balanced with interaction and enough complexity to require an adult, but not annoy that same adult. The simpler game of Study 2 worked well at achieving this, but it did not test the energy literacy levels of the adults like the Study 4 activity did. Competitionally, Studies 2 and 3 also attempted to gather home energy behaviours and habits, which Study 4 did not, so each was attempting to do a variety of different tasks on top of initiating interaction.

7. What is considered a successful interaction?
Basic success would be the occurrence of interactions taking place, this was measured in the Phase 4 final survey. Taking this further, questions also asked what was discussed during the interactions, if they led to any learning for the adult, and finally, if any behaviour changes had happened and if so, will they continue. Similarly, open-text feedback was gathered from the parents at Phase 3 of all the studies, allowing them to respond with any other points. As aforementioned, a baseline was also created in Phase 1 of each of the studies; this allows for direct comparison; if aspects have improved, it could be considered a success.

It was found that, although participation rates were low throughout all three main studies, the feedback from parents at the end of each study showed positive aspects of success. In all three studies, parents (although a small number) reported that discussions had occurred and were initiated by the children. Not only this, but several also reported that they learnt new knowledge and were attempting to maintain some changes that they had made because of the interactions. This could be considered successful.

7.2 Impact of Research

In terms of its contribution to knowledge, this research highlights a currently underutilised link within the home: the role of children as agents of change. The findings suggest that, when the right opportunities are provided to foster intergenerational interactions, children can influence the energy behaviours of the primary household occupants to varying degrees. Heating is, of course, one of the biggest contributors to carbon emissions in the UK, and thus, if this new link were exploited to its full potential, there are considerable savings to be had.

In terms of methodological contributions to knowledge, this research has created the start of a new subject within the primary school environment, drawing topics across environmental awareness, classroom, and online-based lessons, with accompanying resources and activities that have been created, each tailored to the correct abilities of the corresponding key stages. They not only meet important key parts of the National Curriculum, such as 'how to work scientifically', but also incorporate how large ideas, such as embodied carbon, can be diluted down to everyday decisions and choices that can be made by individuals, such as these children. The topics that would normally be reserved for older children and have been put aside for more positive themes (such as nature and wildlife) have featured heavily in this content - fossil fuels, power generation, sea level rise, among other have been taught and understood by primary-aged children. The balance between too much information, or knowledge that may lead to climate/eco-anxiety have been tested, and children have been shown that they can improve their energy literacy levels with just one eco lesson.

The Kids4Climate website is the second main single entity that has been produced by this research. Although it has much scope for growth, the basis of an online activity that allows children to investigate energy and behaviour in the home can be utilised for a variety of uses going forward. Two take-home activities have been created to work with these lessons or as individual entities - the Eco Sticker Game and the Echo Home Card Game. Both of which were professionally produced in large quantities and can be made available again.

In terms of the practical applications of this research, it has been shown that at the small scale of this research, improving the energy literacy levels of children and providing the opportunity for inter-generational interaction to take place can lead to better energy decisions being made by main occupants in the home. It is a recommendation of research that the inclusion of such a topic/subject should be incorporated into the next edition of the National Curriculum. There is also CPD/workshop potential avenue streams of such work like this, but the greatest success would not be monetary, more the realisation that the climate emergency is upon us and the government acknowledging this by introducing environmental lessons into the lives of children across the UK.

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Appendix

The following section contains various documents referred to previously in the document, as well as some that have been considered relevant enough to include for the reader's information.

7.1 Literature Review - Additional Works

7.1.1 Systematic Review Summary Table Search 1

Reference	Study Details	Outcome / Findings	Notes
Gyberg et al., 2009	Study of legislation promoting improved energy behavuour in the home	*Reasons given for change in one's behaviour are motivated both by lower energy costs and a reduced impact on the environment. Common advice for energy reduction is to change to a more energy efficient apparatus. In this sense efficiency is a way of not changing lifestyle*	Legislation now 15 years old.
Wolske et al., 2020	Examines recent findings on social influence in energy behaviour and discuss pathways through which social influence can result in peer effects	*Propose a conceptual framework for predicting which social influence processes will most often result in peer effects, depending on the targeted energy behaviour*	Peers' within this study are neighbouring properties - not within the home
Rinaldi et., 2018	Survey related to occupant behaviours and pref- erences in residential buildings	*Results show a strong relationship between occupants' actions and characteristics of the built environment*	Suggest building characteristics influence occupant behaviour
Gadenne et al., 2011	Developed a conceptualframework of consumer environmental behaviour and its antecedents, and tested hypotheses within that framework by means of a survey	*The results show that general environmental beliefs do influence norms on environmental actions and prices, but only norms on price are correlated with environmental attitudes*	Not just about homes, but all consumers
Fabi et al., 2011	Literature review - influencing parameters affecting final energy end uses are presented and critically discussed	*Put forth an approach to deal with occupants' interactions with building controls, aimed at improving or maintaining the indoor environment.*	
Trotta, 2018	NLPCA and OLS regression on data from "Survey of Public Attitudes and Behaviours towards the Environment"	*Environmental variables are a good predictor of both energy-saving behaviours and investment in energy efficient appliances but not of energy efficient retrofit measures*	
Guerrra-Santin and Itar, 2010	Statistical analyses were carried out on energy use data from a household survey in the Netherlands.	*Occupant behaviour has emerged as an important contributor to energy use in dwellings*	Study in the Netherlands
Iweka et al., 2019	Comparison of interventoins on 'optimal energy use in residential sector'	*Feedbacks, gamification, goal setting and community-based initiatives proved to be the most effective*	46 studies compared
Hetherington et al., 2015	Describes research undertaken to rank the most common occupant behaviours, based upon their impact on greenhouse gas emissions associated with residential energy use	*External blind use was one of the most effective measures. Cooling set point temperature was similarly important. The impact of the heating set point temperature was slightly lower compared to the cooling. Lighting use was the least influential parameter in the context of this study*	Study in Australia

Figure 165: Systematic Review Summary Table Search 1 Page 01

Jakucionyte-Skodien et al., 2020	Evaluate the determinants of energy consumption and CO2 emissions in residential sector	*Results indicated that a complex of different factors needed to be considered to increase energy savings and CO2 reduction in the residential sector regarding heating and electricity consumption*	Study in Lithuania
Khanna et al., 2021	A machine learning-assisted systematic review and meta-analysis to comparatively assess the effectiveness of interventions in reducing energy demand in residential buildings	*both monetary and non-monetary interventions reduce the energy consumption of households, but monetary incentives tend to show on average a more pronounced effect*	122 studies
Meester et al., 2012	Investigates the influence of three parameters related to human behaviour through their modes of occupations	*These results prove that the more the building is insulated, the more the lifestyle proportionally influences the heating loads*	
Lopes et al., 2012	Review of literature on energy behaviours in order to recognise recent trends, quantify energy behaviours potential savings	*Energy behaviours have a crucial role in promoting energy efficiency, but energy behaviours characteristics and complexity create several research challenges*	
Pootinga et al., 2004	The role of values in the field of household energy use is investigated by using the concept of quality of life	*Results suggest that using only attitudinal variables, such as values, may be too limited to explain all types of environmental behavior*	20 years old and focus is 'quality of life'
Zou and Yang, 2014	Using an online survey questionnaire instrument, this research collected 504 sets of responses from households	*Governments should articulate, by means of education, the rationale and benefits of sustainable home development*	Study in Australia and emphasis on new developments
Hitchcock, 1993	Analysis of systems of behviour in terms of social science and engineering	*Proposes an integrated descriptive framework for energy use and behaviour, based on systems theory*	1993 - very old
Wallis et al., 2016	Uses hierarchical regression analysis to systematically investigate determinants on energ consumption	*Socio demographic influences can be explained by the purchasing and use behaviours of residents*	Discusses children as influences. Study In Germany and n=763
Laskari et al., 2022	Quantitative assessment of the impact of different users in residential heating consumption and indoor environmental conditions	*The more complicated and varying the heating practices of a user are the more varying and unpredictable the impacts on heating consumption and comfort are.*	Based on the Energy Performance Gap
Pothitou et al., 2016	Reviews existing up-to-date literature related to individual household energy consumption	*Proposed framework suggests that the individual energy perception gaps are affected by psychological, habitual, structural and cultural variables in a wider-contextual, meso-societal and micro-individual spectrum*	

Figure 166: Systematic Review Summary Table Search 1 Page 02

endfigure

Yohanis, 2012	Survey - discusses domestic energy use and energy behaviour	*Significant energy-saving could be achieved by providing appropriate information to the general public regarding temperature control, efficiency of appliances and energy-saving heating systems*	Emphasis is on appliances and other purchasable goods and technologies such as lightbubs and boilers
Pothitou et al., 2016	Survey - evaluate the impact of knowledge about environmental and energy issues on potential pro-environmental behaviour in households, specifically relating to behaviours, attitudes and habits towards energy use	*Residents with positive environmental values and greater environmental knowledge are more likely to demonstrate energy behaviours, attitudes and habits which lead to energy saving activities in households*	
Al-Marri et al., 2017	This paper investigates the relationship between energy cost and people's consumption behaviour	*The results show that electricity cost was a main factor in their behavioural change; however, other factors also play an important role in their consumer behaviour such as values, education, culture and independent life style*	Quatari / UK comparison
Sweeney et al., 2013	Using a practice-based framework and a qualitative focus group approach, this study presents an exploratory study of Bariiers and factors of environmental behaviour	*Attitudes towards energy saving are not sufficient to change behaviours.*	Looked at general behviour
Webb et al., 2013	Online surveys were administered to a panel of 200 consumers	*The effect of autonomous motivation on behaviour was greater than that of other more established predictors such as intentions, subjective norms, perceived behavioural control and past behaviour*	
Abrahamse et al., 2005	Analyses studies within the field of social and environmental psychology reviewed and categorized as involving either antecedent strategies or consequence strategies	*Information tends to result in higher knowledge levels, but not necessarily in behavioral changes or energy savings. Rewards have effectively encouraged energy conservation, but with rather short-lived effects.*	
Bouddet et al., 2016	Systematically assess a large range of household energy-saving behaviours across nine attributes	*Discusses the implications of the clusters proposed for intervention design.*	
Far et al., 2022	A review of the impact of occupant behavior on reducing the energy performance gap in residential buildings	*Findings have also revealed a lack of objective and subjective data on occupants' behavior towards energy efficiency in residential buildings*	

Figure 167: Systematic Review Summary Table Search 1 Page 03

Laaroousi et al., 2019	Provides a clear definition of the occupant behavior, a review of current approaches to analyze the occupant behavior	*Proposes the possibility of including the occupants as a part of the problem and a solution to the problem*
Pothitou et al., 2017	An empirical study that compares individuals' environmental predisposition and knowledge with their energy behaviour, attitude and habits	*The analysis reveals significant correlations between environmental predisposition and knowledge and elements of individuals' energy attitudes, habits and behaviour.*
Gram-Hanssen, 2014	This paper presents different methodological approaches to study households' energy consumption	*Much of consumption relates to unconscious habits and technological structures which are not very well understood in behavioural or lifestyle approaches*
Merechal, 2010	Study looking at behaviours being sub-concious habits.	*The joint use of feedbacks and commitment strategies appears promising.*
Abrahamse and Steg, 2011	The study examined whether the explanation of household energy use and intentions to reduce it could be informed by variables from the theory of planned behavior and by variables from the value-belief-norm theory, alongside socio-demographic variables.	*Household energy use appeared to be most strongly related to socio-demographic variables (income, house hold size, age)*
Tam et al., 2018	Reviews available resources on energy-related occupant behaviour and its implications in energy use in a building	*One of the key variables impacting real building energy use is occupant behaviour. The way occupants behave and their motivations are some of the main aspects that need to be considered in a building life-cycle.*

Figure 168: Systematic Review Summary Table Search 1 Page 04

7.1.2 Systematic Review Summary Table Search 2

Reference	Study Details	Outcome / Findings	Notes
Keller et al., 2022	Investigates the energy literacy of young participants - 6000 primary and secondary school students , on a cognitive, affective and behavioural level, and compares the putative energy-saving effectiveness of the workshops to that of conventional energy audits	*Results indicate that ETSIT raises students' energy literacy on a cognitive, affective and behavioural level with about three-quarters of participants claiming they will positively change their energy consumption behaviour*	The Austrian Education Energy Initiative ETSIT
Dwyer, 2011	This paper describes curricula materials related to energy literacy, defined as conceptual fluency with the economic and social components of energy use	*The findings of this study suggest that discussion of sustainability disaster themes triggers anxiety that interferes with the development of ERB.*	
DeWaters et al.,	A measurement scale was developed to assess secondary students' energy literacy—a citizenship understanding of energy that includes cognitive as well as affective and behavioral items.	*The instrument's validity was supported with contrasted-groups and developmental-age progression comparisons, as well as factor analyses.*	
DeWaters and P	An energy literacy survey for middle and high school students has been developed according to established psychometric principles and methodologies.	*Results from a pilot of the survey among 955 New York State students indicate low levels of energy-related knowledge, with fewer than 1% of the students scoring above 80%.*	
DeWaters and P	The article presents explicit criteria that serves as a foundation for developing measurable objectives for energy literacy in three dimensions: cognitive (knowledge, cognitive skills), affective (attitude, values, personal responsibility); and behavioral.	*The outcome of the research is a framework from which a quantitative survey of energy literacy for secondary students in New York State, United States, can be created.*	

Figure 169: Systematic Review Summary Table Search 2 Page 01

Boz and Görgülü-Arı, 2021	This study aimed to determine the opinions of high school physics, chemistry and biology teachers about energy literacy and energy education.	*As a result of the research, it was determined that teachers think that students have sufficient knowledge about energy due to the inadequacy of the curricula.*	
Van Khuc et al.,	The study advances the understanding of young adults' intentions to learn about energy conservation and its influencing factors, as well as contributes to the literature on environmental management and environmental culture and development.	*The initial research indicates that young adults are highly concerned about the environment, but more work has to be done to turn perceptions into actions.*	
Rohmatulloh et al., 2021	The purpose of the qualitative research is to capture the views of educational stakeholders on energy literacy programs, especially in Islamic boarding schools.	*teaching aspect in changing understanding does not encounter obstacles. However, habituation and exemplary in forming noble attitudes and behaviours towards the natural use of energy and water are challenging*	Within Islamic boarding s
Cotton et al., 2021	Energy literacy was measured in a sample of 2806 university students in the United Kingdom and China, in addition to their wider environmental attitudes using the New Ecological Para- digm scale.	*Findings indicate that energy literacy was relatively high overall, but there were significant differences between the knowledge, attitudes and behavioural intentions of participants in the two countries.*	
Adams et al., 2022	This paper identifies productive tensions and conceptual affinities between energy literacy and energy vulnerability and suggest, as a way forward, their exploration through the use and development of an energy ecology framework.	*Argues that pinning energy literacy to energy vulnerability foregrounds how the knowledge, skills, and practices of relevance to energy literacy change over time and over the course of life, based upon one's changing position within different energy ecologies and also based upon changes in the relations within and across the open systems of which each energy ecology is composed.*	

Figure 170: Systematic Review Summary Table Search 2 Page 02

Castañeda-Garza and Valerio-Ureña, 2022	This study conducts a review of the content of elementary-level textbooks in Mexico to describe and analyze the scope of these materials and their depth from the perspective of energy literacy.	*The results show that energy-related issues were introduced to students earlier than expected by the government educational authority, energy-related contents were more extensive than expected across the textbooks, and offered a rich interdisciplinary perspective previously unrecognized by national educational guidelines.*	
Ramachandran et al., 2023	This literature review, building on an increasing momentum of research across various disciplines, outlines current energy literacy scholarship focused on a range of educational contexts (i.e., K-12, higher and post-secondary, teacher education and professional programs, and informal education).	*Taking a comprehensive approach will enhance EL as an important intervention in environmental and sustainability education*	
Martins et al., 2	This paper seeks to gather the main contributions of the existing literature on the subject, in order to concentrate and organize them.	*Presents a proposal for a more comprehensive assessment of energy literacy levels, which includes the evaluation of financial and energy knowledge, without neglecting the evaluation of attitudes and behavior.*	
Gladwin et al., 2022	Draws on research from a 7-month collaborative educational research project titled international Youth Deliberation on energy Futures (iYDeF), developing the education needed to activate just and sustainable energy transitions.	*Based upon research from this global classroom case study, this article argues for a collaborative, global effort to promote sociocultural aspects of energy literacy as an underlying framework for energy and climate justice.*	207 high school students

Figure 171: Systematic Review Summary Table Search 2 Page 03

Rohmatulloh et al., 2022	A systematic review of various energy literacy studies in the period 2010–2021 was conducted to explore study trend, research methods, and adapted energy literacy programs.	*The synthesized result is that energy literacy programs were carried out in a comprehensive, integrated manner in instructions at schools, at home, and within communities, involving all stakeholders.*
Lowan-Trudeau and Anne Fowler, 2021	"Theory-building commentary" shares insights related to and principles for the emerging theory of critical energy literacy which coalesced through experience with previous studies into related initiatives and areas of inquiry	*propose critical energy literacy as an emerging theory that denotes understanding of the social, environmental, political and economic challenges, benefits and impacts of various energy sources, developments and technologies*
Zangori et al., 2023	Describes our middle school energy literacy project to develop, implement, and test curriculum materials for a unit titled Energy and Your Environment (EYE)	*EYE is a first step to meet these needs through weaving energy flow between natural and societal systems and culminating in the application of themes within an engineering design process*
Santillán and Cedano, 2023	The objective of the study is to provide a systematic review of the literature concerning energy literacy.	*Results show that most of the work performed around energy literacy addresses its evaluation among different groups, particularly students at different levels, and the construction, application, and evaluation of tools for improving energy literacy.*

Figure 172: Systematic Review Summary Table Search 2 Page 04

Poimenidis and Papavasileiou, 2021	The purpose of this study is to capture and highlight the basic knowledge, perceptions and daily practical functions of children in the use of direct-visible or otherwise functional energy, which is perceived in children relatively easily, directly and quickly and then their correlation of the findings on the effectiveness of children's taught energy literacy in their school education.	*The results of the study reveal lack of knowledge and misunderstandings in matters of forms and sources of energy, in the view of oil by several children wrongly as a Renewable Energy Source, in the knowledge of the unit of measurement of electricity, in the type of main energy sources in Greece and Solar energy as a form applied in Greece, a country with more than 300 days of sunshine per year.*
Dwyer, 2011	This paper describes efforts to develop undergraduate curricula materials in support of Energy Literacy, defined as conceptual fluency with the economic and social components of energy use.	*An analysis of student comments, responses, and survey results suggests that discussions of sustainability with disaster themes can trigger anxiety and emotional withdrawal that is counterproductive and interferes with the development of ERB.*
Poimenidis and Papavasileiou, 2022	highlight the students' energy literacy, after attaining and completing basic education, before their transition to High School.	*results indicate high levels of energy-related knowledge, as the statements show the adoption of basic practices of energy saving and use in daily life, in the context of environmental education and sustainability.*
Sovacool and Blyth, 2015	This article investigates how a mix of energy-users from Denmark perceives energy and environmental issues such as the affordability of electricity and gasoline, the seriousness of climate change, and preferences for different energy systems.	*The data supports the propositions that Danes identify with ''being green'' and prefer national and local policies that endorse sustainable technology and being self-sufficient. However, the data also challenges the propositions that Danes would prioritize low energy prices and affordability as key energy concerns and that they are knowledgeable about energy and environmental issues.*

Figure 173: Systematic Review Summary Table Search 2 Page 05

Bayley et al., 2020	This paper discusses the development of a serious game called Power Pets designed to help children understand where energy comes from, how to save energy, and its connection to the environment.	*Our fndings suggest Power Pets provided preliminary indications for improvements in children's understanding of energy saving and the link between energy saving and the environment, both at a cognitive and afective level, however usability and the steep developmental curve in this age group are key considerations.*
Mola et al., 2018	The aim of this study is investigating energy literacy of the middle school students.	*Results of the survey questions indicated that the cognitive scores of students were lower than the affective and behavioral scores. Findings also indicate that relationship between cognitive-affective aspects and affective - behavioral aspects was positive and significant, but the relationship between the cognitive-behavioral aspects was not significant.*
Akitsu and Ishihara, 2019	This article reports the difference in attributes of energy literacy by applying the energy literacy structural model proposed in our previous study through lower secondary school students in Thailand (N = 635) and Japan (N = 1070).	*Results indicated that Thai students scored higher than those of Japan except the basic energy knowledge and awareness of consequences.*
Kaya and Akcay, 2023	The general purpose of this research is to examine the energy literacy status of secondary school students.	*As a result of the research, it was determined that the students were partially low energy literate in the affective sub-dimension and partially high-energy literate in the behavioural sub-dimension.*

Figure 174: Systematic Review Summary Table Search 2 Page 06

Aguirre-Bielschowsky, 2013	This thesis draws on the theory of planned behaviour and energy literacy (knowledge, attitudes, and intended behaviour) to investigate how children in Dunedin, New Zealand, use electricity in their households, their efforts to save it, and the factors influencing them to acquire electricity saving practices.	*Very few of the children perform electricity saving behaviours voluntarily, consistently, and with the intention to save power. Most of them try to save electricity for financial reasons, and many do not have a clearly developed attitude towards saving energy.*	
Karikari et al., 2023	This paper aims to develop a baseline model to explain the relationship between energy literacy (EL), attitude towards energy, personal energy value, and energy savings behavior (ESB) with a perspective from a Lower Middle-Income Country by integrating Value Belief Norm theory and Theory of Planned Behavior.	*Our indicative results have showed that energy literacy positively affect energy saving behavior.*	
He et al., 2022	This study investigates whether visualising energy efficiency using a continuous-scale label increases consumers' consciousness when purchasing appliances.	*Results suggest that representing energy efficiency on continuous scales can be used as supportive visual information to facilitate purchase decisions.*	
Halpin, 2018	This thesis uses existing research about energy literacy and misconceptions among students to create a cohesive curriculum unit to promote energy literacy through teaching about energy behaviors and use.	*This research shows that although Switch was not created with a classroom audience in mind, it is nonetheless an effective teaching tool for improving energy literacy with significant (0.47) effect size, and it is inexpensive, scalable*	Masters Thesis

Figure 175: Systematic Review Summary Table Search 2 Page 07

Corboy, 2019	Although the energy documentary film Switch was not produced with a classroom experience in mind, the success of the film in connecting with environmentalists, industry, and academia supported using the documentary to test the power of film as an effective teaching tool for improving energy literacy. To test the effectiveness of Switch, we created an assessment tool to first determine students' baseline energy literacy, and then determine whether the documentary effected a change.	*This assessment indicated that many incoming college students identify their Advanced Placement Environmental Science class as the place they learned about energy. The assessment results indicate that students' attitude, behavior, and knowledge about energy and energy-related issues changed in a statistically significant way over the course vi of a 2-3 day learning experience.*
Poimenidis and Papavasileiou, 2021	Regarding students' energy literacy, research was conducted about cycling in the 4th, 5th and 6th grade of Rhodes primary schools in Greece, following planned and implemented didactic and experiential approaches. The main purpose was to determine the pupils' knowledge, views and intentions regarding the usefulness and benefits of using a bicycle and the considerable difficulties of its widespread adoption as a means of transport.	*The findings indicate positive views, good intentions and extensive knowledge of the great environmental and social benefits that result from the bicycle's use as well as a serious intent of its utility as a means of transport.*

Figure 176: Systematic Review Summary Table Search 2 Page 08

Andolfi, 2011	In this literature review, we examine the current state-of-the-art literature on energy literacy's impact on energy consumption in households.	*highlighting its potential and the gaps that exist between the current state-of-the-art research on energy literacy and the new energy concepts (primarily, flexibility) that emerge over time.*
Poimenidis and Papavasileiou, 2021	capture and highlight the basic knowledge, perceptions and daily practices of using material and, indirectly, energy, in the daily lives of children, counting their existing energy literacy.	*Various behaviours were known to be better in terms of energy reduction, but were not appealing to children - vegetarianism for example*
Poimenidis and Papavasileiou, 2021	A study of children learning about the urban environment	*The study results initially outline the children's developing cognitive ability to critically approach the urban issues, to adopt models of sustainable development related to energy*

Figure 177: Systematic Review Summary Table Search 2 Page 09

7.1.3 Systematic Review Summary Table Search 3

Reference	Study Details	Outcome / Findings
Hu et al., 2020	This study divides family population into 4 groups: adolescents (aged 0e17), young people (aged 18e44), middle-aged people (aged 45e59), and elderly people (aged 60 and older) and develops a calculation model for carbon emissions of household energy consumption in accordance with the latest standards of the World Health Organization based on Chinese Family Panel Studies in 2016.	*This study divides family population into 4 groups: adolescents (aged 0-17), young people (aged 18-44), middle-aged people (aged 45-59), and elderly people (aged 60 and older) and develops a calculation model for carbon emissions of household energy consumption in accordance with the latest standards of the World Health Organization based on Chinese Family Panel Studies in 2016.*
Hansen and Jacobsen, 2020	In this article, we investigate the intergenerational transmission of sustainable consumption practices.	*The paper shows significant intergenerational correlations between the energy consumption patterns of adults and their mothers, also when controlling for the energy consumption of the mother-in-law, where possible.*
Sánchez et al., 20:	Energy and Health Seed. From school to home and society) is seen as an opportunity to increase the visibility of the role of science and women scientists in their actual contexts and to present architectural research as essential in mitigating climate change and improving people's health. The goal of this research was to reach the greatest range of people possible through intergenerational transfer.	*Children from 8 to 10 years old were interested and ready to understand and transfer key concepts about energy efficiency and health improvement through the transformation of the buildings surrounding them.*
Isabelle, 2011	This paper's purpose was to understand how individuals, at each stage of life, in the context of historic events and intra-familial relationships, build a specific relationship to energy and "energy care" (paying attention to energy) and a specific appropriation of public policies, energy- efficient technologies and environmental discourses.	*It is possible and probably necessary to develop energy conservation messages and public policies specific to each period of life.*

Figure 178: Systematic Review Summary Table Search 3 Page 01

Wang et al., 2022	To clarify the interplay between parents' and children's willingness to save energy, a large-scale survey was conducted in Jiangsu Province, China (N =3012) from a two-way intergenerational learning perspective.	*The results show that: (1) Parents → Children: The family parenting style significantly predicts children's willingness to save energy, with moral identity and moral disengagement playing a mediating role. (2) Children → Parents: Girls in families with permissive and open parenting styles have a significant effect on their parents' willingness to save energy.*
Ayalon et al., 2022	In view of the inherited temporal dimension of climate change, this study aims to highlight diverse intergenerational effects and coping strategies by examining the state of literature on older people and intergenerational relations in the context of climate change.	*In total, 20 articles were maintained for data extraction. Articles reflect 2 poles in relation to older people and intergenerational relations in the context of climate change. The first emphasizes intergenerational conflicts and differences, whereas the second stresses solidarity and transmission of knowledge and practices between the generations.*
Xiao et al., 2022	In this paper, we re-evaluated environmental tax from an intergenerational perspective, using a three-period overlapping generation dynamic general equilibrium (OLG-DGE) model that incorporates health, education and retirement.	*There is an optimal range of environmental tax rates in which double dividends are achieved, thus breaking the pollution-growth-pollution cycle*
Chen, 2014	In the first chapter, I use China's "Home Appliances Going to the Country-side" policy to study the effects of the spread of household electronic appliances in rural areas on body weight outcomes and on behaviors associated with caloric intake and caloric expenditure.	*Using data from waves 2004, 2006, and 2009 and difference-in-differences and instrumental-variable approaches, I find that household technology increases the likelihood of obesity among female adults, due to more caloric intake and less caloric expenditure.*

Figure 179: Systematic Review Summary Table Search 3 Page 02

endfigure

Andersen, 2016	The aim of this study was to provide a group of children with a tool that could support them to encourage environmental change in their family homes.	*Analysis of the data revealed that the while the Protocol was reasonably effective in enabling the children to be intergenerational environmental change agents, the children had mixed success in negotiating hegemonic familial and social forces such as the dominance of adults in the family domain, the feeling of powerlessness by participants in the face of global environmental problems and the propensity of participants to neglect environmentally responsible behaviour if it threatened their established lifestyles.*
Hu and Chen, 2016	implemented a new climate change educational programme, in 12 rural areas of China, where adolescents communicated with local seniors (aged ≥ 60 years) in focus groups to discuss local climate over the past decades	*climate change education should emphasize place-based strategies that highlight the relevance of global climate change through local impacts.*
Meeusen, 2014	This article reports on the intergenerational transmission of environmental concern and the explanatory power of communication patterns within the family.	*The results clearly confirm the transmission hypothesis: both the mother and the father have a significant influence on the environmental concern of their offspring.*
Filho et al., 2018	to understand whether the children-led, knowledge-based approach that MEEN uses on some projects is an effective way of achieving this aim. As a means of exploring this question, the paper uses 'vignettes', evocative episodes that act as prompts for analysing the dynamics of the projects	*Our explorations of the vignettes have led us to the view that 'reciprocally responsive' intergenerational communications is pivotal to negotiating understandings of climate change and how to act in the face of it.*
Diprose et al, 201	The aim of this research was to explore how citizens relate to the idea of sustainable consumption across generations, acknowledging but also seeking to look beyond the common tropes of thrift and the throwaway society.	*We argue that it is important to develop a more nuanced understanding of generational difference, drawing on findings from a cross- generational study in Sheffield, UK, involving participants from the ages of 16–96.*
Kafkova, 2019	The influence of age on environmental values has been researched using the European Values Study (EVS) 1991 – 2017 in six countries.	*The results showed that the differences in environmental values are not affected by the cohort effect; age has only a weak influence.*

Figure 180: Systematic Review Summary Table Search 3 Page 03

Essiz and Mandrik, 2021	The present study addresses these gaps and adds to the growing body of literature in environmental consumer socialization by ex- amining intergenerational influence on sustainable consumer attitudes and behaviors in a sample of 146 dyads comprised of mothers and college-age daughters.	*Using the co- orientational model and nominal dyad method, we reveal the existence of intergenera- tional similarity in dyads' sustainable consumer attitudes and behaviors—after accounting for nominal effects— and show that stronger parent–child communication between mother–daughter pairs leads to greater intergenerational similarity, whereas stronger peer influence on daughters reduces intergenerational agreement.*
Ballantyne et al., 2001	This paper examines the process of intergenerational influence in environmen tal education through a Quantitative analysis of the factors influencing the frequency and nature of intergenerational discussion.	*The findings are discussed both in terms of their implications for environmenta educators and for future research in the field. DOESN'T REALLY GIVE YOU AN OUTCOME IN THE ABSTRACT.*
Wu, 2020	the focus of this study was on parent-adolescent interactions, their reciprocal impact on environmental behaviors, and the factors that have an influence on these processes.	*The data showed that while the T values were positive in all eight compared groups, there were significant differences in seven of them. These results suggest that the impact of intergenerational interactions on environmental be- haviors is not symmetrical: parents' instructions are far more frequent than adolescents' back-feeding of ecological notions.*
Katz-Gerro, et al., 2020	This paper focuses on intergenerational transmission of environmental behavior, i.e., the processes by which environmental behavior is negotiated and shaped within the family.	*Findings from OLS regressions suggest that all three realms of children's environmental be- havior (sustainable lifestyle, reducing consumption, and reducing impact) have a positive and statistically sig- nificant association with the corresponding parental behaviors, but this association is weaker in Korea.*
Mannion, 2016	This chapter reviews and synthesizes contemporary theorizations and empirical research on intergenerational education and learning.	*This review suggests three emerging and necessary orientations for theory, policy, and practice in support of intergenerational education and learning.*

Figure 181: Systematic Review Summary Table Search 3 Page 04

Scopelliti et al., 2022	when investigations began into the emotional connections with nature and environmental identity, i.e., one's self-concept in relation to the natural world. Finally, research into the parent–child transmission of ecological values was recently developed. We aimed to analyze the role of the above-mentioned variables in predicting different PEBs, within a comprehensive framework.	*The results showed a different pattern of predictors for each PEB.*

Figure 182: Systematic Review Summary Table Search 3 Page 05

7.1.4 Systematic Review Summary Table Search 4

Reference	Study Details	Outcome / Findings
Revell, 2014	The objective of this study was to estimate the environmental impact of a home energy visit programme, known as RE:NEW, that was delivered in London, in the United Kingdom.	*these visits did not overcome the barriers required to generate behaviour change or the barriers to the installation of more signi cant energy saving measures.*
Hafner, 2020	This paper presents a qualitative exploration of domestic energy consumption practices in the UK social housing sector, and perceived effectiveness of varying intervention techniques in motivating energy reductions.	*Thematic analysis revealed that residents were highly engaged with the topic of energy saving, but that several psychological barriers existed which prevented many residents from changing them behaviour.*
Barbu et al., 2013	provides timely and reliable information and analysis to those involved in designing policy measures to reduce energy consumption which target the end consumer	*A significant part of the literature reviewed tends to consider these relationships as static when they are not. Consumer preferences change over time, and consequently the focus should shift from the consumer behaviour per se (which tends to imply emphasis on individual preferences) to how different consumption practices take hold in the society*
James and Ambrc	This paper presents the results of a randomised control trial that compares changes in energy consumption in 320 low income Victorian households which underwent different combinations of retrofit and behaviour change interventions.	*The results show that households which underwent retrofit only interventions reduced total energy consumption by 7.1% and were 1°C warmer in winter; households which underwent a combination of retrofit and behaviour change interventions reduced gas consumption by 18.6% and total energy consumption by 11.4%; households which underwent behaviour change only interventions did not show a noticeable improvement.*
Zainudin et al., 2(	This paper aims to employ behaviour change theories in predicting consumers' intention of buying energy-efficient products.	*The findings of the study suggest that policy makers should thoroughly set the interventions to harmonise the traditional approach using rebates and subsidised incentives since behavioural interventions are considered to be valu- able complements when they are jointly implemented.*
Azizi et al., 2019	The study aims to establish the link between the behaviour of building occupants and their underlying habits.	*The report also argues that a whole range of changes need to take place in the way energy markets function and are regulated in order to enable the consumer to actively engage*

Figure 183: Systematic Review Summary Table Search 4 Page 01

Sarkis Jr, 2017	As the role of consumer behaviour becomes more integral to energy production and consumption systems, models of behavioural decision making are becoming increasingly important. Two models are compared: the planned behaviour theory and the value belief norm theory.	*The results show that the first is better suited to understanding consumer energy efficiency behaviours; the second is preferred for behaviours related to the voluntary green power market.*
Axon et al., 2018	Behaviour, practices and culture constitute a powerful human factor in the energy system; in particular the interactions between technologies, practices and norms lock individuals in to certain patterns of (often inefficient) energy use. Consequently, behaviour change has gained traction amongst policy- makers as a key area of intervention given the impact energy-related behaviours have on climate change. Given the increasing emphasis within policy perspectives in the European Union, it is surprising that a gap in understanding of the success factors of behaviour change initiatives remains. This paper addresses this gap by identifying and characterising behaviour change initiatives across five European countries (the UK, Ireland, France, Italy, and Spain).	*The re- sults suggest that there are significant knowledge gaps between what is known to work to engage in- dividuals in behavioural change and what is currently being applied in practice.*
Wilson and Marselle, 2016	This paper assesses whether the BCW comprehensively describes programmes attempting to reduce energy consumption.	*Based on our work in this paper, we believe that the BCW offers a useful aid for the systematic design and development of behaviour change around end-use energy efficiency.*

Figure 184: Systematic Review Summary Table Search 4 Page 02

Erell et al., 2018	A 2-year study was carried out in a sample of 120 apartments in two cities in Israel, Jerusalem and Nesher, in which different strategies to influence energy consumption were tested using an interventional case-control design.	*The study underlines the importance of controlling for endogenous factors, such as weather and building thermal performance, while evaluating the effectiveness of different intervention strategies, to avoid potentially wrong inferences about the effectiveness of such strategies. We conclude that effective behaviour modification may require repeated implementation of a broad range of tools over a sustained period of time.*
Hafner et al., 2019	We review the psychological barriers to reducing thermal energy demand in the context of energy-efficient technology adoption, and discuss ways these barriers may be overcome.	*provide a framework of suggestions for future research which together constitute an important first step in informing behaviour change efforts designed to reduce thermal energy consumption in households.*
Mogles, 2018	We put forward an integrated agent-based computa- tional model of energy consumption behaviour change interventions based on personal values and energy literacy, informed by research in persuasive technologies, environ- mental, educational and cognitive psychology, sociology, and energy education.	*The preliminary evaluation results demonstrate that the model can predict energy saving behaviour much better than a random model and can correctly estimate the effect of persuasive technologies.*
Pothitou et al., 2(	This paper reviews existing up-to-date literature related to individual household energy consumption.	*The proposed framework suggests that the individual energy perception gaps are affected by psychological, habitual, structural and cultural variables in a wider-contextual, meso-societal and micro-individual spectrum. All these factors need to be considered in order for a variety of combined intervention methods, which are discussed and recommended, to introduce a more effective shift in the conventional energy-consuming behaviour, advancing insights for successful energy policies.*
Koroleva et al., 2019	This paper discusses the design and evaluation of a holistic socio-technical behaviour change system for energy saving that combines insights from behavioural theories and the persuasive system design in a systematic way.	*Obtained results indicate reduced energy consumption compared to a control group and a positive change in energy knowledge in the treatment group using the system, as well as positive user feedback about the suitability of the designed system to encourage energy saving.*

Figure 185: Systematic Review Summary Table Search 4 Page 03

Boomsma et al., 2018	This paper discusses the suitability of serious gaming as an educational and behavioural change tool within the context of social housing.	*Some residents liked the idea of a game for energy, particularly if clear, actionable solutions for reducing energy bills were provided. However, others were disinterested, due to existing time pressures, negative perceptions of gaming, and limited confidence using computers or tablets.*
Stinson, 2015	If the UK is to address its energy reduction targets, it is vital to understand energy use behaviours and to devise technology that positively encourages domestic occupants to use less energy. This study is cross-over research that spans energy research, social science and socio-technology.	*These findings demonstrate that a simple 'push-information' style IHD may need to evolve further with greater smart home control functionality, internet capability and user interaction for this technology to be part of the low-carbon solution. However, it has also been demonstrated that, for particular household groups, IHDs can lead to longer term changes in energy consumption behaviour, specifically for heat.*
Bottrill, 2007	This paper reviews twenty-three calculators concluding that in most cases this environmental learning tool is falling short of giving people the ability to accurately monitor their energy use; to receive meaningful feedback and guidance for altering their energy use; or to connect with others also going through the same learning process of saving energy and conserving carbon.	*Recommendations are made for the development of accurate, informative and social Internet-based carbon calculators.*
Heiskanen et al., 2011	This paper draws on evidence from behavioural economics and psychology to outline a new approach to enabling people, at home and at work, to reduce their energy consumption and reduce their bills in the process.	*we can reduce carbon emissions by informing people about what other people living in similar households are doing to manage their own emissions, or how much money they may be wasting by being relatively energy inefficient.*
Barr et al., 2011	This paper examines the assertion that individuals with seemingly high levels of commitment to the environment at home may also be those engaged in less sustainable leisure and tourism behaviours, including a high dependency on air travel.	*The paper concludes by arguing that both academics and policy-makers need to address the role of different consumption settings in which behaviours are undertaken and the ways in which these relate to underlying social practices within these settings.*

Figure 186: Systematic Review Summary Table Search 4 Page 04

Gynther et al., 2011	This article is based on the findings of the BEHAVE Project (Evaluation of Energy Behavioural Change Programmes) which was supported by the European Commission under the EU Intelligent Energy–Europe (IEE) Programme. The project started with a review of behavioural theories and their applicability in the development and evaluation of energy-related behavioural change programmes, progressed to a case study analysis and finished with a publication of guidelines for programme developers and policy makers.	*Planning and evaluation were recognised as two of the most critical phases. Many of the pro- grammes operated with quite formal plans but were typically not based on scientific theories or evidence. In many cases, there was lack of market segmentation; the goals were not targeted and the programmes tried to offer "everything to everybody". A multitude of ex-post evaluation methods for programme impacts were reported ranging from participant surveys, testing and comparison with control groups to top–down method evaluating the impact of several programmes focusing on the same target group. Process evaluation (25 cases) was slightly less common than impact evaluation (29 cases). Evaluation of the cost-effectiveness of the programmes was a rarity, most likely due to difficulties in quantitative impact evaluation.*
Foster, 2009	"Can online social networks such as Facebook facilitate the motivation and behaviour change to reduce energy consumption in the home?" An investigation into the role of social interaction in social networks provides evidence to support the research question.	*The results indicate that the users of the Wattsup energy application integrated in Facebook assisted the participants in reducing their energy consumption.*
Composto and Weber, 2022	This paper provides a scoping review of behavioural interventions that target household energy demand.	*We recommend that researchers focus future work on high impact behaviours and the evaluation of synergistic combinations of behavioural interventions.*
Carlsson-Kanyama, 2005	In this study we tested the relevance of the generational hypothesis, that is, whether the era in which household members grew up matters when understanding and predict- ing their behaviour, on a sample of 600 Swedish households.	*The results showed that age was as good an indicator as the other parameters.*

Figure 187: Systematic Review Summary Table Search 4 Page 05

Moloney and Strengers, 2014	Drawing insights from interviews with Australian households and workshops with behaviour change practitioners, we demonstrate how the 'Going Green' discourse, which focuses on targeting individuals to participate in 'easy' sus- tainability actions, overlooks the majority of consumption implicated in everyday practices.	*We argue for an ontological framing of social change underpinned by theories of social practice.*
Wemyss et al., 2023	We argue that co-design is well-suited to address the unique challenges of climate-relevant behaviour change and propose an abductive co-design methodology to develop a behavioural intervention with household members based on the Model of Action Phases (MAP) framework.	*We conclude that co-design provided novel inputs relevant for progressing through the behaviour change stages identified by the MAP framework.*
Fudge and Peters, 2011	This paper explores the politics around the role of agency in the UK climate change debate.	*The paper concludes by considering whether the aims of the Big Society approach (recently established by the UK's Coalition Government) hold the potential to engage more directly with some of these issues or whether they merely constitute a —repackaging‖ of the individualism agenda.*
Karatasou et al., 2013	The research focuses mainly on the residential sector, attempting to explore the relationships between energy use, behavioral determinants, and effective strategies to promote more efficient behaviors.	*While the promise is significant, it is also clear that not only the complexity of behaviors but also our interpretation and elaboration of existing volume of behavior change theory, create a set of challenges that research should overcome, if it is to move towards a more integrated approach.*
Petkov et al., 2012	The research aims at understanding what feedback different people find relevant and therefore attempts to bridge the gap between environmental psychology and HCI.	*study shows how environmental psychology can play an important role in informing the design of persuasive applications that motivate energy saving behaviour*

Figure 188: Systematic Review Summary Table Search 4 Page 06

Martiskainen, 2007	This report provides a review of the literature on household energy consuming behaviours and how those behaviours can best be influenced with the goal of reducing energy consumption and carbon dioxide emissions (CO2).	*existing research on intervention measures fails to provide clear evidence on which measure or a combination of measures is the most effective in achieving quantifiable, long-term energy savings.*
Spence et al., 2014	This research considers the psychological impact, and potential for behavioural spillover, resulting from receiving energy information framed in terms of financial costs or the environment.	*Data suggest that highlighting climate change in relation to energy savings may be useful for promoting broader environmental behaviour.*
Whitmarsh et al., 2021	while many behavioural models exist to explain and predict mitigation and adaptation behaviours, we argue that their utility in establishing mean- ingful change is limited due to their being too reductive, indi- vidualistic, linear, deliberative and blind to environmental impact.	*Addressing the climate crisis requires a focus on high-impact behaviours and high-emitting groups; interdisciplinary interventions that address the multiple drivers, barriers and contexts of behav- iour; and timing to ensure interventions are targeted to mo- ments of change when habits are weaker.*
Carmichael, 2019	This report aims to identify and recommend strategies for the UK Government to facilitate much greater behavioural and societal change towards net-zero emissions scenarios for the UK.	*Recommendations for transport, heating and diet*
Hargreaves, 201	This article applies the insights of social practice theory to the study of pro- environmental behaviour change through an ethnographic case study (nine months of participant observation and 38 semi-structured interviews) of a behaviour change ini- tiative – Environment Champions – that occurred in a workplace.	*By considering the planning and delivery of the Environment Champions initiative, the article suggests that practice theory provides a more holistic and grounded perspective on behaviour change processes as they occur in situ.*

Figure 189: Systematic Review Summary Table Search 4 Page 07

Fraternali et al., 2	This paper presents the research objectives of the enCOMPASS project, which aims at implementing and validating an integrated socio-technical approach to behavioural change for energy saving.	*Still an ongoing study*
García et al., 201	Abstract: Real-time Localization Systems have been postulated as one of the most appropriated technologies for the development of applications that provide customized services. These systems provide us with the ability to locate and trace users and, among other features, they help identify behavioural patterns and habits. Moreover, the implementation of policies that will foster energy saving in homes is a complex task that involves the use of this type of systems. Although there are multiple proposals in this area, the implementation of frameworks that combine technologies and use Social Computing to influence user behaviour have not yet reached any significant savings in terms of energy. In this work, the CAFCLA framework (Context-Aware Framework for Collaborative Learning Applications) is used to	*The proposed system integrates a Real-Time Localization System and Wireless Sensor Networks, making it possible to develop applications that work under the umbrella of Social Computing. The implementation of an experimental use case aided efficient energy use, achieving savings of 17%. Moreover, the conducted case study pointed to the possibility of attaining good energy consumption habits in the long term. This can be done thanks to the system's real time and historical localization, tracking and contextual data, based on which customized recommendations are generated.*
Casals et al., 201	This paper presents lessons learnt from the EU-funded EnerGAware research project, in which an innovative serious game (a game designed for purposes other than purely entertainment) was developed to promote reduced energy consumption and carbon emissions by changing social housing tenants' energy efficiency behaviour.	*While some aspects of the game did not work as intended, there were nevertheless some positive impacts.*

Figure 190: Systematic Review Summary Table Search 4 Page 08

Drewett and Crov	This exploratory study uses in-depth interviews and focus groups to investigate the values, motivations and routes to engagement of UK homeowners in adopting pro environemnatl behavioural changes.	*The findings suggest that the greatest barriers homeowners feel prevent them form adopting a lower carbon lifestyle are issues related to a lack of money, time and a perception that their actions are insignificant.*

Figure 191: Systematic Review Summary Table Search 4 Page 09

7.2 Study 1 - Additional Works

Variables Table

REQUIRED	Cell# /Q#	Variable Name	Description	Source
	2	RecpientEmail	Igloo Email address	Latent Survey
	3	Gender	Female (1) Male (2) Other (3) Rather say (4)	Latent Survey
	6	Highest Qualification	No qualification (1) O levels / GCSEs (any grade) (2) 5+ O levels (passed)/GCSEs (A*-C) (3) 2+ A levels / 4+ As levels (4) Apprenticeship (5) Degree or higher degree (6) Other (7) Rather not say (8)	Latent Survey
	7	Household Income	Less than £20,000 (1) £20,000-£39,999 (2) £40,000-£59,999 (3) More than £60,000 (4) Rather not say (5)	Latent Survey
	8	Household Family Type	one person (1) couple, no dependent children (2) couple with dependent child(ren) (3) lone parent and dependent child(ren) (4) other multi-person household (5)	Latent Survey
	8.1_1	No of Children	1=1 child 2=2 child 3=3 child 4=4 child 5=5 child 6=6 child	Latent Survey
	8.2_1	Children 1 Age	6 sliders (one for each child) Sliders range from 1-18 number equals age	Latent Survey
	8.2_2	Children 2 Age	6 sliders (one for each child) Sliders range from 1-18 number equals age	Latent Survey
	8.2_3	Children 3 Age	6 sliders (one for each child) Sliders range from 1-18 number equals age	Latent Survey
	8.2_4	Children 4 Age	6 sliders (one for each child) Sliders range from 1-18 number equals age	Latent Survey
	8.2_5	Children 5 Age	6 sliders (one for each child) Sliders range from 1-18 number equals age	Latent Survey

Figure 192: LATENT Survey Document Page 01

	8.2_6	Children 6 Age	6 sliders (one for each child) Sliders range from 1-18 number equals age	Latent Survey
	9.3	No of Elderly	1=1 elderly 2=2 elderly 3=3 elderly 4=4 elderly 5=5 elderly 6=6 elderly	Latent Survey
	12	Main Heating Source	gas boiler (1) oil boiler (2) biomass boiler (3) electric heat pump (4) electric radiator (5) electric storage (6) gas fire (7) solid fuel (8)	Latent Survey
	13_12	Average Thermostat Temperature	Slider from 12 to 30 degrees Number equals Value	Latent Survey
	14	Thermostat Mode	Set point (1) Set schedule (2) Monitor/adjust schedule (3)	Latent Survey
	15	Thermostat Time Strategy	Always (1) Morning (6am-11am) (2) Afternoon (11am-5pm) (3) Evening (5pm-11pm) (4) Overnight (11pm-6am) (5) No typical schedule (6) Other (7)	Latent Survey
	18	Last word on heating	Myself (1) My partner (2) Shared equally (3) Other (4)	Latent Survey
	19	Cold Behaviour	Put on additional/warmer clothes on (1) Turn the heating on for a short burst (2) Turn the heating on for a prolonged duration (3) Close windows (4) Use additional heating (e.g. a fire or electric radiator) (5) Wait for the scheduled heating (6) Drink a hot beverage (7) Other (8)	Latent Survey
	20	Other Heaters	No (never) (1) Rarely (once or twice a year) (2) Occasionally (3-14 days a year) (3) Often (14+ days a year) (4)	Latent Survey

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	29	Energy in School	Strongly agree (1) Mostly agree (2) Neither agree nor disagree (3) Mostly disagree (4) Strongly disagree (5)	Latent Survey
	30	Energy Literacy	A lot (1) A fair amount (2) Only a little (3) Practically nothing (4) Don't know (5)	Latent Survey
	35	Consumers in home	Hot water heating (1) Cooking (2) Lighting and appliances (3) Space heating (4)	Latent Survey
	36	Perception of home during winter	Cold (1) Cool (2) Slightly cool (3) Neutral (4) Slightly warm (5) Warm (6) Hot (7)	Latent Survey
	37	Perception of home environment	Extremely comfortable (1) Comfortable (2) Slightly comfortable (3) Neither comfortable/ uncomfortable (4) Slightly uncomfortable (5) Uncomfortable (6) Extremely uncomfortable (7)	Latent Survey
	38	Preferred comfort	Much cooler (1) Cooler (2) Slightly cooler (3) Without change (4) Slightly warmer (5) Warmer (6)	Latent Survey
	39	Clothing during winter	Image Choice T-Shirt (1) Long Sleeve Top (2) Shirt + Jumper (3) Thick Jumper / Hoody (4)	Latent Survey
	SC1	Discussion about the environment with child?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	SC2	Who starts discussions?	Adult (1) Child (2) Equal likelihood between adults and children (3)	Latent Survey

Figure 194: LATENT Survey Document Page 03

	SC3	Influenced by Children?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	SC4	Heating Change?	Turn the heating up (1) Turn the heating down (2) Both up and down (3) Neither (4)	Latent Survey
	CNA4-11	Secondary children influence?	Written repsonse	Latent Survey
	Mcintro	Differing children?	Yes, considerable difference (1) Predominantly similar (2) No, exactly the same (3)	Latent Survey
	MC1	Discussion about the environment with child?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	MC2	Who starts discussions?	Adult (1) Child (2) Equal likelihood between adults and children (3)	Latent Survey
	MC3	Influenced by Children?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	MC4	Heating Change?	Turn the heating up (1) Turn the heating down (2) Both up and down (3) Neither (4)	Latent Survey
	MCD1	Discussion about the environment with child?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	MCD2	Who starts discussions?	Adult (1) Child (2) Equal likelihood between adults and children (3)	Latent Survey
	MCD3	Influenced by Children?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	MCD4	Heating Change?	Turn the heating up (1) Turn the heating down (2) Both up and down (3) Neither (4)	Latent Survey

Figure 195: LATENT Survey Document Page 04

	MCD5	Discussion about the environment with child?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	MCD6	Who starts discussions?	Adult (1) Child (2) Equal likelihood between adults and children (3)	Latent Survey
	MCD7	Influenced by Children?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	MCD8	Heating Change?	Turn the heating up (1) Turn the heating down (2) Both up and down (3) Neither (4)	Latent Survey
	MB1C1	Discussion about the environment with child?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	MB1C2	Who starts discussions?	Adult (1) Child (2) Equal likelihood between adults and children (3)	Latent Survey
	MB1C3	Influenced by Children?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	MB1C4	Heating Change?	Turn the heating up (1) Turn the heating down (2) Both up and down (3) Neither (4)	Latent Survey
	MB1C8	Secondary Child Influence	Written Answer	Latent Survey
	3+C1	Discussion about the environment with child?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	3+C2	Who starts discussions?	Adult (1) Child (2) Equal likelihood between adults and children (3)	Latent Survey

Figure 196: LATENT Survey Document Page 05

	3+C3	Influenced by Children?	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	3+C4	Heating Change?	Turn the heating up (1) Turn the heating down (2) Both up and down (3) Neither (4)	Latent Survey
	E1	Elderly Heating Change	Turn the heating up (1) Turn the heating down (2) Both up and down (3) Neither (4)	Latent Survey
	E2	Elderly Heating Influence	Almost everyday (1) Frequently (2) Occasionally (3) Infrequently (4) Almost never (5)	Latent Survey
	E3	Influence Explanation	Written Answer	Latent Survey
	40	CC Attitude	Not concerned at all (1) Partial concern (2) Somewhat concerned (3) Strong concern (4) Very concerned (5)	Latent Survey
	41	Willingness to pay more	Strongly disagree (not at all) (1) Somewhat disagree (2) Neither disagree nor agree (3) Somewhat agree (4) Strongly agree (Yes, absolutely) (5)	Latent Survey
	50	Energy Important	______ Help to reduce my carbon footprint (1) ______ Help to reduce the cost of my energy bills (2) ______ Give me the tools to understand and control my energy use (3)	Latent Survey
	45	Personality	15 traits, each with a 1-7 agree-disagree scale	Latent Survey
	149	Importance of principles	4 principles, each with a 1-7 not important to important scale	Latent Survey
	H	Heating_Control	Smart Thermostat (1) Thermostat Automatic (2) Thermostat Manual (3) Timer Programmer (4) NA / Blank (5)	Me + My Home
	I	Heating_Extent	Whole Home (1) Specific Rooms (2)	Me + My Home

Figure 197: LATENT Survey Document Page 06

	J	Number of Bedrooms	1=1 bedroom 2=2 bedroom 3=3 bedroom 4=4 bedroom 5=5+ bedroom	Me + My Home
	K	Number of Occupants	1=1 occupants 2=2 occupants 3=3 occupants 4=4 occupants 5=5+ occupants	Me + My Home
	L	Heating Age	< 2005 (1) 2005 - 2017 (2) > 2018 (3)	Me + My Home
	M	Dwelling Age	< 1850 (1) 1850 - 1899 (2) 1900 - 1918 (3) 1919 - 1930 (4) 1931 - 1944 (5) 1945 - 1964 (6) 1965 - 1980 (7) 1981-1990 (8) 1991 - 1995 (9) 1996 - 2001 (10) > 2002 (11)	Me + My Home
	N	Heating Set Point	17 (1) 18 (2) 19 (3) 20 (4) 21 (5) 22 (6) 23 (7) 24 (8) 25+ (9)	Me + My Home
	O	Main Heat Source	gas boiler (1) oil boiler (2) biomass boiler (3) electric heat pump (4) electric radiator (5) electric storage (6) gas fire (7) solid fuel (8)	Me + My Home
	P	Dwelling Type	Bungalow (1) Detached House (2) End Terrace (3) Mid Terrace (4) Semi-detached (5)	Me + My Home
	BA	CV Person Age	0 - 9 (1) 10 - 17 (2) 18 - 64 (3) 65 + (4)	Me + My Home

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	CW	User ID	Unique IDs	Me + My Home
	A	Account ID	Unique IDs	EPC Data
	F	Current Energy Ratings	A = 1 B = 2 C = 3 D = 4 E = 5 F = 6 G = 7	EPC Data
	G	Potential Energy Ratings	A = 1 B = 2 C = 3 D = 4 E = 5 F = 6 G = 7	EPC Data
	H	Current Energy Efficiency	Scale form 0 - 100	EPC Data
	I	Potential Energy Efficiency	Scale form 0 - 100	EPC Data
	J	Property Type	House (1) Bungalow (2) Maisonette (3) Flat (4)	EPC Data
	K	Built Form	Detached (1) Semi-detached (2) Mid Terrace (3)	EPC Data
	AK	Main Heating Controls	2102 (1) 2104 (2) 2106 (3) 2107 (4)	EPC Data
	AL	Multi Glazing Proportion	<25 = 1 <50 = 2 <75 = 3 <100 = 4	EPC Data
	AM	Glazed Type	Double Glazing <2002 (1) Double Glazing >2002 (2) Double Glazing UNKNOWN (3) Single Glazed (4) Not defined/no data (5)	EPC Data
	AP	Number of habitable rooms	Scale form 1 - 20	EPC Data
	AR	Low Energy Lighting	Scale form 0 - 100	EPC Data
	AS	Open Fire Places	Scale form 0 - 10	EPC Data
	AT	Hot Water	From Main System (1) Main System No Thermostat (2) Main System No Thermostat + Solar (3) Electric Cylinder (4)	EPC Data

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	AW	Floor Description	Average U-Value 0-0.5 (1) Average U-Value 0.5-1 (2) Average U-Value 1-1.5 (3) Average U-Value 1.5-2 (4) Average U-Value 2-2.5 (5) Solid + no Insulation Assumed (6) Solid + limited Insulation Assumed (7) Suspended + no Insulation Assumed (8) Suspended + limited Insulation Assumed (9)	EPC Data
	BC	Wall Description	Average U-Value 0-1 (1) Average U-Value 1-2 (2) Average U-Value 2-3 (3) Average U-Value 3-4 (4) Cavity As Built Insulated (5) Cavity As Built NOT Insulated (6) Cavity As Built *Partially* Insulated (7) Solid Brick No Insulation (8)	EPC Data
	BI	Roof Description	Average U-Value 0-0.5 (1) Average U-Value 0.5-1 (2) Average U-Value 1-1.5 (3) Average U-Value 1.5-2 (4) Pitched 0-100mm Insulation (5) Pitched 100-200mm Insulation (6) Pitched 200-300mm Insulation (7) Pitched 300+mm Insulation (8)	EPC Data
	BL	Main Heating Description	Boiler + Radiators (1) Boiler + Underfloor (2)	EPC Data
	BU	Main Fuel	Mains Gas (1)	EPC Data
	CI	Storeys	Scale between 1 + 4	EPC Data
	CL	Ground Floor Area	<25 = 1 <50 = 2 <75 = 3 <100 = 4 <125 = 5 <150 = 6 <150 = 7 <200 = 8	EPC Data
	DB	Age Band	A <1900 (1) B 1900-1929 (2) C 1930-1949 (3) D 1950-1966 (4) E 1967-1975 (5) F 1976-1982 (6) G 1983-1990 (7) H 1991-1995 (8) I 1996-2002 (9) J 2003-2006 (10) K 2007-2011 (11) L >2012 (12)	EPC Data

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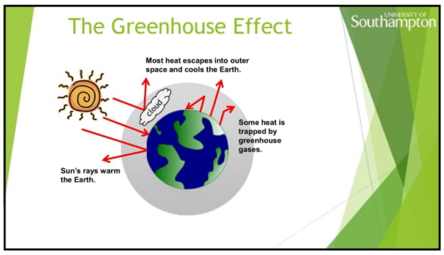
	DD	Air Changes	<0.5 (1) <1 (2) <1.5 (3) <2 (4) >2 (5) No data/blank (6)	EPC Data
	EE	Window U-Value	Average U-Value <0.5 (1) Average U-Value <1 (2) Average U-Value <1.5 (3) Average U-Value <2 (4) Average U-Value <2.5 (5) Average U-Value <3 (6) Average U-Value <3.5 (7) Average U-Value <4 (8) Average U-Value >4 (9)	EPC Data
	EF	Wall U-Value	Average U-Value 0-0.25 (1) Average U-Value 0.25-0.5 (2) Average U-Value 0.5-0.75 (3) Average U-Value 0.75-1 (4) Average U-Value 1-1.25 (5) Average U-Value 1.25-1.5 (6) Average U-Value 1.5-1.75 (7) Average U-Value 1.75-2 (8) Average U-Value >2 (9)	EPC Data
	EG	Roof U-Value	Average U-Value 0-0.25 (1) Average U-Value 0.25-0.5 (2) Average U-Value 0.5-0.75 (3) Average U-Value 0.75-1 (4) Average U-Value 1-1.25 (5) Average U-Value 1.25-1.5 (6) Average U-Value 1.5-1.75 (7) Average U-Value 1.75-2 (8) Average U-Value >2 (9)	EPC Data

Figure 201: LATENT Survey Document Page 10

7.3 Study 2 - Additional Works

Figure 202: Example Presentation of a Lesson A



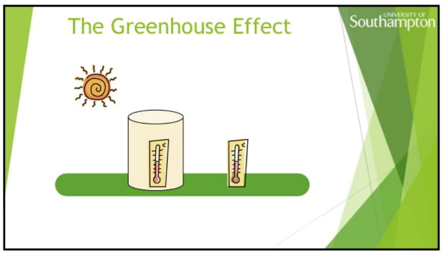
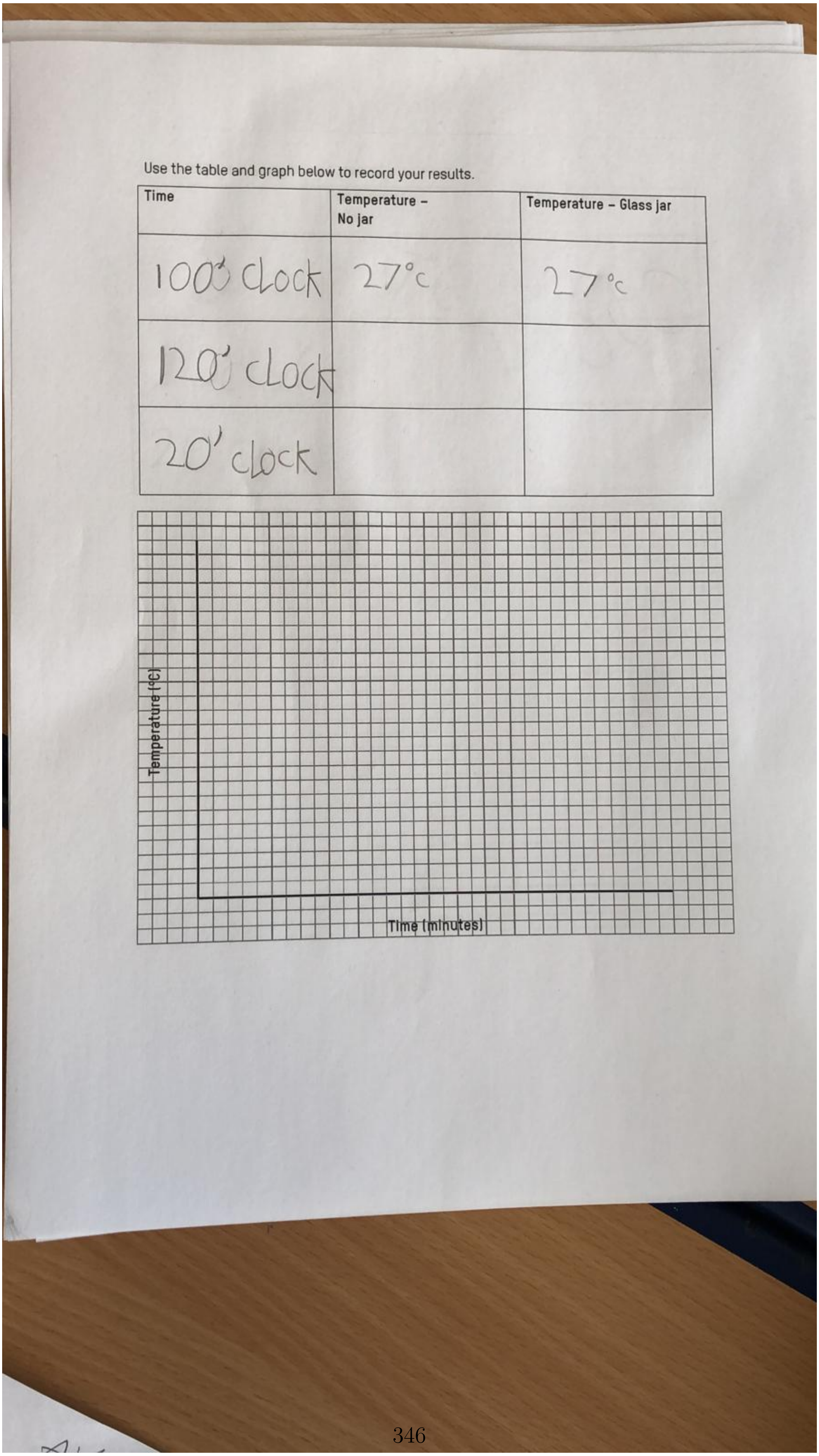


Figure 203: Example Presentation of a Lesson B

If possible, please could you briefly explain the reason that your elderly relative/relatives influence your household heating strategy?
They find the heating too hot.
they feel cold more than me
She is at home pretty much 24/7 due to her age and disabilities
She is 99 years old feels the cold and has an electric heater on 24/7 plus ch radiator in her room.
Because they feel the cold
If she's too warm or too cold we turn the heating up to accommodate her wishes in her granny annex
she lives here
Feels the cold, her heating is set at 22.5, degrees C and ours is 20/21.
Is environmental conscious
She is on. Loos thinning medication and feels the cold more than the rest off the household
Because the elderly have difficulty regulations body temperature &/or noticing when they are getting cold
They live at the top of the house and it is occasionally a lot cooler up there.
They want to be comfortable
We care about their comfort
Keep her warm
They generally feel the cold more and we want to keep the home environment healthy warm during colder
Sheâ€™s 90 frail and pretty immobile, doesnâ€™t realise when sheâ€™s got cold, cannot be relied on to
I would not want my mum to be cold.
They always feel cold
She needs keeping warm
He pays for it
I keep the house warm for my mother as shes 80 and gets up at 4am.
My mother has her own annex and it is generally warmer than the remainder of the house, she makes her own decisions on heating although we do request a complete 'turning off' of heating during summer months.
She feels the cold and can feel a draught.. Iâ€™m always hot
They feel the cold as less mobile
they feel cold and have lmited mobility
My wife, aged 82, cannot walk and has a 24/7 carer. At times she feels cold when the room temperature is
She keeps the annexe at 25C while we keep the house at 15 - 16 C. We don't mind.
She is not very mobile so the heating is adjusted accordingly.
My elderly relative lives in the annexe and has his own boiler and controls his own heat. I.e. the house has
To avoid risk of illness and to provide comfort
My elderly friend (not relative) owns the property. I pay the fuel bills. We discuss heating arrangements and
Whoever is feeling too hot or too cold should have an influence.
They did not have double glazing or central heating, they just lit a fire and got on with life
Feels the cold more
Because she is 80, doesnâ€™t pay the bill but need to be comfortable as she feels the cold
If they are cold it gets turned up
It's all about their comfort. Elderly people are not as active and seem to need a slightly warmer environment in their daytime area. The correct warm clothes are worth spending the money on too. Rather than over
Underfloor heating (groundfloor), rads.upper not all ever used. Thermostats set to 21C with additional oil filled rads in lounge to raise temp slightly. When v cold extra woodburner or convector used for xtra warmth
They live in a separate zone. When they interact with us, the heating may be increased slightly.
Her temperature fluctuates depending on how long she had been seating down for.

Figure 204: LATENT Question 7 Results

Figure 205: Work completed by children in Study 2 - Embodied Carbon Lesson - Year 1 class lunch



Use the table and graph below to record your results.

Time	Temperature – No jar	Temperature – Glass jar
10 0'clock	27°c	27°c
12 0'clock		
2 0'clock		

Figure 296: Work completed by children in Study 2 - The Greenhouse Effect

7.4 Study 3 - Additional Works

7.5 Study 4 - Additional Works

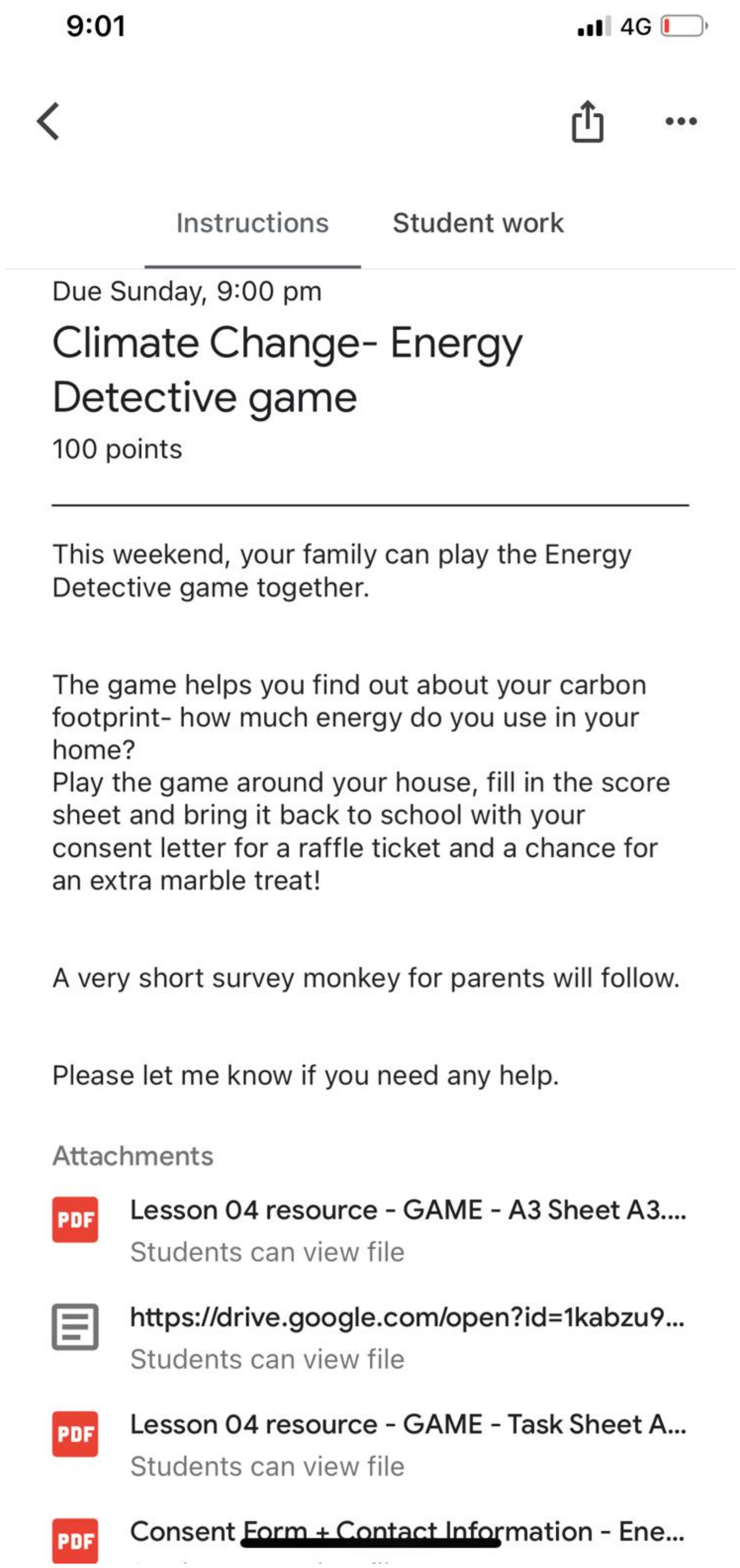


Figure 207: Example of take-home activity available on Google Classroom on IOS - Accessible by parents on any device

7.6 Other Works

7.6.1 Annex 79 Expert's Meeting + Occupant Behaviour Research Symposium

Title of oral presentation:

7.6.2 ICEC Evolving Cities 2021

Title of oral presentation: Investigating inter-generational factors on behaviour and human building interaction.

7.6.3 ICEC Evolving Cities 2022

Title of oral presentation: Utilising Children as Agents of Change to Reduce Heating Use in Domestic Dwellings.

This presentation won the 'Best Presentation' Award given by the IET.

7.6.4 Journal Papers

Journal Paper 1 - Predicting differences in domestic electricity and gas consumption between different household compositions.

energies

MDPI

Article

Predicting UK Domestic Electricity and Gas Consumption between Differing Demographic Household Compositions

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Abstract: This paper examines the influence of building characteristics, occupant demographics and behaviour on gas and electricity consumption, differentiating between family groups; homes with children; homes with elderly; and homes without either. Both regression and Lasso regression analyses are used to analyse data from a 2019 UK-based survey of 4358homes (n = 1576 with children, n = 436 with elderly, n = 2330 without either). Three models (building, occupants, behaviour) were tested against electricity and gas consumption for each group. Results indicated that homes without children or elderly consumed the least energy. Property Type emerged as the strongest predictor in the Building Model (except for homes with elderly), while Current Energy Efficiency was less significant, particularly for homes with elderly occupants. Homeownership and number of occupants were the most influential factors in the Occupants Model, though this pattern did not hold for homes with elderly. Many occupant and behaviour variables are often considered 'unregulated energy' in calculations such as SAP and are thus typically disregarded. However, this study found these variables to be significant, especially as national standards improve. The findings suggest that incorporating occupant behaviour into energy modelling could help reduce the energy performance gap.

Keywords: domestic energy; occupant behaviour; lasso regression; energy performance gap; SAP (standardised assessment procedure)

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1. Introduction

1.1. Research Background

In 2008, the United Kingdom (UK) government put forward the Climate Change Act, which stated to "reduce carbon emissions by at least 80% from the 1990 levels by the year 2050" [1]. In April 2021, this was tightened to 73% by 2035 [2]. Yet in 2023, the UK consumed 163.8 million tonnes of oil equivalents (mtoe) [3], thus making the UK the 16th biggest energy consumer in the world [4]. Breaking down the energy mix, energy consumption from domestic buildings is responsible for over 32% of the overall UK consumption [3]. Space Heating (SH) is singularly responsible for nearly 61% of UK heat consumption [5]; it is the largest contributor of carbon emissions in the home and thus has the greatest potential for positive change of all factors in the home.

Unlike the numerous incentive schemes put forth by the government to increase the uptake of electric vehicles, for example, there have been relatively few successful schemes or initiatives aimed at reducing domestic energy consumption or improving homes. These have included The Green Deal, Feed In Tariffs (FITs) and Code for Sustainable Homes (CFSH), all of which have had incentives reduced over time or closed entirely [6,7]. Households' participation is often low, and many schemes have shown little success; for

Figure 208: Paper 1 Page 1

example, 4 years after the launch of the Green Deal in 2013, only 2% of those homes assessed had completed installation of upgrades [8]. The UK now has some of the 'worst performing residential buildings (from an energy efficiency perspective) in Europe' [9].

It is apparent, with the removal of fabric-first approaches such as CFSH [7] and the addition of Air Source Heat Pumps (ASHP) in 2022 introduced into the Boiler Upgrade Scheme (BUS) [10], that the UK government has chosen a technology-centric approach to reduce residential emissions, rather than a fabric-first approach. This contradicts the well-established 'Energy Hierarchy', which states that 'Energy Conservation' (using less energy by having better envelopes and less heat/energy wastage) is the most influential factor. Meanwhile, utilising 'Renewable Energy' sits third on the hierarchy, as it is considerably less effective [11]. With this in mind, fabric-first improvements are often more expensive and disruptive to occupants, hindering their uptake, especially when considering the relatively low price of energy before 2022 [12].

Numerous factors impacting energy use within the home make modelling energy consumption difficult; 'even the same aspect will vary considerably between one building to another' [13]. Xu et al. (2020) found that minor occupant behaviour differences such as window opening/closing times can be responsible for over 10% of energy demand variances between identical homes [14]. Occupants, and their energy-related behaviours within the home, may be responsible for much of the unregulated energy consumption that makes up the 'Energy Performance Gap' (EPG) [15]. Mahdavi et al. (2021) reviewed occupants' behaviour contribution to the EPG, suggesting that as the requirements to meet building regulations around the world become stricter, buildings are increasingly built with higher performance envelopes and systems. Therefore, "the relative role of occupant energy behaviour is suggested to have increased, thus becoming the main contributor to this discrepancy" [16]. The study goes on to state that although occupant-related research has seen a twofold increase in the last five years (compared to the previous five years), there was not yet enough evidence to suggest occupants are significant or exclusive contributors to the EPG. Similarly, implementing some improvements to homes has also led to "Rebound Effects" occurring, which are negative effects that may arise *"when increased consumption of new goods and services offsets the savings that would occur under unchanged consumption"* [17]. An example of this is a driver purchasing a more fuel-efficient car only to then drive further and more often, increasing their overall emissions [18].

The importance of energy consumption in the home has become more apparent in recent years. The outbreak of COVID-19 initially changed the work–life balance for many in the UK [19], leading to unexpected changes in the UK's energy consumption and emissions [20]. Following this, 2022 saw conflict begin in Ukraine, which led to UK energy prices rising by up to 400% [12]. Economic factors have always played a role in energy behaviour in the home (especially with respect to heating) [21]. However, with the energy price cap continuing to rise, government financial support being reduced in mid-2023, and home improvements often being expensive or intrusive to undertake, how occupants behave in their home may play a more important role than ever before.

1.2. Influencing Factors to UK Domestic Electricity and Gas Consumption

Understanding how differing influences can impact energy consumption in the home is key to achieving the reduction required to meet national targets and mitigate the effects of climate change. Climatic and physical building factors have been shown to explain over 40% of variability in domestic energy use [22] but many other factors also influence the overall consumption of energy. Factors such as occupants' demographics and behaviour can play a significant role that is often noted but overlooked in place of factors that can be measured and improved through building efficiency retrofits [22]. The ever more energy-consuming modern way of life, including unregulated energy from working from home and a greater number of devices and appliances means occupant behaviour is becoming increasingly important in terms of domestic energy consumption and future flexible energy grid management [23,24].

Figure 209: Paper 1 Page 2

Guerra Santin et al. (2013) found that 42% of variation in energy use can be attributed to building characteristics, whilst Huebner et al. (2015) found a similar 39% of variability came from building factors alone. Both studies estimate building characteristics as the largest influence on energy use [25,26]. These characteristics include the 'floor area', 'year built', 'built form' and 'construction type' of the dwelling. Some of these factors, such as 'year built' and 'built form' (e.g., flat, terraced, detached), cannot change or be improved through retrofit. Similarly, larger properties have a greater surface area of external walls and will require more energy to heat than smaller homes. These factors cannot be altered with typical remedial works or technologies, thus alternative improvements must be found. Building envelope improvements, which can drastically change the building energy performance, are not represented in variables such as 'year built', a more accurate measurement would be 'wall construction', which expresses the dwelling today. Building characteristics not only produce the most variability in energy consumption [26] but also often require the most financial or invasive retrofitting to improve them. Larger properties will require substantially more capital to be invested upfront, often leading occupants to choose cheaper or less effective methods of house improvement. Also, improvements such as zonal space heating may lead to ignoring areas of the home, resulting in poor ventilation and the build-up of mould [27]. Furthermore, building characteristic improvements are unattainable for occupants who are not homeowners due to their invasive nature and/or changes to physical building aspects that are not allowed.

Occupants' socio-demographics and behaviour are another major influencing factor to UK domestic electricity and gas consumption. Aragon et al. (2022) undertook a two-year heating use study on five identical tower blocks and found significant differences in energy consumption between identical flats, which the authors associated with occupant behaviour. Many factors affect occupants' behaviour in the home [28]. Previous research has grouped these factors into three categories; (a) socio-economic, (b) comfort and (c) lifestyle, which overlap in a triple Venn Diagram [29,30]. On socio-economic (a), household annual income is a major influencing factor in energy consumption [31]. Also, it is well established that thermal comfort (b) is one of the largest drivers behind energy consumption in the home with space heating singularly responsible for nearly 60% of residential emissions [32]. Currently, occupant behaviour is modelled simply within industry standard energy assessments, for example, occupant influence within the UK Standardised Assessment Procedure (SAP) is limited to impacting space heating only. Within SAP, it is presumed that occupants will heat a home to 18 Degrees Centigrade throughout the year, with the main living room temperature increased to 21 Degrees Centigrade during the winter months [33]. Similarly, the Building Research Establishment Domestic Energy Model (BREDEM) [34] is designed with 'heating demand temperature' and 'heating pattern' as the two most sensitive variables, representing a large effect changes on the overall energy consumption in the home [35]. This is as far as occupant behaviour is analysed within the two assessments and has the greatest potential for positive change. Finally, lifestyle (c), upbringing and other aspects of life may affect how occupants live and behave in the home, for example, people moving from warmer countries to colder countries [36] or opening windows [37].

Traditionally, inter-generational influences on energy consumption focus primarily on the effects of having elderly relatives in the home [38–41]. With increased life expectancy, these issues are intensified. Pais-Magalhaes et al. (2022) stated 'it is universally predicted that an ageing population will increase energy consumption in households'. This rise is due to longer occupancy hours (and thus longer heating periods), levels of comfort requiring a higher temperature, and concerns regarding ill health [41,42]. There is also another generation that occupies dwellings, which have seen less research than elderly occupants, these are younger generations—children and teenagers. The generational shift also brings changes in energy consumption patterns. Young people now lead a more energy-intensive lifestyle than their parents at similar ages—particularly in terms of electricity consumption [40]. That said, children and teenagers are exposed to more environmental

Figure 210: Paper 1 Page 3

knowledge than previous generations; an example of this being the Greta Thunberg Effect, significantly improving exposure and energy literacy among young people globally [43]. Not only do households with children use more energy than those without, but energy consumption increases as children age [44]. To add to this, although children use far less energy outside the home than their parents, Japanese studies have shown that inside the home, children's rate of consumption is almost identical to that of adults [45]. This is expected, as all occupants need to complete the same generic activities in the home (e.g., washing) and the hobbies of children now often include electronic devices.

1.3. Objectives

The aim of this paper is to (1) show how various influencing factors account for the variability in residential energy consumption, (2) compare these factors between different household types, and (3) determine which of these factors and household groups have the greatest impact on domestic energy consumption.

This study will estimate and compare the explanatory power of different variables on domestic energy consumption by replicating calculations for households with varying compositions: homes without children, homes with elderly relatives, and homes with children. Building on the above literature review of factors influencing energy consumption, the independent variables will be categorised into three groups: (1) building variables, (2) socio-demographic variables, and (3) heating behaviour variables.

2. Method

2.1. Data Collection Methods

Within a large research project based in the UK in 2019, an online survey of customers from an Energy Supplier was undertaken to determine the influence of personality traits and socio-economics metrics on deferrable heat reduction at the household level [46]. The data was collected subject to UoS ethics (ERGO/FEPS/47164) with data kept strictly confidential and only accessible to members of the research project team.

The online survey was sent to approximately 20,000 households, and 4594 household responses were collected, equivalent to a 23% response rate. Incomplete datasets were removed, leaving a total sample size of n = 4358. These households were divided into the following four groups, described as follows: Group A. Homes with children (n = 1576), Group B. Homes with elderly (n = 436), Group C. Homes with neither children or elderly (n = 2330), and Group D. Homes with both children and elderly (n = 16). Group D was removed due to the low number of participants leading to poor statistical power during future analysis.

The online survey was sent to participants via email with a link that automatically opened the survey on their device, which lasted 10–15 min. The survey had questions related to seven distinct themes, described as follows: (1) study consent, (2) demographic, (3) dwelling, (4) heating, (5) thermal comfort, (6) energy literacy and (7) personality trait questions. The consent detailed taking part, use of data, and use of the information provided for the project and beyond and its completion. 'Demographic' questions collect information such as age, education, number of children and income which are all known factors that can influence behaviour [26,47]. 'Dwelling' questions collect information on home ownership, occupancy, years living at the address and total useable floor area, building on the English Housing Survey (EHS) [48]. 'Heating' questions collect information on the current heating system, control of appliances, type of boiler, heating schedules and approval and potential acceptance of heat deferral. 'Thermal comfort' questions asked how participants perceive their home environment in terms of temperature and comfort; building on BS EN ISO 10551 [49]. 'Energy literacy' questions collect information on energy education preference, actions, and knowledge, with the latter including energy finance and awareness. Lastly, 'personality trait' questions were the standard 15-part BFI-S [50] along with questions on risk, attitude, environmental concern, impulsivity, and personal norms; all factors needing to be considered. Many of the online survey questions have been

Figure 211: Paper 1 Page 4

taken from established survey scales. This created a dataset that can be compared with past and future studies that used the same scales. In addition to this online survey, this dataset was combined with information from the National Energy Performance Certificate (EPC) database [51].

Finally, this study used data from empirical readings; 'Gas Consumption' and 'Electricity Consumption'. These consumptions were recorded from gas and electricity meter readings in the participating homes. These are measured in kWh annually for the households. It included a total of all regulated and unregulated consumption; including, but not limited to domestic hot water (DHW), space heating, cooking, lighting, and all appliance usage.

In summary, the dataset included data from the online survey, EPC information, and annual meter readings. The variables reviewed in this study are summarised in Table 1, along with descriptive statistics.

Table 1. Participants' characteristics.

Characteristic	Range	UK (%)	Survey (%)
Age	<18 years	21.3	0
	18–29	16.2	5.3
	30–49	27.8	35.3
	50–64	18.1	42
	>64	16.4	17.2
Gender	Male	49	65.2
	Female	51	34.8
Household annual income	<£20,000	24.3	8.7
	£20,000–£39,000	51.3	25.3
	£39,999–£59,999	18.6	20.2
	>£60,000	5.8	34.3
	Rather not say		11.5
Heating Decision Maker	Myself		40.4
	My partner		6.6
	Shared equally		52.3
	Other		0.7
Main Occupation	Full-time	38.5	54.8
	Part-time	13.7	11.7
	Self-employed	9.5	4.5
	Retired	13.9	26.1
	Unemployed	4.4	1.4
	Full-time education	9.3	0.7
	Other	10.8	0.8
Qualification	No qualification	23.2	2.8
	GCSEs (any grade)	14.1	9.4
	5+ GCSEs (A*-C)	12.1	9.3
	2+ A-levels	3.3	10.8
	Apprenticeship	27	5.7
	Degree	5.1	56.5
	Other		5.4
Homeowner	Yes	64	88.7
	No	36	11.3

2.2. The Sample

Although the sample size was relatively large (n = 4358), it was not representative of the UK population, see Table 1. Most participants were between 50 and 64 years old, male, in full-time employment, had a degree or higher and were part of a household earning more than £60,000 per year.

Figure 212: Paper 1 Page 5

2.3. The Dataset

The dataset includes two dependent variables ('Gas Consumption' and 'Electricity Consumption') and twenty-two independent variables summarised in Table 2. The independent variables have been split into the three groups described below.

The first group, 'Predictors Model 1—Building', includes physical building characteristics. From the original survey responses, the variable 'Local Authority' has been grouped by UK regions rather than the local authority, reducing the number of variables from 317 to 20. Using more traditional wall types, the variable 'Wall Type' has also been reduced from circa 100 variables down to 4. The same process has been applied to the 'Main Fuel Type'. The other variables have not been streamlined to allow participant answers to remain bespoke.

The second group, 'Predictors Model 2—Occupants', includes socio-demographic variables. Household income has not been balanced or equivalised in any way. The variable 'Number of children' is not applicable to Group B 'Homes with elderly', and to Group C 'Homes with neither children or elderly', but has been retained for any potential analysis between family size within Group A 'Homes with children'.

The third group, 'Predictors Model 3—Behaviour', includes variable on the occupants' heating behaviour. The variables in this group have all been taken from the survey or EPC data and are on the heat source, additional heating and heating behaviours in the home.

Table 2. Summary of the independent variables, divided into three groups 'Predictors Model 1—Building', 'Predictors Model 2—Occupants' and 'Predictors Model 3—Behaviour'.

Predictors Model 1—Building	Categories (N) E = Electricity Model. G = Gas Model
Total floor area	E—N/A (continuous: M = 136m2, SD = 61m2) G—N/A (continuous: M = 135m2, SD = 59m2)
property type	E—Bungalow (212) Flat (204) House (1238) Maisonette (22) G—Bungalow (167) Flat (70) House (1030) Maisonette (12)
Local authority label	E—East Midlands (205) East England (216) London (147) Northeast (62) Northwest (136) Southeast (429) Southwest (171) Wales (64) WestMidlands (131) Yorkshire and The Humber (115) G—East Midlands (160) East England (124) London (104) Northeast (48) Northwest (120) Southeast (349) Southwest (137) Wales (45) West Midlands (111) Yorkshire and The Humber (81)
Wall description	E—Very Good (139) Good (497) Average (840) Poor (88) Very Poor (110) N/A(2) G—9in Solid Wall (316) Cavity Uninsulated (243) Cavity with Insulation (579) Other (141)
Main fuel	E—Biogas (1) Electric (189) Gas (1284) LPG (20) NA (25) Oil (133) Solid Fuel (23) Waste Combustion (1) G—Electric (12) Gas (1251) LPG (2) NA (1) Oil (4) Solid Fuel (9)
Current energy efficiency (SAP Rating)	E—N/A (continuous: M = 61.0, SD = 14.2) G—N/A (continuous: M = 61.5, SD = 13.3)

Figure 213: Paper 1 Page 6

Table 2. *Cont.*

Predictors Model 2—Occupants	Categories (N) E = Electricity Model. G = Gas Model
Number of occupants	E—N/A (continuous: M = 4.3, SD = 0.9) G—N/A (continuous: M = 4.3, SD = 0.9)
Number of children	E—N/A (continuous: M = 2.3, SD = 0.6) G—N/A (continuous: M = 2.3, SD = 0.6)
Do you own your home?	E—No (342) Yes (2387) G—N0 (198) Yes (1896)
Please state your gender	E—Female (855) Male (1905) Non-binary (4) Self-describe (2) Rather not say (9) G—Female (632) Male (1492) Non-binary (3) Self-describe (2) Rather not say (5)
Person age	E—0–9 (261) 10–17 (113) 18–64 (1620) 65–74 (410) 75+ (93) G—0-9 (224) 10–17 (101) 18–64 (1215) 65–74 (317) 75+ (69)
How many years have you been living in your current home?	E—Less than 1 (230) 1–2 (322) 3–4 (378) 5–9 (535) 10–19 (583) 20–29 (387) 30+ (313) G—Less than 1 (165) 1–2 (222) 3–4 (293) 5–9 (401) 10–19 (463) 20–29 (306) 30+ (261) [1]
Predictors Model 3—Behaviour	**Categories (N) E = Electricity Model. G = Gas Model**
Main heat source	E—biomass Boiler (9) Electric Radiators (158) Electric Heat Pump (112) Electric Storage (29) Gas Boiler (2184) Gas Fires (6) Oil Boiler (253) Solid Fuel (14) G—Electric Radiators (8) Electric Heat Pump (12) Gas Boiler (2094) Gas Fires (4) Oil Boiler (2) Solid Fuel (2)
Set room temperature	E—N/A (continuous: M = 20.0C, SD = 1.7C) G—N/A (continuous: M = 19.9C, SD = 1.7C)
Heating schedule	E—Monitor/adjust Schedule (1156) Set Point (326) Set Schedule (1293) G—Monitor/adjust Schedule (859) Set Point (224) Set Schedule (1047)
What time is the heating on? *	Always, Morning (6am–11am), Afternoon (11am–5pm), Evening (5pm–11pm), Overnight (11pm–6am), No typical schedule, Other
Would the heating periods stated above change for a typical weekend?	E—No (1938) Yes (855) G—No (1455) Yes (685)
Weekend—what time periods do you typically have the heating on? *	Always, Morning (6am–11am), Afternoon (11am–5pm), Evening (5pm–11pm), Overnight (11pm–6am), No typical schedule, Other
Who has the last word in household heating decisions?	E—My Partner (182) Myself (1101) Other (16) Shared Equally (1479) G— My Partner (144) Myself (831) Other (8) Shared Equally (1144)

Figure 214: Paper 1 Page 7

Table 2. *Cont.*

Predictors Model 3—Behaviour	Categories (N) E = Electricity Model. G = Gas Model
What are you most likely to do when you feel cold in your home? *	Put on additional/warmer clothes on, Turn the heating on for a short burst, Turn the heating on for a prolonged duration, Close windows, Use additional heating (e.g., a fire or electric radiator), Wait for the scheduled heating, Drink a hot beverage, Other
Do any of the household occupants use an additional electric heater during the winter months?	E—Never (208) Occasionally (95) Often (155) Rarely (61) G—Never (144) Occasionally (65) Often (101) Rarely (39)

* indicates Prticipants able to select multiple options from the available answers for both electricity and gas.

2.4. Data and Analysis Methods

The dataset was divided into three household groups: Group A. Homes with children (n = 1576), Group B. Homes with elderly (n = 436), and Group C. Homes with neither children nor elderly (n = 2330). Gas and Electricity consumption are the two dependent variables analysed in this study; the same analysis was undertaken for each of these consumption data. The analysis undertook three Lasso Regression Models, each looking at the 3 different aforementioned models; 'Building', 'Occupants' and 'Behaviour'. The models were repeated for the three household groups, allowing comparisons between groups and between gas and electricity consumption. The data analysis framework is summarised in Figure 1.

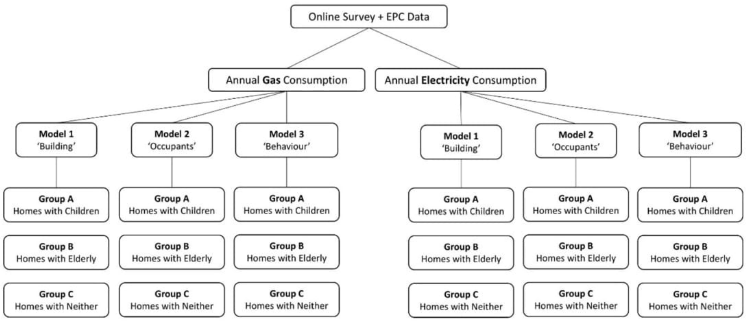

Figure 1. Data analysis framework.

First, the analysis reviewed each variable through descriptive analysis, identifying outliers. Then, an analysis of variance (ANOVA) of Electricity and Gas consumption between the three groups was carried out. This was followed by Lasso regression analysis to identify which variables are strong predictors of consumption for each group.

Lasso regression (Least Absolute Shrinkage and Selection Operator) was used as it not only produces data on predictors but also mitigates any multicollinearity—when several variables within a regression model may be highly correlated, which is detrimental to interpretation and analysis [26]. Lasso accomplishes this by "introducing a penalty term in the model and shrinking the regression coefficients to zero, allowing the model to achieve a higher level of accuracy when compared to traditional models" [52]. The regression values within Lasso may remain positive or negative depending on whether the correlation is positive or negative; the more the value is shrunk (the closer it gets to

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zero), the less powerful it is as a predictor. K-fold cross-validation was first used to find the optimal lambda value for each of the Lasso regressions; for the 3 groups, 3 models and 2 m reading types (18 tests in total). The Lasso regressions were then completed using these lambda values.

Finally, within each group, relationships between each variable and consumption were tested using either Spearman-Rank test or Kruskal–Wallis test depending on the variable type.

3. Results

3.1. Exploring the Difference in Annual Electricity and Gas Consumption between Household Groups

The electricity and gas consumption appears to be very similar between household groups, see Figure 2. However, there are statistically significant differences between household groups for gas consumption (H(2) = 2; $p = 2.2 \times 10^{-16}$) and electricity consumption (H(2) = 2; $p = 4.197 \times 10^{-13}$). This is to be expected and follows existing literature suggesting homes with more occupants, or with elderly or young family members consume more energy, usually to maintain thermal comfort [42].

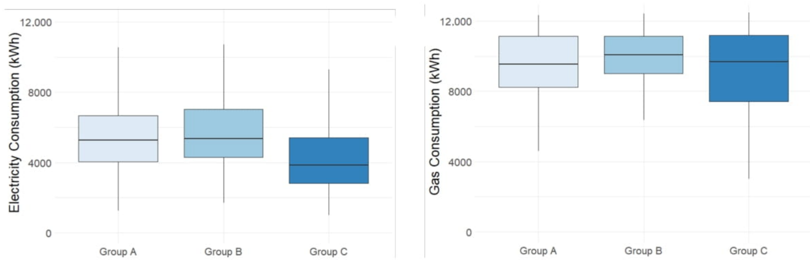

Figure 2. Annual Electricity (on the **left**) and Annual Gas consumption (on the **right**) for the three household groups.

Group C (with neither) has the lowest median and mean of the three groups which is also to be expected [39]. Again, following the pattern seen in the literature, Group B (with elderly) has the highest median and mean with elderly relatives usually requiring more energy consumption to maintain comfort levels and remain healthy [40].

3.2. Identifying the Predictors of Annual Electricity and Gas Consumption for Each Household Group

Results from the Lasso Regression on electricity and gas consumption show a difference between the final predictors within each group (see Table 3). The two strongest predictors are highlighted in Table 3; these are the two predictors with absolute values furthest from 0. These results are explored in the following sections, starting with 'Model 1—Electricity' and 'Model 1—Gas', then 'Model 2—Electricity' and 'Model 2—Gas', and finally 'Model 3—Electricity' and 'Model 3—Gas'.

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Table 3. Lasso regression analysis results.

	Electricity			Gas		
Predictors Model 1 Building	**Group A**	**Group B**	**Group C**	**Group A**	**Group B**	**Group C**
Intercept	8150	8199	6737	17,064	16,024	1614
Total floor area	19	14	19	91	147	102
Property type	−173 *	−762 *	−92 *	−1784 *	.	−757 *
Local authority label	−3	.	−1	−6	−129	6
Wall description	.	−99 *	.	86	167 *	144
Window efficiency	.	.	40	−148 *	.	−49
Main fuel	−213 *	.	−183 *	.	.	636 *
Current energy efficiency	−32	−5	−25	−97	−241 *	−84
Predictors Model 2 Occupants	Group A	Group B	Group C	Group A	Group B	Group C
Intercept	1581	8040	1353	−3578	10,356	−23
Number of occupants	1025 *	.	967 *	1817	.	2393 *
Number of children	−318	.	.	−872	.	.
Homeownership	49	.	598 *	3612 *	5192 *	3298 *
Gender	381 *	−821 *	.	2340 *	.	1585
Age	.	.	.	278	.	.
Years in current home	−20	−171 *	−38	6	364	−175
Predictors Model 3 Behaviour	Group A	Group B	Group C	Group A	Group B	Group C
Intercept	12,225	5298	5698	6855	26,543	−5890
Main heat source	−1440 *	.	−504 *	229	.	1306
Set room temperature	109	.	44	779	.	695
Heating schedule	188	.	296	867	.	1606 *
What time is the heating on?	−59	.	−33	−149	−683 *	−49
Would the heating periods stated above change for a typical weekend?	−456	.	−460	−2418 *	.	−1357 *
Weekend—what time periods do you typically have the heating on?	.	.	−1	203	.	.
Who has the last word in household heating decisions?	−52	240 *	277	−644	.	184
What are you most likely to do when you feel cold in your home?	−23	.	14	−25	.	83
Do any of the household occupants use an additional electric heater during the winter months?	582 *	.	522 *	1127 *	.	1165

* indicates the two most powerful predictors in each group.

Within 'Model 1—Electricity', 'Property Type' is one of two the most powerful variables for all three household groups. For Group B, it is the most powerful predictor. 'Property Type' is also the most consistently powerful result of any variable within any group or model, suggesting that the type of property will be one of the strongest determining factors of energy consumption. 'Main Fuel' is then the second most powerful variable for both Group A and Group C, but has been reduced to zero for Group B, which interestingly has instead 'Wall Type' as the second most powerful variable, this has been reduced to zero for both Group A and C. Interestingly, 'Window Energy Efficiency' is only powerful for Group C and 'Current Energy Efficiency' which is simply the EPC Score of the property, shows very low levels of prediction power. EPC is the national standard to test how much energy a home will consume, yet other predictors are more powerful.

Within 'Model 1—Gas', 'Property Type' is again the most powerful variable for two of the three household Groups; A and C. Yet it has been reduced to zero in Group B. 'Wall Description' sees a small increase from the Electricity Model to the current Gas Model and again is one of the top two predictors for Group B, suggesting that this variable is

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particularly important for predicting overall energy consumption in homes with elderly occupants. The variable 'Window Energy Efficiency' also sees an increase in levels of power from Electricity to Gas models for two household groups A and C, becoming the second most powerful variable for Group A. This suggests that the performance of windows is more important for electricity saving than for gas saving for households with children. The variable 'Main Fuel' remains one of the top two predictors for Group C, but has now been reduced to zero for Group A and remains at zero for Group B. Interestingly, the variable 'Current Energy Efficiency' has now become the most powerful predictor for Group B and is now also slightly more powerful for the two other groups. This reaffirms that SAP is more based on gas consumption, not electricity, overall consumption or unregulated energy.

Within 'Model 2—Electricity', there is slightly less consistency between which variables are powerful when compared to 'Model 1—Electricity'. The variable 'Number of Occupants' is the most powerful predictor for both Group A and C, but has reached zero for Group B. It would be expected that those homes with more occupants would consume more energy, but it appears that this variable is not powerful enough to be the case for homes with elderly. Groups A and B show 'Please state your gender' as a strong predictor, which could show some interesting results after further analysis. 'Do you own your own home?' is then one of the strongest two predictors for Group C. Whilst the variable 'How long have you lived in your home?' is a strong predictor for Group B only.

Within 'Model 2—Gas', the variable 'Do you own your home?' is a strong predictor for all three groups. This may suggest that the difference in consumption between those owning their homes and those renting could be substantial, potentially because of the improvements one can make on their own home relative to rented accommodation. The variable 'Number of occupants' is again a strong predictor for Group C, and the variable 'Please state your gender' is again for Group A, but both variables see decreases within other groups within the model. The variable 'How long have you lived in your home?' is a strong predictor for Group B once again, suggesting that this could be a reliable predictor for overall energy consumption.

Within 'Model 3—Electricity', Group B has had all but one variable reduced to zero through the Lasso Regression. The variable 'Who has the last word with heating decisions' is the only variable to remain a predictor. This variable is also a low-scoring predictor for the two other groups. The variable 'Main Heat Source' is a strong predictor for both Groups A and C, as well as the variable 'Do you use additional electric heating in the winter?'. This result is unexpected as the literature would suggest that households with elderly more often use additional heating sources to spot heat individual rooms [41].

Within 'Model 3—Gas', the variable 'What time is heating on?' has increased in power across all three groups (from Model 3 Electricity to Model 3 Gas) and become a top predictor for Group B. This may suggest that households with elderly abide by different heating time schedules, likely to maintain the thermal comfort of those elderly which falls in line with literature [41]. Only one variable within 'Model 3—Gas' is the same as 'Model 3—Electricity', 'Do you use additional electric heating in the winter?', and it has remained a strong predictor for Group A. Interestingly, the variable 'Heating Schedule' has also increased in power (from Model 3 Electricity to Model 3 Gas) and is now a strong predictor for Group C, but reduced to zero for Group B, where one would expect a similar increase for the reasons suggested above.

3.3. Exploring Differences with the Predictors of Annual Electricity and Gas Consumption for Each Household Group

The relationship between the outcome of 'electricity and gas consumption' and the predictors within each household group are reviewed by applying either Spearman Rank test or Kruskal–Wallis test depending on the nature of the data (discrete or continuous). The highlighted results in Table 4 are those that show a significant difference between groups. As above, these results are explored in the following sections, starting with 'Model

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1—Electricity' and 'Model 1—Gas', then 'Model 2—Electricity' and 'Model 2—Gas', and finally 'Model 3—Electricity' and 'Model 3—Gas'.

Table 4. Spearman Rank test and Kruskal–Wallis test analysis results.

	Electricity			Gas		
Predictors Model 1 Building	**Group A**	**Group B**	**Group C**	**Group A**	**Group B**	**Group C**
Total floor area	0.00 *	0.94	0.00 *	0.00 *	0.00 *	0.00 *
Property type	0.29	0.26	0.01 *	0.01 *	0.50	0.00 *
Local authority label	0.66	0.62	0.02 *	0.06	0.08	0.00 *
Wall description	0.17	0.65	0.74	0.00 *	0.37	0.00 *
Window efficiency	0.27	0.86	0.18	0.00 *	0.36	0.00 *
Main fuel	0.00 *	0.16	0.00 *	0.84	0.24	0.01 *
Current energy efficiency	0.03 *	0.63	0.00 *	0.00 *	0.03 *	0.00 *
Predictors Model 2 Occupants	Group A	Group B	Group C	Group A	Group B	Group C
Number of occupants	0.00 *	0.79	0.00 *	0.35	0.96	0.00 *
Number of children	0.00 *	NA	NA	0.04 *	NA	NA
Homeownership	0.02 *	0.76	0.00 *	0.00 *	0.03 *	0.00 *
Gender	0.29	0.11	0.45	0.00 *	0.98	0.00 *
Age	0.02 *	0.52	0.52	0.41	0.96	0.00 *
Years in current home	0.04 *	0.72	0.00 *	0.31	0.01 *	0.00 *
Predictors Model 3 Behaviour	Group A	Group B	Group C	Group A	Group B	Group C
Main heat source	0.00 *	0.11	0.00 *	0.34	0.27	0.00 *
Set room temperature	0.00 *	0.04 *	0.00 *	0.00 *	0.18	0.00 *
Heating schedule	0.00 *	0.80	0.00 *	0.02 *	0.65	0.00 *
What time is the heating on?	0.00 *	0.58	0.00 *	0.00 *	0.05	0.00 *
Would the heating periods stated above change for a typical weekend?	0.06	0.75	0.00 *	0.53	0.56	0.00 *
Weekend—what time periods do you typically have the heating on?	0.60	0.23		0.07	0.68	0.01 *
Who has the last word in household heating decisions?	0.23	0.20	0.00 *	0.18	0.17	0.00 *
What are you most likely to do when you feel cold in your home?	0.00 *	0.63	0.00 *	0.00 *	0.14	0.00 *
Do any of the household occupants use an additional electric heater during the winter months?	0.00 *	0.57	0.00 *	0.00 *	0.07	0.00 *

* indicates $p < 0.05$

Within 'Model 1—Electricity', no variables show a significant difference between groups for Group B, but 'Total Floor Area' and 'Main Fuel', both show significant differences between groups for Group A and C, suggesting that these two variables may be the most important for gauging energy use in the home. Group C, electricity consumption shows a significant difference between groups for the variables 'Property Type' and 'Local Authority', the latter suggesting the local climate can play a role in electricity consumption.

The 'Model 1—Gas' results vary considerably compared to the electricity model; both 'Total Floor Area' and 'Property Type' show a significant difference between groups for all three household groups with 'Wall Description' and 'Window efficiency' showing significant difference between groups for groups A and C. Group C shows a significant difference between groups for all variables.

Eight of the 18 tests of 'Model 2—Electricity' show significant differences between groups for all three household groups. Group B has identical results to 'Model 1 -Electricity', as it shows no difference within any variable. Groups A and C both show significant differences within 'Number of Occupants' and within 'How many years living in the home'.

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The variable 'Number of Children' shows a significant difference between groups for Group A, but not for Groups B and C. Finally, 'Gender' shows a significant difference between groups for Group C only.

Within 'Model 2—Gas', the variable 'Do you own your home' is the only variable to show a significant difference between groups for all three household types, suggesting again that there may be a benefit from the freedom that owning one's home brings in terms of mitigating gas consumption. It would be expected that the variable 'Number of Occupants' would have a strong relationship with gas consumption, but it only shows statistically significant results for Group C. This household type is only made up of single people or couples, potentially meaning the change from one to two occupants plays a larger role than the following change from more than two occupants. The variables 'Gender' and 'How many years living in the home' show significant differences between groups for two out of three household groups. The variable 'Person Age' only shows a significant difference between groups for Group C.

Within 'Model 3—Electricity', the variable 'Set Room Temperature' shows a significant difference between groups for all three household groups. This is to be expected as space heating in domestic properties is the largest energy consumer [5]. However, the majority of space heating in this study is gas-powered, thus this may require further analysis. The variables 'Main Heat Source', 'Heating Schedule', 'Time Heating is on', 'Action when Felling Cold' and 'Additional Heating?' all show significant differences between groups for household groups A and C. Group B again shows very few significant differences for the variables included in this analysis.

The same can be said for Group B in 'Model 3—Gas'; there is no significant difference between groups for any variable. Yet, Group C shows a significant difference between groups for all variables. Group A in 'Model 3—Gas' has almost identical results to Group A in 'Model 3—Electric'; showing only one change, no longer having a significant difference between groups for the variable 'Main Heat Source'.

4. Discussion

The first step of the analysis was to review the variability in electricity and gas annual consumption between household groups; 'Group A—With Children', 'Group B—With Elderly' and 'Group C—With Neither'. Although little difference in central tendency was observed, there was a significant difference between groups, with households with elderly residents consuming more energy. This analysis led to the review of the energy consumption predictors of each household group.

From the Lasso regression analysis, 'Model 1—Building' results show that the variable 'Property Type' is the strongest predictor for both electricity and gas consumption, often reaching scores of a magnitude of ten times larger than other variables. Importantly, this result is observed across all three household groups. This falls in line with the literature, which showed physical building variables have the largest effect on domestic energy consumption [26], but it is important to approach energy consumption mitigation from other angles, especially when property type cannot be changed or improved in around half of the UK dwellings (e.g., rented accommodation, historic properties, etc.) [53].

It is apparent from the results of both the Lasso regression analysis and the inferential analysis, that variables relating to dwelling ownership seem to play a large role in terms of energy consumption. The variable 'Do you own your home?' is a strong predictor of the Lasso regression analysis for four out of six groups, and shows significant differences between groups for five out of six household groups within the inferential analysis. Similarly, the variable 'Length of time in home' is a strong predictor of the Lasso regression analysis for two out of six groups, and shows significant differences between groups for four out of six household groups within the inferential analysis. Literature considered the ownership of homes an important aspect of mitigating energy use [26].

The results of this analysis appear to fall in line with points raised by other studies; that those who own their home can upgrade their envelopes or systems over time, thus reducing

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their energy consumption compared to similar dwellings that are not owned by occupants. This difference between rented/ownership status, and thus the difference between who pays and who benefits from building upgrades, is known as the 'Split Incentive Effect'. Kristrom et al. (2015) found that "owners are substantially more likely to have access to energy-efficient technologies and better insulation", thus could reduce energy consumption more than renters [54]. This issue is currently being discussed at the national level, with potential plans to enforce a mandatory EPC rating 'C' for all rented dwellings by 2025 [55]. This would require improvements to the buildings' envelopes and systems/technologies, which this study's result also suggests being the most powerful influencers and thus sensible improvements to be made first.

In the UK, 63% of households own their place of residence [53], but within this survey, 75% (n = 3688) of participants stated they owned their home. This higher rate demonstrates how the sample is not truly reflective of the UK. It can be expected that, with this higher rate of ownership along with the aforementioned opportunities homeowners have to implement upgrades, energy consumption may be lower in the survey than that of the UK average household. However, this study's results show the opposite with the owned group representing larger average energy consumption than non-owners (both for gas and electricity), see Figure 3. This may be because other variables are affecting energy consumption. The average floor area in the sample is 117sqm, whereas the UK average is lower at 97sqm [55]. This will likely mean that energy consumption is higher within the study results than would be expected based on UK averages. Similarly, the average income for a household in the UK is £35K [56], whereas 40% of the sample falls within the 'greater than £60K' category. This implies that participants have on average more disposable income and are less constrained to consume energy, thus the energy consumption data is higher than expected.

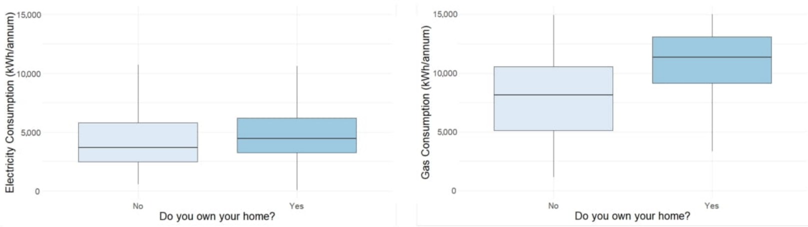

Figure 3. All household groups, variable 'home ownership' (Yes/No) for electricity consumption (on the **left**) and gas consumption (on the **right**).

This study and the review of literature have highlighted that variables such as 'dwelling age' are unreliable for a study such as this because this variable does not allow for dynamic measuring, it only refers to a single point of measurement in time. However, the variable 'Wall Description' is a current measurement of a dwelling that also encompasses any changes that may have been made to the property. Thus, it may be a better representation of building performance. The Lasso regression analysis shows that the variable 'Wall Description' is a predictor of gas consumption for all household groups and a strong predictor for Group B, but it is less powerful within the electricity models, with it only being a predictor for Group B. The skew to gas over electric may suggest that the wall types are more influenced by aspects such as heating (which is predominantly gas-sourced). In the future, this may change with the gradual transition to electric heating. The result, that wall type is only a strong predictor in homes with elderly, may also be based on heating use, but because of the higher temperature levels (and longer heating periods) that the elderly require to maintain thermal comfort as discussed earlier and put forward by Pais-Magalhaes et al. (2022). Figure 4 shows gas consumption vs. wall types

Figure 221: Paper 1 Page 14

for groups A, B and C, respectively, and that Group B (with Elderly) does not show the same pattern as groups A and C, which are very similar [42].

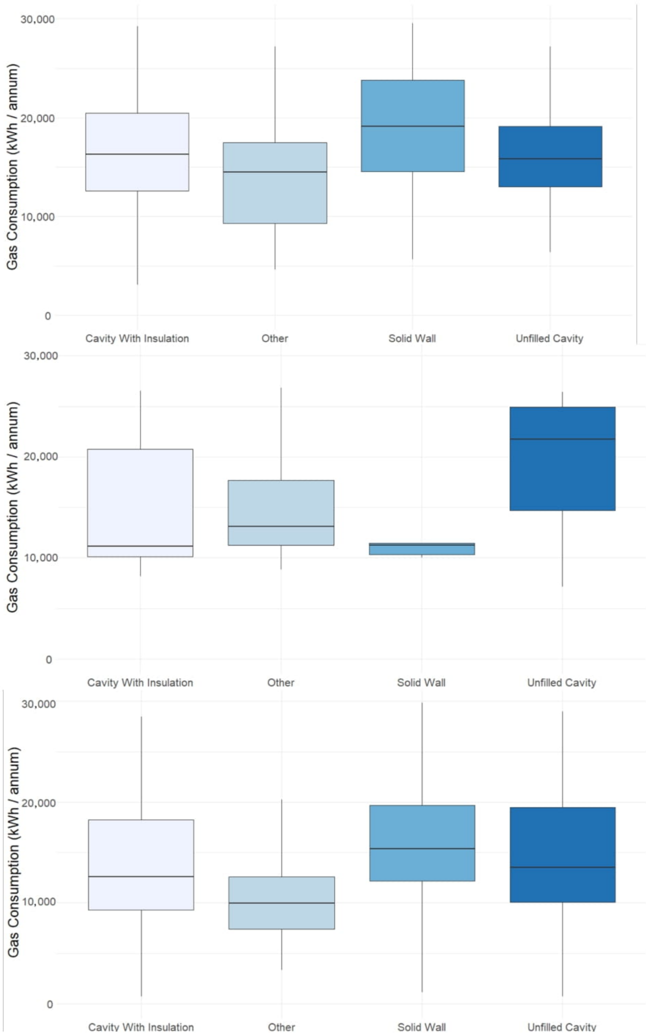

Figure 4. Variable 'Wall construction' vs. Gas consumption in kWh/annual for 'Group A—With Children' (**top**), 'Group B—With Elderly' (**middle**) and 'Group C—With Neither' (**bottom**).

On the variable 'current energy efficiency', It could be expected that the SAP rating would be the strongest predictor and show the strongest relationship with energy consumption as this is the tool used by the UK government to predict energy consumption. However, the results show that the variable is only a strong predictor for Group B gas consumption. Yet, it shows a significant difference between groups with all but one group within the inferential analysis (Spearman Rank). The difference between the two sets of

Figure 222: Paper 1 Page 15

results would suggest further analysis is required. This does however reinforce the idea that the EPG may be at least partly due to variables not considered within SAP, such as occupant behaviour and unregulated energy consumption as previously discussed. More research is required that consistently measures similar variables (both for modelling and real-world measuring). The results also call into question the validity of any modern EPC as the score is marketed as a true representation of energy consumption. The mean average EPC rating for the participant group is 62 (E), which is very similar to the national average of 60 [32]. This variable is far closer to the UK average than many of the others analysed in this study. It could be expected that with higher levels of ownership and income, homes in the sample would achieve a higher-than-average EPC rating. Figure 5 shows EPC Results against gas and electricity consumption. The regression lines suggest that the higher the score, the less energy is consumed, which is to be expected, but the shallowness of the line suggests the differences between the scores are small (see Table 5).

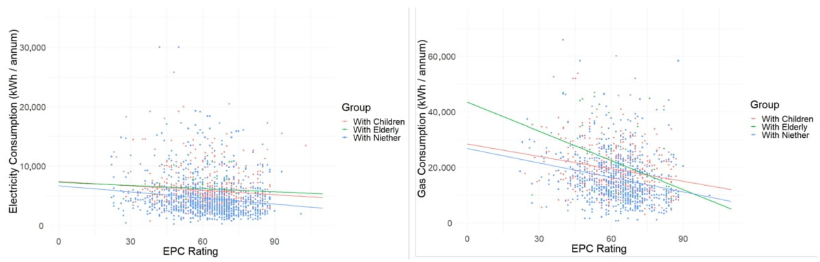

Figure 5. Variable 'current energy efficiency'(EPC rating) vs. electricity consumption (on the left) and vs. gas consumption (on the right), for 'Group A—With Children'(red line), 'Group B—With Elderly' (green line) and 'Group C—With Neither' (blue line).

Table 5. Summary of Results from variables 'current energy efficiency'(EPC rating) vs. consumption (gas and electricity).

	Electricity			Gas		
Result	**Group A**	**Group B**	**Group C**	**Group A**	**Group B**	**Group C**
p Value	0.00 *	0.14	0.00 *	0.00 *	0.03 *	0.00 *
R2 Value	0.02	0.03	0.02	0.03	0.09	0.004

It can be seen from Figure 5 that the regression lines in the electricity graph maintain the same position as the EPC rating increases. Homes with elderly consistently consume more electricity. but as the EPC improves, the gap between the three regression lines increases, suggesting that having dependents in the home limits the potential energy saving that may come by living within a high-performing home. The gas consumption graph on the right shows that having elderly in a poor-performing home will mean gas consumption is significantly higher than the two other groups, but this improves strongly as the EPC improves until having elderly in the home means that energy consumption will be less than the other two groups (A and C). The two regression lines of groups A and C maintain a consistent position and steepness to each other throughout the EPC rating range.

The results from the variables such as 'Number of Occupants' and 'Floor Area' are as expected; when there are more bodies to feed, wash and maintain comfort for, energy use increases [26]. Similarly, when there is a larger home to heat then overall energy consumption of gas and electricity increase. the variable 'Number of Occupants' is a strong predictor for 'Electricity—Group A', 'Electricity—Group C' and 'Gas—Group C', it is also a predictor for 'Gas—Group A'.

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The variable 'Gender' is also important within surveys, especially regarding aspects such as heating. Males generally require a lower temperature to maintain thermal comfort [57] or genders may have different roles in the home which means they behave in different ways or have knowledge of differing aspects of energy in the home [58]. Within this survey, the variable 'Please state your gender' is a strong predictor for three of the six household groups ('Electricity—Group A', 'Electricity—Group B' and 'Gas—Group A'). The gender in the sample was 30% Female (n = 1499), 57% Male (n = 2815) and 13% Other (n = 639).

Continuing with occupant factors, the variable 'Who has the last word on heating decisions?' is a strong predictor for 'Electricity—Group B' and is only disregarded in one of the six household groups ('Gas—Group B'). Thus, this variable can be considered an important aspect. 34% (n = 1700) of participants stated they have the final word, 44% (n = 2202) stated it was equally shared, 6% (30) stated their partner had the final say and circa 20% stated 'other' or did not answer.

It is important to remember that both gas and electricity consumption data within this study were taken directly from meter readings, including regulated and unregulated uses from water heating, space heating and more. Thereby, singularly looking at the main heating source as a variable may not portray a true representation of energy in the home. Having said that, within the Lasso Regression analysis, the variable is a strong predictor for 'Electricity—Group A', 'Electricity—Group C', and 'Gas—Group A', suggesting when there are elderly relatives in the home (Group B), the heating source is not an important factor in predicting energy consumption, but when there are children in the home (Group A), the main heat source is. This is the opposite result when compared to the variables 'How many years lived in home' and 'wall description', which appear to be far more powerful predictors for homes with elderly.

The 'Additional heaters used' variable, which would be expected to be a powerful predictor for group B (with elderly) based on the literature, interestingly is a top predictor for the groups without elderly in the home.

5. Conclusions

5.1. Summary of Findings

Domestic energy consumption is a significant and highly complicated issue, dependent on an array of variables and influences. This study aimed to gain insight into the aspects that influence gas and electricity usage in three different household groups: homes with children, homes with elderly and homes with neither older nor younger generations. Using Lasso Regression analysis on three different models of variables (Building, Occupants and Behaviour), the results identified the most powerful predictors of energy consumption within each group.

Property Type was found to be the most powerful predictor of both gas and electricity consumption across the six groups (three for electricity and three for gas), fundamentally suggesting that the physical building should be the first variable considered when discussing energy consumption in homes. However, this is one of several factors that cannot be changed—a detached dwelling cannot be changed into a flat. The first significant conclusion from this work follows that if the most significant variable cannot be altered, then it reaffirms the idea that less studied aspects such as occupant behaviour should be considered more in policies addressing change in reduction in energy consumption. Improving occupant energy behaviour could be one of the most effective ways to achieve a reduction in energy consumption in dwellings that can have little else improved. Although this paper discusses only several factors occupants control, it has shown that some may act as powerful predictors, thus with more evidence and modelling could be applied to potential future energy model predictions such as the design stage SAP.

Homeownership was the second most powerful predictor, showing a significant relationship with five of the six groups. Interestingly, homeowners used slightly more electricity and gas than non-owners, which contrasts with existing literature suggesting

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that homeowners typically retrofit their homes to improve energy efficiency. However, the sample's higher-than-average levels of homeownership, education, income, retirement rates, and house size may explain these results.

The variables 'Main Fuel Type', 'Number of Occupants', 'Gender' and 'Additional Heaters' are the next most powerful predictors, each being one of the two highest scoring results across three total of six groups. Only the first of which is considered within the SAP calculation, the latter are not, yet appear to be important variables that can be used to predict energy consumption in the home. This could be more evidence to inform the EPG. Current Energy Efficiency (EPC Rating) as a variable is also only a top predictor in one of the six groups (elec B) but is used nationally as the main comparison of energy consumption between dwellings. This paper has produced results that add to supporting evidence that shows SAP needs to be updated to fall in line with the way homes are used today. Of course, more research and accurate models are still required, but if SAP included both regulated and an accurate assumption of unregulated energy use (possibly dependent on the occupant demographics within the property—as this paper investigates), it would support reducing the energy performance gap.

The variables 'Set room temperature' and 'Floor area' show significant relationships with more groups than any other variable, but are not top predictors within any group. Having said that, they still show results within the Lasso regression analysis, rather than being reduced to 0, thus they can still be used to predict energy consumption. These two variables are intrinsically linked to space heating; the most influential consumer of energy in the home and one that can be completely controlled by the occupiers. Is there a potential for improvement in how occupants use their heating systems? The government, or energy providers, could target users with campaigns that promote more conscientious use of heating systems in homes, helping in the reduction of energy consumption in the UK.

Comparing the three models, Building Variables should be the first part of any decision that aims to improve energy use. For example, a fabric-first approach to retrofitting would be more influential than improving systems or technologies within the home. But these, along with occupant behaviours, are also important influencers that should be encouraged to be considered more often [59]. This is especially important within dwellings that are unable to be retrofitted in traditional ways such as insulation improvements.

The results from this study seem to show that occupant behaviour not only plays an important role in energy consumption in the home but also should be incorporated into future alterations to energy models. It is expected that more research needs to take place in this area before this is the case, but with the energy performance gap being as prevalent as ever, it is vital that all areas are investigated with the aim of reducing it.

5.2. Limitations of Study and Future Research

There are several important aspects to note regarding the limitations of this study. The participant sample is not fully representative of the UK population, with higher-than-average figures for household income, home size, homeownership rates, education levels, and EPC ratings.

Although the gas and electricity metering data were automatically collected, and the building data were extracted from the EPC certificates, most of the other data were self-reported by participants. This not only leads to human error in occurrences but also an internal bias. Surveys were also completed by one occupant within the home, which means inherently there may be some bias. The participants would have given answers on their own behaviours over other occupants in the home. Also, there may be some bias in the response, as participants may have answered inaccurately or falsely to appear better or simply did not know the true answer and gave their opinion. Previous research by Gauthier, (2015) has shown that when asked about their behaviours, participants will often suggest they behave differently than they do in real life [60].

The gas and electricity meter readings have been collected over one year, which may have been a hotter or colder than average year. Heating Degree Days (HDD) are a way

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of balancing data such as this to make it comparable to other years and could be used if further analysis is required.

This survey was carried out before 2022, UK energy bills have increased substantially over the past two years and thus the economic factors of today's climate may have led to some participants behaving and data differently.

This study has shown that occupant behaviour, although not the most influential factor, should still be considered when attempting to model or predict energy consumption in the home. It is especially important during the design stage as a method of mitigating the energy performance gap that has become apparent in recent years. Although not a true representation of the UK, this study suggests that some demographic or occupant behaviour factors (such as the use of a secondary heating system) could not only be used as predictors for electricity and gas consumption but may be as accurate as traditional predictors such as EPC scores. The inherent inclusion of unregulated energy within this study (by using meter data) has shown how influential it can be and how future predictions should aim to include this aspect.

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