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**Gamifying Carbon Footprints to Motivate Pro-Environmental Behavioural Change Through A Social Mobile App**

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**Declaration**

I, the undersigned, declare that this work has not previously been submitted as an exercise for a degree at this, or any other University, and that unless otherwise stated, is my own work.

Stephen Davis\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 11/03/23\_\_\_

Name Date

**Acknowledgements**

**Abstract**

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# **Introduction (1,500 words)**

The purpose of this chapter is to provide the reader with some background information and motivation for this project, accompanied by a navigational aid of the structure of this report.

## **Background and Motivation**

In 2021, Ireland set a target of reducing greenhouse gas emissions by 4.8%. The result? An increase in greenhouse gas emissions of 5%. This example highlights the problem of a knowledge action gap towards climate change, and specifically, towards reducing individual carbon footprints. With 196 Parties joining The Paris Agreement, a legally binding international treaty on climate change, and with Ireland having set the target of reducing Irish greenhouse gas emissions by 4.8%, it is clear that society has ample knowledge about the threat and importance of reducing carbon footprints to tackle climate change. The problem is the realised action, or lack of action taken to achieve these targets. The solution to achieve these targets is not difficult - reduce carbon footprints. This project focuses on this core issue of a knowledge action gap towards reducing individual carbon footprints. Without a change in meaningful pro-environmental action towards reducing carbon footprints, society will never reach global emissions targets such as reducing global greenhouse gases by 43% by 2030. Clearly there is a need for change to bridge this knowledge action gap.

The difficulty with achieving this shift in reducing individual carbon footprints comes from the fact that there is limited societal motivation to do so. A number of reasons contribute to limited societal motivation to reduce individual carbon footprints such as ineffective altruistic message framing, this issue not targeting psychological needs of the human race and individuals feeling powerless when large corporations continue to release massive amounts of emissions in relation to individual contributions. In order to accomplish sustainability targets, such as reducing Irish emissions by 4.8% in 2021, a more effective form of motivation needs to be applied to society to reduce individual carbon footprints as opposed to the current altruistically framed system of “saving our shared planet”. Without a change in approach to motivating pro-environmental behavioural change, society will continue on its current trajectory of falling far short of emissions targets. Thus, the need for this change in approach to motivating pro-environmental behaviour change is another focal motivation for this project.

Over time, gamification has been proven to be effective at motivating behavioural change, a point evident from analysing the results of existing social mobile apps whose focus is to increase pro-environmental behaviour. The success of existing gamified, environmental social mobile apps has been a massive motivation for this project, proving that gamification has the potential to deliver on this much needed, crucial change in approach to motivating pro-environmental behaviour, specifically to reduce individual carbon footprints, and thus reach global emission targets.

Although gamified social mobile apps to motivate pro-environmental behaviour change already exist, it is clear that there is still much more room for increased engagement and meaningful action to be taken towards reaching global emission targets, and thus reducing the threat of climate change.

## **Goals and Objectives**

The overall goal of this project is to apply a social app implementing gamification frameworks to motivate pro-environmental behavioural change. To achieve this goal, the objectives for app design and implementation are providing users the ability to track their daily carbon footprint emissions, compete and view position in individual and team leaderboards, view the history of their individual scores over time to analyse progress, view the breakdown of their carbon footprint score and to view suggestions on how to reduce their carbon footprints. Non-functionally speaking, the app should be easy and enjoyable to use.

After collecting data on users’ carbon footprint scores over time through the app, the goal of this project is to analyse the potential impact and success gamification can have on reducing individual carbon footprints.

## **Structure of Thesis**

**Introduction**

This chapter outlines the background and motivation for the project, the goals and objectives of the project, and finally the structure of this report.

**Literature Review**

This chapter provides the reader with relevant background information sourced from academics, in the fields of carbon footprints, behavioural psychology, gamification and existing solutions that exist to motivate pro-environmental behavioural change through a social mobile app.

**Design**

This chapter illustrates how and why the social mobile app implemented in this project was designed, relating back to insights from the previous chapter, the literature review, as well as from insights from the field of Human Computer Interaction (HCI). A series of low-fidelity (hand-drawn) and high-fidelity (software) prototypes are presented for illustrative purposes.

**Implementation**

Having established how and why the social mobile app should be designed, this chapter focuses on how this design was actually implemented by the author. Implementation issues experienced by the author are also presented in this chapter.

**Evaluation and Discussion**

This chapter focuses on how effective the social mobile app created in this project was at achieving the goals and objectives specified in the introduction chapter at the beginning of this report.

**Conclusion**

The final chapter of this report, the conclusion, addresses the limitations of this project, the challenges faced by the author, and areas of future work for the project.

# **Literature Review (3,000 words, 6-8 pages)**

The purpose of this chapter is to provide the reader with background information about the project and its key areas of carbon footprints, behavioural psychology and gamification along with existing solutions.

## **Introduction**

This literature review will discuss the method, scope and purpose of this literature review, before diving into the three key areas of this project: carbon footprint, behavioural psychology and gamification. In the first section, the carbon footprint metric and the factors contributing to this metric will be discussed. To understand why a knowledge-action gap exists in reducing carbon footprints, the second key area of behavioural psychology will be discussed, before reaching the final key area of applying gamification as a potential solution to address the problem of a knowledge action gap towards reducing individual carbon footprints. To enhance knowledge surrounding a successful implementation for this project, existing solutions will be discussed, taking inspiration from their success factors and learning from their mistakes.

## **Method, Scope and Purpose**

Using “Carbon Footprint”, “Behavioural Psychology” and “Gamification” as search strings, reputable sources were searched in Scopus and the original results returned an overwhelming number of results. After reading through hundreds of abstracts, this figure was then filtered down to results based on their level of overlap across the different key search strings, before deciding on the most applicable papers.

In order to correctly reference original authors, particularly in terms of definitions which have been around for a long time, a lengthy scope dating back as far as x years was used throughout this project. Where statistics were needed, every effort was made to use the most up to date material.

The purpose of this literature review was to provide background information to this problem of a knowledge-action gap towards reducing carbon footprints. By carrying out this initial extensive research, informed design decisions could be made throughout this project. Without such research, design decisions would be merely guesswork, a point argued by Kraus, S., Mahto, R.V. and Walsh, S.T. (2021) when they state that literature reviews are crucial to inform and guide future researchers aiming to advance the field.

## **Carbon Footprint**

This section focuses on two major subsections: the mainstream metric of carbon footprint used for measuring impact on climate change, followed by the main factors contributing to carbon footprint emissions, namely transport, meat consumption and energy usage.

### **Metric for Environmental Impact**

As Mulrow, J. et al. (2019) mention, carbon footprints have become the industry norm for calculating individual impact on climate change through greenhouse gas emissions, highlighting the causes of such emissions and providing opportunity to reduce such emissions. The main purpose of a carbon footprint score is simply to “measure the carbon emissions that result from a given set of activities“ (Wiedmann, T. and Minx, J. (2007)).

The reasons for wide spread adoption of this metric over its competitors are its ease of use, greater ability to track necessary data and consumer interest in the areas contributing to this metric (Mulrow, J. et al. (2019)).

With such adoption, carbon footprints have become a useful tool to educate and motivate pro-environmental behaviour. Kenny, T. and Gray, N.F. (2009) observe a growing trend of using carbon footprint calculators to measure individual carbon footprint scores.

### **Critiques**

Mulrow, J. et al. (2019) emphasis how users complain about the length of time and effort it takes to calculate their score with existing calculators, but that these are necessary steps to take to get an accurate indication of their overall carbon emissions.

With this in mind, one approach could be to simply focus on the most contributing factors to one’s carbon footprint score, such as meat consumption and transport, as opposed to focusing on every single contributor. This introduces a trade-off in terms of actual overall carbon emissions and the time spent by the user calculating their score. This topic will be discussed further in section 3.2.

### **Alternative Metrics**

Possible alternative metrics for measuring individual climate change impact are ecological footprint and water footprint. The differences here are that the ecological footprint focuses on “measuring the use of bio-productive space”, and water footprint measures the extent of water use in relation to consumption (Rees, (1992)). Again, the carbon footprint metric has proved to be more popular due to ease of use and simplicity, resulting in its mainstream adoption.

### **Main Factors Contributing to Carbon Footprint**

Although many factors contribute to carbon footprint emissions, for the sake of brevity, this report will now discuss the most dominant contributors which are transport, meat consumption and energy usage, and which aspects society members are most interested in. It is important to note that carbon footprint calculators tend to use different factors and underlying calculations so there is no universal answer. The following statistics are based off of Irish emissions.

#### **Transport**

Transport accounts for 17.7% towards Irish carbon emissions (Environmental Protection Agency (EPA) (2022)). This is unsurprising due to the nature and frequency of use of vehicles, where they burn fossil fuels to operate.

In their academic journal on analysing the state of carbon footprint calculators, Mulrow, J. et al. (2019) discuss that users of these calculators are not only aware of the impact transport has on their carbon footprint, but are also curious about learning more about the impact transport has on their scores.

#### **Agriculture**

Agriculture, and predominantly meat consumption, accounts for 37.5% of Irish carbon emissions (Environmental Protection Agency (EPA) (2022)).

Westhoek, H. et al. (2014) propose that a 50% reduction in meat, dairy products and eggs in the European Union would result in a 25%-40% reduction in greenhouse gas emissions associated with food production.

The problem here is identified by Sanchez-Sabate, R. and Sabaté, J. (2019) when they say that consumer awareness of the environmental impact of meat production is surprisingly low, as well as the willingness to change meat consumption behaviour in terms of reducing or substituting meat (for example, by eating insects or meat substitutes).

In terms of user interest, Mulrow, J. et al. (2019) identified food and meat consumption as an area of high interest and curiosity to consumers when receiving their carbon footprint scores.

#### **Energy Usage**

Agriculture, accounts for 16.7% of Irish carbon emissions (Environmental Protection Agency (EPA) (2022)).

Mulrow, J. et al. (2019) found in their research on carbon footprint calculators that a majority of participants are unable to accurately estimate the level of energy usage in their homes. Mulrow, J. et al. (2019) outline that users can retrieve this information, but this extra step would place more effort on the users’ behalf, increasing the cost of trying to learn about and implement pro-environmental behaviour.

An interesting point to note from Mulrow, J. et al.’s (2019) study is that users reported the most enjoyable and rewarding calculators to be those which pair user carbon scores with recommendations on activities to reduce such scores.

There are other factors included in calculating a carbon footprint score, however, for the sake of brevity only the primary above three have been discussed.

### **Conclusion**

This section has introduced the concept of carbon footprint as a metric to measure individual impact on climate change, analysing the different factors contributing to this metric’s score, and providing some insights into critiques of this mainstream metric.

Taking the popularity but also criticisms of carbon footprints into account, suggests there is need for a reduced, tailored “carbon footprint” score. With the tool of the carbon footprint metric at their disposal, and the arguably adequate knowledge of the factors contributing to this detrimental impact on the environment, this raises the central question motivating this project. Why is there such a large knowledge-action gap? This is where the next section provides an answer, discussing behavioural psychology towards climate change.

## **Behavioural Psychology and Carbon Footprint**

This section focuses on the key concern this paper addresses whereby having identified that consumers have the metrics and knowledge necessary to pro-actively reduce their individual carbon footprints, why do the majority of such consumers still not take meaningful action? The subsections to be discussed are self-determination theory, the inclusion model for environmental concern, social identity and a feeling of a lack of responsibility.

### **Self-Determination Theory**

Self-determination theory illustrates that in order to effectively motivate human behavioural change, basic psychological needs of autonomy, competence, and relatedness need to be addressed (Ryan, R.M. and Deci, E.L. (2000)).

The need for autonomy refers to the feeling of being in control, of making your own choices, experiencing a sense of self-direction (Wei, M. et al. (2005)).

When a person has the psychological freedom to engage in an activity void of external control, the person’s sense of autonomy is high and thus increases their intrinsic motivation (Peng, W. et al. (2012)).

Relatedness refers to feeling a personal connection, of belonging in a social environment, experiencing a sense of community (Ryan, R.M., Rigby, C.S. and Przybylski, A. (2006)).

Competence refers to feeling like you are improving, getting better, or even mastering the topic (Rigby, S. and Ryan, R.M. (2011)).

To maximise the potential to motivate pro-environmental behavioural change, it is essential to target all three components of the self-determination theory of autonomy, competence and relatedness. Any attempts to motivate behavioural change which do not address all of these areas of behavioural psychology will be made in vain, achieving little to no success. Self-determination theory explains how even though humans have the knowledge and tools (carbon footprint calculators) needed to reduce their individual carbon footprints, being told to reduce your footprint does not satisfy the psychological need of autonomy, and it is difficult to feel competence around sustainability because the effects are not immediately seen.

### **Inclusion Model for Environmental Concern**

De Dominicis, S., Schultz, P.W. and Bonaiuto, M. (2017) argue that traditional and historic attempts to promote pro-environmental behaviour have failed because of focusing on highlighting the altruistic benefits on nature or the greater good, where they should have focused more on self-interest or self-enhancement. De Dominicis, S., Schultz, P.W. and Bonaiuto, M.’s (2017) work expands that of the Inclusion Model for Environmental Concern (Nolan, J.M. and Schultz, P.W. (2013)), which explains how egoistic or self-interest motivated values and altruistic or self-transcendent values are hierarchically structured, whereby altruism is inclusive of self-interest. The significance of this is emphasised when De Dominicis, S., Schultz, P.W. and Bonaiuto, M. (2017) undertake 3 studies all highlighting how self-enhanced message frames, whereby users’ individual self-interests are targeted, have a much greater effect on pro-environmental behaviour than using self-transcendent message frames, such as the positive impact a participant would make on the environment.

An example of this in action, is where even though societal members know, as discussed in the previous section, that transportation increases carbon emissions, damaging the environment, individuals receive an individual reward by arriving at their location faster. Similarly, if meat consumption is popular within friend groups, individuals tend to focus on the extrinsic reward of social status and keeping with social norm, prioritising this over the environmental effect.

This theory and work explains why even with access to the knowledge and tools such as carbon footprint metrics to understand and measure environmental impact, society still continues to disregard and avoid adapting to pro-environmental behaviour.

The value of De Dominicis, S., Schultz, P.W. and Bonaiuto, M.’s (2017) research is the signification that individuals may behave pro-environmentally for non-environmental reasons, such as gaining social status (Griskevicius, V., Tybur, J.M. and Van den Bergh, B. (2010)) or being healthy (Gifford, R. (2011), (2013)) and many times individuals behave pro-environmentally even without knowing they are doing so (Gifford, R. (2013)).

### **Social Identity**

Bouman, T., Steg, L. and Zawadzki, S.J. (2020) argue that the values individuals perceive their groups to endorse can critically motivate individuals to engage in pro-environmental action. In their study, Bouman, T., Steg, L. and Zawadzki, S.J. (2020) present concrete evidence where Americans with no concern for the environment begin to change their concern for the planet after groups the participants strongly identify with show environmental concern. Bouman, T., Steg, L. and Zawadzki, S.J. (2020) expand on the work of the “Social Identity” outlined by (Fielding, K.S. and Hornsey, M.J. (2016); Jans, L., Bouman, T. and Fielding, K. (2018)), whereby groups can provide standards that guide individual actions. Bouman, T., Steg, L. and Zawadzki, S.J.’s (2020) social identity argument aligns with the Inclusion Model, where self-enhancing social image is a key indicator for motivating behavioural change in individuals.

### **Lack of Responsibility - Proportion of Individual Impact**

Schwenkenbecher, A. (2014) poses in her research, “Is there an obligation to reduce one’s individual carbon footprint?” Her work tackles the societal issue of environmental responsibility and proportionality.

With increasing awareness of the proportion of individual impact being tiny compared to large corporations, society feels a lack of responsibility to tackle climate change and argues that no one individual has the capability to make a meaningful change in global emissions.

To excellently discredit this notion of individuals contributing no harm and being unable to have a significant effect, Schwenkenbecher explains in depth the power of aggregate harm, where yes individual contributions are too negligible to have a meaningful effect, but through the power of compounding, aggregated individual change leads to meaningful emission reductions. Additionally, Schwenkenbecher highlights how individual change can be influential, pushing others towards making similar change, which we have seen can be powerful in the case of social identity discussed by Bouman, T., Steg, L. and Zawadzki, S.J. (2020).

Acceptance must be made towards the fact that compounded individual acts can be harmful, and the need for individual action to be taken to break this compounding effect.

### **Conclusion**

This section has illustrated why society continues to avoid pro-environmental action even when faced with the tools and knowledge that facilitate and encourage such change. Intrinsic and extrinsic motivations play a key role in unlocking the key to achieving societal behavioural change, and without appealing to these factors, any attempts are made in vein.

## **Gamifying Carbon Footprint**

This section introduces the concept of gamification, and how it can be applied to tackle the behavioural psychology challenges outlined in the previous section, with the ultimate goal of reducing individual carbon footprints. First the theory, then the importance of selecting design features, and finally the effects of gamification as evident from existing solutions applied to climate change will be discussed.

### **Theory of Gamification**

Deterding, S. et al. (2011) define gamification as “the use of game design elements in non-game contexts”, with Sailer, M. et al. (2017) expanding on this definition, saying “to foster human motivation and performance in regard to a given activity.” The significant factor here is the purpose of gamification being to motivate behaviour change.

Applying this logic to this project proposes the potential success of applying gamification principles and design to spark pro-environmental behavioural change.

At its core, gamification has three broad, categorical features: immersion, achievement and social features.

Immersive features are those such as avatars (Annetta, L.A. (2010); Peng, W. et al. (2012)), narration and personalisation (Kim, K. et al. (2015)), attempting to provide the player with a sense of freedom and control through the feeling of voluntary participation (Bormann, D. and Greitemeyer, T. (2015); Kim, K. et al. (2015); Koivisto, J. and Hamari, J. (2019), Rigby, S. and Ryan, R.M. (2011); Sailer, M. et al. (2017)), targeting the autonomy aspect of self-determination theory.

Achievement-related features are those such as badges, points, levels, leaderboards and performance graphs which ultimately target the competence aspect of self-determination theory, where users want to improve their skills or get feedback on their performance or progress (Xi, N. and Hamari, J. (2019)), valuing self-mastery and growth (Rigby, S. and Ryan, R.M. (2011)).

Social-related features are those such as teams, cooperation, competition, groups and chat, which ultimately target the relatedness aspect of self-determination theory, providing players with a sense of community and belonging stemmed from frequent communication, sharing of ideas and reciprocity (Francisco-Aparicio, A. et al. (2013)).

Each type of gamification feature fulfils a corresponding psychological user need, improving overall user experience, fulfilment and engagement with the application. By implementing a combination of immersive, achievement and/or social features, gamification can effectively achieve its goal of motivating behaviour change, when appropriate design choices are made. The theory suggests that gamification can be applied to overcome the psychological barriers outlined in the previous section, ultimately resulting in meaningful behavioural change towards reducing individual carbon footprints.

“Not surprisingly, in 2017, the global gamification market was valued at $2.17 billion and is estimated to reach $19.39 billion by 2023” according to Mordor Intelligence, (2018). Such a valuation is a clear indication that gamification, when appropriately designed, is an effective, efficient, and widely popular method of achieving behaviour change, and is promising for achieving this project’s goal of reducing individual carbon footprints.

### **Selecting Effective Design Features**

Gamification is well known for its success in various applications by fulfilling basic psychological user needs (Sailer, M. et al. (2017)), however, one cannot assume that gamification will automatically work. Gartner, (2012) states that 80% of current gamified applications fail to meet their objectives due to poor design (Xi, N. and Hamari, J. (2019)). This coincides with Sailer, M. et al.’s (2017) argument that “gamification is not effective per se, but specific game design elements have specific psychological effects.”

With this in mind, it is crucial to carefully plan which features to include in the design of a gamified application. Xi, N. and Hamari, J.’s (2019) research discovers that among the three broad categories of gamification features of immersion, achievement and social features, achievement had the most significant impact on fulfilling the psychological user needs of autonomy, competence and relatedness, followed by social and then immersive features. Each feature had its own benefits, however with immersion only targeting autonomy, and achievement features having a greater impact on autonomy, competence and relatedness than social features, achievement features were the clear winners, followed by social features as a close second.

This research provides great motivation for this project to prioritise implementing achievement features such as leaderboards, points and progress maps, before progressing on to social features such as chatting and teamwork.

### **Conclusion**

This section has introduced the theory and importance of selecting gamification design features, providing great insight into how specifically to overcome the psychological barriers to pro-environmental action outlined in section 4.

## **Existing Solutions**

This section is arguably the most important section, analysing existing solutions to gamify climate change to reduce carbon footprints. The existing solutions of “Ant Forest” and “Green Life” will be analysed, 2 solutions with contrasting levels of success.

### **Ant Forest**

Ant Forest is a Chinese based app, which pioneered the use of gamification for public environmental protection. As shown in Figure 1, users on the platform can earn "green energy" to cultivate a virtual tree by online and offline low-carbon behaviours. When the virtual tree grows, a real tree will be planted by the public welfare partner of Ant Financial Services Group. The Ant Forest has now developed multiple forms of gamified interactions, such as team up or race with friends (Cao, Y. et al. (2022)).

Timeline

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Figure 1: Workflow of Ant Forest app to promote and gamify pro-environmental behaviour (Cao, 2022).

The success of Ant Forest is indicative of its user base reaching 500 million users as of 2019, all participating in reduced carbon actions. The cooperative and competitive features in Ant Forest have resulted in more than 20 million tons of “green energy” (It takes at least 17 kg of "green energy" to plant one tree). To put this into perspective, the carbon emissions reduction of this “green energy” is equivalent to saving 29.4 billion kwh of electricity, which is equivalent to one full day of China’s electricity consumption (Cao, Y. et al. (2022)).

This impressive reduction is proof that individual environmental action, when aggregated, can have significant benefits, as outlined previously by Schwenkenbecher, A. (2014) in her paper on the proportion of individual impact.

Not only have emissions drastically reduced, but Ant Forest is evidence that individual environmental change, can influence others to do the same, as seen by companies agreeing to work with Ant Forest to incentivise green consumption behaviour, again previously proposed by Schwenkenbecher, A. (2014).

As such, Ant Forest is hard evidence that applying gamification to climate change can reduce carbon footprint scores. With such success, Ant Forest is a key motivation for the design and rationale of this project.

### **Green Life**

“Green life” is an app that encourages waste separation and recycling by offering free trash bags or other cash rewards. Having an underwhelming user base of 700,000 users in total so far, with a concerning app store rating of only 2.3 out of 5, “Green Life” is a good example of how solely providing financial incentives is inadequate to achieve behavioural change amongst a wide customer base. Green Life is the perfect illustration of the danger of assuming any form of gamification will result in effective behavioural change, and that, as previously mentioned by (Gartner, 2012), 80% of current gamified applications were estimated to fail to meet their objectives due to poor design. (Xi, N. and Hamari, J. (2019)). With this example in mind, this project will focus on the most effective combination of gamification features needed to achieve the required environmental behavioural change.

## **Conclusion**

This literature review has analysed the area of a carbon footprint, outlining the need for an adapted carbon footprint metric, targeted at the most contributary actions towards carbon emissions. After identifying the knowledge-action gap problem, the central motivation for this project, the inclusion model, social identity and lack of responsibility put into perspective why such infrequent action is taken. By connecting the ability of gamification to tackle these psychological barriers to pro-environmental behaviour change, and analysing this in practice through existing solutions of Ant Forest and Green Life, motivations and direction will be taken forward throughout this report, to aid in the design of this project.

# **Design (2,500 words)**

This chapter discusses the design for the social mobile app created in this project. Firstly, insights from the literature review discussed in the previous chapter will be presented, then a requirements analysis from the field of Human Computer Interaction (HCI) is presented with insights from this, before finally presenting both low and high-fidelity prototypes.

## **Literature Review Insights**

The literature review discussed in chapter two of this report examined the areas of carbon footprints and carbon footprint calculators, behavioural psychology and effective gamification design. Based on the literature review, the prioritised value-adding features which should be implemented are achievement and social features, competition and cooperation, a quick and easy footprint calculation and a way to educate users. As discussed in the literature review there are a variety of ways to include these features, and the specific ways implemented in this social mobile app are points, a leaderboard and an individual progress chart for achievement features, team and individual leaderboards for social features, to focus on meat consumption and transport for a quick footprint calculation, individual leaderboard for competition, team leaderboard for cooperation and finally to view the emissions from various activities to educate users. All of these insights are illustrated in figure 1 below.

Table

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Figure 1: Table representing the recommended features from the literature review in the 1st column, with how the feature is implemented in the app in the 2nd column.

As discussed in the literature review and illustrated in figure 1 above, competition, cooperation, information, achievement features and social features are highly effective functional requirements for implementing mobile applications targeted at motivating pro-environmental behavioural change.

In addition, a quick, reduced user effort footprint calculator is needed, focusing on meat consumption and transport. This is because meat consumption, transport and energy usage are the three most contributary components of an individual’s carbon footprint, but energy usage requires pre-prepared knowledge of utility bills and information which is more difficult for users to collect, as well as not having control of these emissions such as how a home is powered when renting or living with parents, as previously outlined in the literature review. Thus, meat consumption and transport are the emission factors this app focuses on collecting from user input.

It is important to note that the literature review also referenced other features which could add value such as immersive gamification features (avatars, narration), but with the limited time constraint of this project and adhering to agile best practices, the features which add the most value are of the highest priority.

## **Requirements Analysis**

This section implements the frameworks used in the field of Human Factors (HF), or Human Computer Interaction (HCI), namely scenarios and hierarchical task analysis, to develop further insight into what users may feel, experience and what they are trying to achieve by using the gamified mobile app in this project. By implementing the scenario and hierarchical task analysis frameworks, improvements can be made to the design of the app to provide a more seamless experience for the users.

### **Scenarios**

This section provides a user scenario associated with the mobile application to be built for this project. The scenario illustrated in this section is that of an unmotivated environmentalist. The purpose of this section is to gain insight into how the users feel, what they experience and what they are trying to achieve when using the mobile application, taking into account their personal characteristics and diverse backgrounds.

#### **Unmotivated Environmentalist**

Dave is a student at Trinity College Dublin, where he studies Environmental Science. Dave has always been fascinated by science and often spends his time outdoors enjoying nature and watching documentaries about the environment. Dave is environmentally concerned but lacks motivation to take meaningful action to reduce his carbon footprint because there is nothing holding him personally accountable for his environmental actions and it is too easy to avoid change. Any consequences for his lack of action he feels is too distant and does not affect him directly. Dave wishes there was an easy way to increase his motivation to reduce his individual carbon footprint.

While researching academic papers for an assignment, Dave comes across a gamified social mobile app where students compete individually and in teams through their carbon footprints. Dave has experience using carbon footprint calculators and has frequently found them to be too time-consuming, requiring too much effort and ultimately frustrating and de-motivating him. If the calculation of his footprint does not require much effort, Dave would like to use the app to compete against his friends, hopeful that this app will help him feel accountable. Ultimately, Dave sees this app as a great opportunity to help him achieve his goal of increasing his motivation for reducing his individual carbon footprint.

After signing in to the app with his credentials, Dave observes the screen displayed to him. He notices the “Add Emission” button and decides to click it. Next, Dave sees the option to select either a transport emission or a food emission. Dave selects a transport emission. Dave sees a list of fields he needs to fill in and immediately feels concerned because of his experience using time-consuming carbon footprint calculators in the past. Dave is prompted to select what size car he uses, which he has no idea. He notices there is a key explaining how a small car is a mini, and a large car is an SUV. Dave drives an SUV so he selects a large car. Dave is grateful the app is helpful for selecting the appropriate answers.

Next, Dave selects diesel as his fuel type. Since he drove by himself to work Dave selects 1 for the number of passengers. Since Dave has driven to work every day he knows the commute distance is 4.8km. By accident, Dave enters 48 and selects kilometres. To log his commute, Dave selects “save”. After selecting “save”, Dave is shown the information he has entered and is asked to confirm the details are accurate. Dave glances through the details and notices he entered 48 instead of 4.8km and quickly fixes this mistake, before clicking confirm. Dave is grateful the app prompted him to review his entry, preventing him from logging an incorrect distance, and appreciates how easy it was to change the distance entered.

After arriving home from work, Dave opens the app to log his commute home. To his delight, Dave sees the new entry has his previous commute entry already filled in. Dave simply clicks save, confirming his new log and takes great satisfaction in not having to refill in all the details all over again.

At the end of the day, Dave views his position in the individual leaderboard and sees he is ranked third out of fifth amongst his friends. In the team leaderboard his team is coming 4th and he notices this is because his score has dragged them down. Dave feels the urge to improve his score in the future so he does not let his team down.

After logging his emissions through the app and competing with his friends through his carbon footprint score, Dave notices an overall reduction in his carbon footprint over time and takes great comfort in the environmental change the app has brought about amongst him and his friends. Dave’s environmental concerns begin to ease and he is relieved to finally feel motivated to take meaningful action to reduce his carbon footprint. Feeling personally accountable to help his team win, Dave finds it difficult to avoid changing his damaging environmental actions and that the consequences for his lack of action is reflected on a day to day basis. By competing against his friends, Dave’s motivation to improve his environmental behaviour improves greatly, giving him a great appreciation for how convenient and helpful the app is.

### **Hierarchical Task Analysis**

Following on from the scenario discussed in the previous section, this section provides the hierarchical task analysis for logging emissions, which was a focal task in the previous scenario, offering insights into the most frequent, complex, and error prone tasks.

#### **Log Emission**

0. Log Emission

1. Sign in

1.1. Enter email

1.2. Enter password

1.3. Select sign in

2. Add Emission

2.1. Select add emission

2.2. Select emission type

2.3. Add transport emission

2.3.1. Select mode of transport

2.3.2. Select car size

2.3.3. Select fuel type

2.3.4. Enter number of passengers

2.3.5. Enter distance

2.3.6. Select unit of distance

2.4. Add food emission

2.4.1. Select food type

2.4.2. Enter portion size

2.4.3 Select unit of measurement

2.5. Select save

2.6. Select cancel

3. Confirm details of emission log

Plan 0: Do 1, then 2, then 3.

Plan 1: Do 1.1, then 1.2, then 1.3.

Plan 2: Do 2.1 then 2.2. If 2.2 equals transport, do 2.3., else if 2.2 equals food, do 2.4. Do 2.5 or 2.6. Do 3.

Plan 2.3: Do 2.3.1. If 2.3.1. equals dart, Luas or train, then skip to 2.3.5. Do 2.3.5 and 2.3.6 in any order. If 2.3.1 equals bus, do 2.3.4., 2.3.5. and 2.3.6 in any order. If 2.3.1 equals car, do 2.3.2., 2.3.3., 2.3.4., 2.3.5., and 2.3.6., in any order.

Plan 2.4: Do 2.4.1, then do 2.4.2. and 2.4.3 in any order.

##### **Log Emission Analysis**

With logging an emission, the most frequent tasks involve filling out all the details time and time again. This may prove to be painful for users and time consuming if they have the exact same commute to work every day, or they eat the same food for certain meals. A simple solution to solve this pain point of users could be the option to save or copy a previous entry, with the ability to edit the new copied entry.

Complex tasks are those which either take a long time, or can be confusing to achieve. Complex tasks for logging an emission involve knowing the car size, knowing the number of passengers if on a bus, Luas or dart and knowing the portion size for eating food, especially if eating out in a restaurant or when you do not have a scales to weigh food. Additionally, it could be confusing when you cycle or ate pasta or do some activity where there is no option to select this food type or mode of transport. Knowing the distance travelled is not considered complex because users can easily use google maps.

Solutions to the above complex tasks involve providing the engine size and examples beside car size selection such as 1.2L for a small car, and a small car is a mini, large car is an SUV, providing average or recommended values for fields which users may not know an accurate answer for such as portion sizes for food, or number of passengers on a bus, Luas or dart and finally to provide different units of measurement because users may be more familiar with kilograms instead of pounds, and some food packets provide different units of measurement.

Serious errors in logging emissions involve making mistakes such as forgetting to add a decimal point for distance travelled or portion size of food. Additionally, if users cannot remember if they have already logged an emission so they either have duplicate logs, or no log at all because they think they have already recorded this activity.

Solutions to these serious errors outlined above involve providing a summary of the emission entry asking user to confirm, cancel or edit the entry, displaying a history of logs for the current day to avoid duplicates/forgetting to enter an activity and providing the ability to edit or delete logs once confirmed if duplicates or incorrect logs are made.

### **Scenarios and Hierarchical Task Analysis Insights**

The scenario and hierarchical task analysis discussed in sections 2.1. and 2.2. provide great insight into what user’s may experience, reflecting good or bad design decisions. By taking into account diverse user abilities and backgrounds, as well as the most frequent, complex and error prone tasks of using the app, overall design of the app can be drastically improved.

By analysing the scenarios and hierarchical task analyses, value-adding features to address frequent, complex and error prone tasks of using the mobile app can be established.

Table

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Figure 2: Insights gathered from Hierarchical Task Analysis which outlines how to improve design through adding value-adding features to improve user experience when using the mobile app to motivate pro-environmental behavioural change.

### **Conclusion**

This section has explained how in addition to the literature review insights, scenarios and hierarchical task analyses drive the design decisions rationale. After analysing the prioritised list of value-adding features from the literature review and from the scenarios and hierarchical task analyses, there is heavy overlap across these prioritised lists. Various other features could be added to the mobile app at a later stage, but to deliver the most value in the given time constraints of this project, the features outlined in the previous sections will be the focus for implementation.

## **Prototyping**

This section focuses on prototyping, further applying the knowledge from the field of Human Factors and Human Computer Interaction (HCI). In this section, low-fidelity (hand drawn) and high fidelity prototypes were created to visualise the users’ workflow, simulating their experience with using the app.

### **Low Fidelity (Hand Drawn) Prototypes**

The first stage of prototyping for this mobile app began with low-fidelity prototypes in the form of hand drawn prototypes. Hand-drawn prototypes were first created since they are very quick to create, effectively aid in visualising user flow and avoid the designer experiencing sunk-cost fallacy, where the designer is reluctant to abandon the prototypes because they have spent a lot of time working on the prototypes, even though they know abandonment would be more beneficial” (Ronayne, D., Sgroi, D. and Tuckwell, A. (2021)).

Figures 3-9 below illustrate the original hand-drawn prototypes for the app.

Diagram

Description automatically generatedA white board with writing on it

Description automatically generated with low confidenceText, letter

Description automatically generated

Figure 3: Sign in page

Figure 4: Home screen

Figure 5: Home screen expanded

Text, letter

Description automatically generatedA piece of paper with writing on it

Description automatically generated with medium confidence

Figure 7: Log food emission

Figure 6: Log transport emission

A piece of paper with writing on it

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Figure 8: Individual leaderboard screen

Text, letter

Description automatically generatedText, letter

Description automatically generated

Figure 10: My Scores screen

Figure 9: Team Leaderboard screen

### **High Fidelity Prototypes**

After analysing and iterating through different versions of low-fidelity prototypes, high-fidelity prototypes were then created using the online software tool Figma. The high-fidelity prototypes provide a cleaner, crisper, more realistic user experience to further gauge feedback from users’ experience, frustrations and enjoyment with using the app.

Figures 11 – 17 below illustrate the high-fidelity prototypes for the app.

Graphical user interface, text, application, chat or text message

Description automatically generatedApplication

Description automatically generatedApplication

Description automatically generated with low confidence

Figure 13: Log transport emission

Figure 12: Home screen expanded

Figure 11: Home screen

Graphical user interface, text

Description automatically generated

Figure 14: Log food emission

A screenshot of a cell phone

Description automatically generated with medium confidenceA screenshot of a cell phone

Description automatically generated with medium confidence

A picture containing graphical user interface

Description automatically generated

Figure 17: My Scores screen

Figure 16: Team Leaderboard screen

Figure 15: Individual Leaderboard screen

## **Conclusion**

This chapter has focused on the design for the gamified mobile app to be implemented for this project. The scenario and hierarchical task analysis frameworks from the field of Human Computer Interaction (HCI) were implemented, gaining further insight into user experience when using the app. The design decisions rationale are motivated through the insights gained from the literature review and the scenarios and hierarchical task analyses. By iteratively creating the hand-drawn prototypes and then progressing to high fidelity prototypes, user flow was visualised and improvements to the overall design were made.

# **Implementation (2,500 words)**

## **User Interface (Front End)**

## **Database (Back End)**

## **Implementation Issues (May have these…)**

# **Evaluation & Discussion (3,000)**

## **Requirements**

### **Functional Requirements**

### **Non-functional Requirements**

## **Testing**

# **Conclusion (1,000 words)**

## **Limitations of the Study**

## **Challenges Faced**

## **Future Work**

## **Final Conclusion**

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# **Appendix (0 words)**

## **Plan of Work and Gantt Chart**

## **Ethics Application Form**

### **Informed Consent Form**

### **Information Sheet for Prospective Participants**

### **Details of Research Project**

### **Survey**