Supporting Conservation of Food, Energy, and Water Resources at Households:

A Role-Playing Game Approach

by

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ABSTRACT

The consumption of food, energy, and water (FEW) resources in U.S. households is very carbon-intensive. However, these negative climate change impacts are often invisible due to insufficient awareness and knowledge. Serious games (SGs) can potentially address this issue through an experiential and rigorous approach to simulate household actions and impacts in a playful but realistic setting. This dissertation focuses on: (a) the design and testing of an SG called HomeRUN (Role-play for Understanding Nexus); (b) the effectiveness of gameplay in advancing player knowledge about the upfront costs, financial returns, and greenhouse gas (GHG) emissions of various household decisions; and (c) the effectiveness of intervention messages in increasing FEW conservation to reduce household GHG emissions. The results of gameplay sessions played by 150 university students show that HomeRUN is fun to play, creates a flow experience, and results in experiential learning. The majority of players agreed that the game experience will continue over time to influence their future consumption behaviors to conserve FEW resources. Female players tended to gain more knowledge about financial aspects of interventions, whereas male players were more likely to increase their understandings of GHG emissions and resource consumption after playing HomeRUN. Social comparison intervention messages about energy and food consumption led to the highest reductions in household carbon emissions. The messages associated with each FEW resource tended to be most likely to lead to FEW conservation actions with the game that most closely corresponded to the particular FEW resource addressed in the message. This dissertation

advances understandings about the design and use of SGs to foster learning and promote sustainable household FEW consumption.

DEDICATION

To Muhammad Hanif, my father, my greatest inspiration, my lighthouse.

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TABLE OF CONTENTS

CHAPTER Page

APPENDIX Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The conservation of household resources is a multifaceted challenge. Most people lack knowledge about the carbon footprint of their everyday lives (Røpke, 2009). The knowledge about the impacts of the household actions and tailored feedback about the household consumption may result in sustainable consumption. A household with sustainable resource consumption needs knowledge and input about voluntary behavior changes (Semenza et al., 2008) and the adoption of technological advances (Barisa et al., 2015). This dissertation highlights the challenges and opportunities of using serious games (SGs) to support households to achieve sustainable consumption. Researchers, public officials, and policymakers need a better understanding of household resource choices and their impacts. Furthermore, they need to consider all available tools and their interactions with household dynamics to conserve household resources.

The current pattern of food energy water (FEW) nexus consumption at US households is carbon-intensive (Feng et al., 2021), and the associated greenhouse gases (GHGs) emissions account for over 80% of total US emissions (Jones and Kammen, 2011). The household carbon footprints are unevenly distributed, with developed countries generating the most significant impacts per capita (Ivanova et al., 2016). The demand for food, energy, and water is estimated to increase by 40%, 50%, and 35% respectively by 2030 (NIC, 2012) mainly because of the population growth and economic prosperity (Bazilian et al. 2011). The rising demand for resources and the increasing household GHG emissions intensify the challenges to reduce FEW consumption. The challenges include lack of consumer awareness, disconnection between consumption choices and impacts (Arthur, 1989), and little understanding of actions that can effectively guide households towards low-carbon choices (Moore, 2012).

1.2 Theoretical background

Games are competitive exercises with the objective of winning, and players must apply subject matter to advance and win. Serious games do not have entertainment as their primary purpose (Michael and Chen, 2006). However, a game is fair if it gives all players an equal opportunity to achieve the game goals (Salen and Zimmerman, 2003). Zyda (2005) represents an SG as a mental contest played with a computer following rules that use entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives.

SGs are progressing because of a growing interest in their application in various areas such as in education and training and consultation, counseling, and shaping behaviors (Peters and Van de Wastelaken, 2014). The gameplay of an effective SG is a series of exciting choices tailored to explore the underlying problem or address specific issues (Morris and Rollings, 2000). Role-playing game (RPG) comprises an interestingly diverse genre, with two crucial aspects; players' role that improves with experience and a well-defined storyline (Rollings and Adams, 2003). RPG encourages higher-level mental stimulation on top of the chance to explore the depths of their empathy (Sundberg, 2016). The players' role facilitates behavior consistent with the actions of a target above and beyond the behavior facilitated by priming (Nelson and Norton, 2005). The role-playing simulation helps learn, plan, apply, visualize, and reflect (Podleschny, 2008).

The purpose of educational games includes; practicing and refining already acquired knowledge, identifying gaps or weaknesses in learning, serving as a summation or review, and developing new relationships among concepts and principles (Gredler, 2013). SGs are robust, innovative learning tools whose foremost goal is to integrate education rather than provide entertainment (Michael and Chen, 2006), while modern pedagogies constitute essential characteristics (Zyda, 2005). Thus, they are powerful learning tools, comprising supportive, engaging, and motivational contexts for learning and substituting traditional teaching methods considered overly bland (Burguillo, 2010; Girard et al., 2013).

Games have been discussed regarding learning social skills and practices, such as problem-solving (Gee, 2008), gender equity (Flanagan and Nissenbaum, 2007), participation, and community of practice (Shaffer et al. 2005), or identity (Gee, 2004). Digital games have become powerful contexts for learning by providing people with the opportunity to join new worlds by thinking, talking, and acting, taking roles otherwise inaccessible to them (Shaffer et al., 2005). Games incorporate specific attributes connected to the way people learn; they are experiential social environments where players necessarily research and reflect on their prior knowledge, solve problems during the game process, and transfer their knowledge from other contexts (Oblinger, 2004). During gameplay, players deal with challenges and tasks. They must make decisions to accomplish (Gee, 2004) in a safe environment without external consequences, while mistakes and failure are parts of the game process (Whitton, 2012).

This dissertation thus develops an RPG, HomeRUN (Role-play for Understanding Nexus), that simulates real-world household actions to interact with responsibilities and constraints. The simulations permit players to execute a range of strategies and provide feedback for participant actions. Immediate feedback on player decisions and actions also supports players to try new methods and activities related to gameplay (Kirriemuir and McFarlane, 2004).

Intervention is commonly defined as a purposeful action by an agent to create change (Midgley, 2000). An intervention is a combination of program elements designed to produce behavior changes among individuals or even communities. The most effective interventions typically (i) combine several policy tools (e.g., information, persuasive appeals, and incentives) to address multiple barriers to behavior change; (ii) use strong social marketing, often featuring a combination of mass media appeals and participatory, community-based approaches that rely on social networks and can alter community social norms; and (iii) address multiple targets (e.g., individuals, communities, and businesses) (Dietz et al. 2009). The cumulative emissions impact of any behavior depends on the magnitude of the action and its public adoption (Wynes and Nicholas, 2017). The first step to understanding cumulative effect is to know the effectiveness of the action for a single person. The intervention message (IM) tailored to individual action makes it most effective.

Researchers can only be sure that their messages will be understood if they understand their audiences, values, fears, hopes, and communication situation. Furthermore, communication can only lead to behavior change if it is measurable (Bird, 2008). Greater sensitivity to positive and motivational message framing, including greater attention to the specific verbs utilized, would seem to make behavior change messages more effective (Gifford and Comeau, 2011). Asensio and Delmas (2015) found that health and environment messages, which communicate the public health externalities of electricity production such as childhood asthma and cancer, outperform monetary savings information as a driver of behavioral change in the home. Anderson et al. (2017) found a positive effect on the durability of energy behavior change when normative feedback messages were continued over time. Schleich et al. (2017) combined in-home displays of electricity use with feedback and realized significant savings in those households over an 11-month intervention.

Ten IMs are embedded in the gameplay session of HomeRUN. There are four groups of messages: (a) reduction messages, provide an example of FEW resource household action and the subsequent carbon reduction (b) social comparison messages, provide feedback on the use of FEW resources in the previous round (c) sector-wise impact messages, shares the economics, ecological and health impacts of current resource consumption and (d) baseline message, encourages the participant to have a good game.

1.3 Research framework

In this dissertation, we aim to explore the use of a role-playing game (RPG) to foster knowledge about the behavioral and technological actions necessary to reduce GHG emissions at the household level. Using the RPG, we expect to understand the effectiveness of the intervention message to achieve sustainable household GHG emissions and to quantify the learning from the gameplay sessions. The research framework that this dissertation proposes to use is shown in Figure 1. Three major components are proposed: (1) the RPG design integrates the actions linked with FEW nexus, climate change, and sustainable development goals (SDGs) in the gaming simulation, and the household metabolism and life-cycle analysis (LCA) are used to quantify the impacts of actions; (2) the effectiveness of gameplay in advancing player knowledge about the upfront costs, financial returns, and greenhouse gas (GHG) emissions of various household decisions; and (3) the effectiveness of intervention messages in increasing FEW conservation to reduce household GHG emissions.

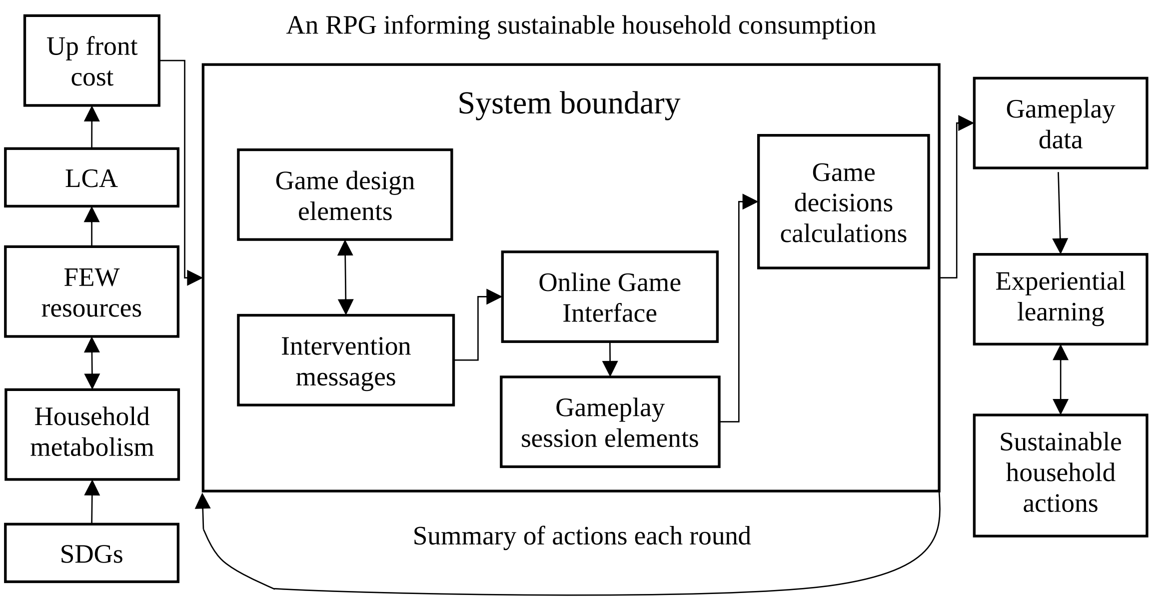

Figure 1 System diagram of the RPG study framework

The critical elements of the research framework to develop an RPG that informs sustainable household consumptions are elucidated as follows:

1.3.1 The Food Energy Water nexus

The Food Energy Water (FEW) nexus was developed in response to climate change and social changes, including population growth, globalization, economic growth, and urban sprawl (Hoff, 2011). United Nations Food and Agriculture Organization defines FEW nexus as an emerging concept to describe and address the complex and interconnected global resource systems to achieve different social, economic, and environmental goals (FAO, 2014). The nexus concept is about balancing different resource user goals and interests–while maintaining the integrity of ecosystems. It stresses promoting cooperation with various sectors and provides the opportunity to open up disciplinary divides (Allan, 2003).

The FEW nexus is internationally inferred as a process to link ideas and actions of different stakeholders under different sectors and levels for achieving sustainable development (Endo et al. 2017). The nexus is a system-wise approach that recognizes the intrinsic interdependencies of the FEW sectors for resource use and seeks to optimize the trade-offs and synergies and can thus help provide a framework. It can be used to design integrated policies and strategies and provides a means for systematically assessing cross-sectoral interactions, identifying areas of interconnections, and identifying options to implement integrated policies. By enhancing understanding of the interconnectedness among the FEW sectors, the nexus approach will also help to strengthen cross-sectoral coordination (Rasul and Sharma, 2016). The added benefit of the framework approach is that it can be specifically tailored to a location and/or problem. However, its tradeoffs lie in the necessity for more granular data and the need for highly-skilled analysts to ensure proper application of the framework in a real-life application (Dargin et al., 2019).

The novelty of the nexus approach is that through its use of the concept of trade-offs, it begins to address issues that were overlooked by previous approaches; notably, accountability of revenue and expenditure decisions, especially as they relate to infrastructure operation and maintenance for delivery of critical public services such as irrigation or wastewater collection and treatment (Kurian, 2017). The current academic progress in FEW nexus research is making towards answering the challenges which were not addressed by the previous approaches. Relevant FEW research adequately addresses problems inherent in system boundary definition (Zhang et al., 2018) and the uncertainties associated with data and modeling (Li et al., 2019). A concise description of nexus systems is resolving the internal mechanism analysis of nexus issues. Challenges in system performance evaluation, such as interdependence of subsytems and synergies across sector, are studied (Newell et al., 2019; Rasul and Sharma, 2016), and nexus-specific assessment metrics and quantitative approaches are also being developed (Sušnik et al., 2018). However, FEW nexus related consumption still needs more extensive research efforts to move towards a sustainable household in future.

1.3.2 Household metabolism

Household metabolism is a model to facilitate the description and analysis of the flows of the materials and energy within a household, and it is linked to a complex feedback process involving environmental, economic, psychological, and cultural factors and relationships (Turner and Noorman, 1998). The recent developments are mostly in the field of regional and urban sustainability (Sinclair et al., 2005; Baynes and Wiedmann, 2012). Meanwhile, a very large body of research on household environmental impacts (HEIs) derived from household metabolism has appeared (Di Donato et al., 2015). Overall, under different perspectives and using a set of innovative quantitative methods, the household metabolism of different scales (nations, regions, or cities) has been analyzed in energy and material inflows and outflows terms, which are based on household energy and material requirements, and emissions or wastes disposal, both directly and indirectly (energy from goods and services used up, materials embodied, and so on).

Different studies focused on regional and local household metabolism confirm that per capita impacts of suburban and rural households are often larger than urban households due to the higher share of direct energy in total requirements (Munksgaard et al., 2005). On the other hand, urban households seem to present a higher level of total energy and emission than rural households due to a higher income level and the consequent requirements of associated goods and services (Wier et al., 2001; Lenzen et al., 2004). There is a general agreement about the positive correlation between household size (people) and emissions in absolute terms (Tukker et al., 2010). Some studies find a negative correlation between larger household size and per capita energy requirements, especially if more children are present (Wier et al., 2001; Lenzen et al., 2006; Wiedenhofer et al., 2013). The share of facilities and space is argued to be the reason for this (Weber and Matthews, 2008).

1.3.3 Life-cycle Analysis

Life-cycle analysis (LCA) is one of the most widely used methods for quantifying the environmental impacts of a given product or process throughout its entire life cycle. It can accurately show the quantification of any unit during its life cycle and easily export its calculation processes, with the characteristics of identifying all of the inputs or outputs that may have significant impacts on the environment (Loiseau et al., 2012). The LCA approach provides a consistent analytical framework and environmental data support for decision-making at the household level. It has been extensively applied in assessing the environmental impact of FEW nexus sectors across their production and consumption processes, aiming to seek effective ways to cope with the current resource shortage and global climate change.

There is significant literature on the topic of LCA. It ranges from product cycles to industrial processes, and from cleaner production to value-chain accounting. Heller and Keoleian (2000) emphasize that the product life cycle system is a valuable framework for studying the links between societal needs, the natural and economic processes involved in meeting these needs, and the associated environmental consequences. The ultimate goal is to guide the development of system-based solutions. These studies often consider resource sectors such as food, energy, and water and the food, energy, and water, inputs into products (Bazilian et al., 2011).

Multiple LCA methods have been applied to quantify household metabolism. Input-output (I-O) analysis is the technique usually employed within the top-down approaches seeking to encompass the whole economy and sectors providing goods and services to the final demand (Munksgaard et al., 2005; Kerkhof et al., 2009). Under this approach, direct inputs or outputs are obtained from national (IO-Basic) or household-level (IO-Expenditure) statistics. At the same time, I-O tables (IOTs) combined with energy, material, or wastes and emissions intensity factors (physical input or output per unit of added value in monetary terms) can be used to reallocate resources requirements or outputs to actual household consumption of goods and services, obtained from different data sources: consumption data for different items from household expenditure surveys (IO-Expenditure) or financial data on the final demand of households by sectors, available from supply IOTs, or by commodities, available from use IOTs (IO-basic) (Kok et al., 2006).

The LCA method still has some drawbacks despite its extensive applications in FEW nexus research. With a high dependency on data, the LCA method is challenging to apply in data-scarce regions (Hamiche et al., 2016). Moreover, due to the subjective decision of the definition about the system boundaries, it is therefore inevitable to leave out some production processes, which often leads to significant truncation errors in LCA calculations. Further, the LCA seems to be a static method and may not be directly suitable for dynamic analyses of complex systems (Nair et al., 2014). To some extent, it is not easy to consider social factors within a coupled system based on the LCA method, focusing on assessments of environmental impacts (Balkema et al., 2002).

1.3.4 Sustainable development goals

The Sustainable Development Goals (SDGs) are a collection of 17 interlinked global goals, set up in 2015 by the United Nations General Assembly, which is considered to be a plan to achieve a better and more sustainable future for all and are intended to be achieved by the year 2030 (Assembly, 2017). SDGs are included in a UN Resolution called the 2030 Agenda (Cf, 2015) and are developed in the Post-2015 Development Agenda to succeed the Millennium Development Goals, which ended in 2015. The 17 SDGs are (1) No Poverty, (2) Zero Hunger, (3) Good Health and Well-being, (4) Quality Education, (5) Gender Equality, (6) Clean Water and Sanitation, (7) Affordable and Clean Energy, (8) Decent Work and Economic Growth, (9) Industry, Innovation and Infrastructure, (10) Reducing Inequality, (11) Sustainable Cities and Communities, **(12) Responsible Consumption and Production**, (13) Climate Action, (14) Life Below Water, (15) Life On Land, (16) Peace, Justice, and Strong Institutions, (17) Partnerships for the Goals.

The SDGs can inform a sustainable, inclusive, and resilient recovery from global challenges, including pandemics, climate change, and the biodiversity crisis, thereby it require a strong multilateral system. Damages to ecosystems and nature may lead to the emergence of other zoonotic diseases and pathogens, possibly with a much higher case fatality rate next time. To ensure sustainable consumption, multiple challenges, including reducing global consumption rate, production practices respecting the biophysical boundaries, and resource and impact decoupling, need to be addressed. This research adds explicitly to the 12th sustainable development goal by promoting knowledge about sustainable consumption.

1.3.5 Climate change mitigation and adaptation

Climate change is a long-term shift in global or regional climate patterns. Often climate change refers specifically to the rise in global temperatures from the mid-20th century to the present. Human influence on the climate system is evident, and recent anthropogenic emissions of greenhouse gases have been the highest in history (Stern and Kaufmann, 2014). In recent decades, climate changes have caused impacts on natural and human systems on all continents and across the oceans. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) notes some significant concerns related to climate change with high confidence, including risks to freshwater resources, terrestrial and freshwater ecosystems, coastal systems and low-lying areas, marine systems, food security, and human health. The report also calls attention to the potential impacts of climate change on urban and rural areas and human security, among other concerns. Impacts are due to observed climate change, irrespective of its cause, indicating the sensitivity of natural and human systems to changing climate (IPCC, 2014).

While social and behavior change is recognized as central to any effective response to climate-change mitigation and adaptation, there has been relatively little consideration for how this might be achieved (Moore, 2012). To be effective, social and behavioral approaches need to have an impact in the long term (thus changing habits and values) and involve individuals, systems, and social practices across all levels of society (Dunn et al., 1998; Munro et al., 2007). Ultimately, the transition towards a carbon-neutral society is a societal project—people must be engaged, informed, be willing to participate, and change their behavior for climate-change mitigation to take place (Moore, 2012).

It has been argued that changing behavior in households, referred to as ‘the behavioral wedge’, is a low-cost under-utilized strategy that could be successful if implemented effectively, drawing on research evidence (Vandenbergh et al., 2010). A recent European Commission report outlines how ‘changes in the behavior of households and consumers can result in large reductions of GHG emissions in the European Union (EU), both in the shorter and in the long term’ (Faber et al., 2012). The report concludes that across heating, transport, food, and housing, there are options for behavior change that could decrease GHG emissions.

Public perceptions about climate change are not unequivocal and, at times, do not converge with the scientific evidence (Weber and Stern, 2011). Community support for climate change policy is greatly influenced by people’s beliefs, attitudes, and risk perceptions (Howe et al., 2015). People’s perceptions of climate change often reflect their concerns over the specific impacts of climate change on their daily life (Ayal and Leal Filho, 2017). The public perception of climate change is thus an essential element of understanding climate change adaptation problems and delivering potential solutions (Weber, 2010). Combining scientific observations with public perceptions would help deepen the knowledge base and, hence, help reduce uncertainty in adaptation planning (Marin, 2010). Knowledge of likely climate-related hazards and their interactions in specific locations with the existing and future population and different kinds of assets enables the planning of adaptation measures and rationale for their implementation (IPCC, 2014).

1.4 Research questions

This dissertation provides a novel research method by designing an SG and using it as a study tool to answer multiple research questions. HomeRUN has incorporated knowledge-based information in the gameplay session, and the actions taken during them can inform and influence real-world household consumption and conservation behavior.

The following three research questions (RQ) are specified to guide this dissertation learning from the existing literature on game design, SGs, IMs, and sustainable household consumption.

RQ1. How to design an effective and fun SG to promote conservation of resources at the household level?

The first question focuses on the significance of an effective design process of SG. An SG with a rigorous design is instrumental in answering the research questions related to the subject matter. Paper I describes the development process of an SG designed to facilitate household resource conservation. The importance of gameplay design is also discussed for the experience of flow. The game's objectives and extensive testing play a vital role in developing an SG with the capability to answer multiple research questions.

RQ2. How to quantify experiential learning from the gameplay sessions of HomeRUN?

The second question focuses on the importance of the gameplay session of HomeRUN and studies its use to foster knowledge about the conservation of resources. The gameplay session is designed by simulating the household actions. Paper II conceptualizes and quantifies learning from the gameplay session. Pre-game and post-game surveys are used to determine the increase in knowledge about household actions and IMs.

RQ3.How effective are IMs for conservation in a simulated SG environment designed to facilitate a reduction in GHG emissions at a household level? Which group of IMs are most effective for the conservation of household resources?

The third question explores the use of HomeRUN as a research tool to study the effectiveness of IMs tailored to steer household consumption towards sustainable consumption. Paper III experiments with IMs embedded randomly in the gameplay session of HomeRUN. The in-game actions of players are critical to understanding the effectiveness of IMs.

1.5 Summary of papers

This dissertation mainly uses household data from a tool developed by UC Berkeley, called cool California calculator (Calculator, 2017), and consists of three papers briefly introduced below.

Paper I outlines the design process of HomeRUN, an SG used as a research tool in this study. This paper focuses on designing an effective and fun SG to promote the conservation of resources at the household and designing the gameplay session such that participants experience flow. The results of the gameplay sessions show that the gameplay of HomeRUN was fun, engaging, facilitated learning, and provided insight into the impacts of household actions. In addition, the gameplay created a high experience of flow for the participants.

Paper II studies the use of the gameplay session of HomeRUN to promote learning about household actions. The results support the effectiveness of the gameplay session to foster learning and show that the gameplay sessions of HomeRUN encourage experiential learning. Females demonstrate more knowledge related to financial aspects of interventions, whereas males exhibit more understanding about emissions and consumption of resources

Paper III focuses on understanding the effectiveness of IMs for the conservation of GHG emissions. The results show that social comparison messages on energy and food consumption lead to the highest reduction in household GHG emissions. Furthermore, the messages associated with each FEW resource lead to an action corresponding to the particular message type.

CHAPTER 2

RESEARCH METHODOLOGY

2.1 Introduction

This dissertation focuses on the use of a role-playing game to support conservation of food, energy, and water resources at households requires an understanding of: (a) the design and development of an SG, (b) measuring and translating household conservation action into financial and carbon savings, and (c) framing of intervention messages to steer household consumption towards sustainability. Therefore, this dissertation uses mainly a quantitative research approach to focus on the design of SG and gameplay sessions, experiential learning, and effectiveness of IMs. In addition, the qualitative research approach is used to analyze participants' comments and feedback. Methods and research design (Table 1) are discussed in detail in each research paper. They are summarized here.

Table 1 Summary of the Research Materials

Quantitative methods and data		
Paper I	Paper II	Paper III
Pre-game and post-game questionnaire-based surveys data of university students (N=281)	Pre-game and post-game questionnaire-based surveys data of university students (N=193)	Pre-game questionnaire-based survey data of university students and gameplay data of HomeRUN (N=157)
Qualitative methods and data		
Paper I	Paper II	Paper III
Open-ended feedback from the post-game survey	Open-ended feedback from the post-game survey	

The development of HomeRUN was an iterative process based on initial brainstorming and review of other SGs. The game was tested with students, games professionals, and information technology specialists. Suggestions, feedback, failures, shortcomings were integrated into the subsequent revisions of the game HomeRUN simulates household actions regarding annual upfront financial cost, yearly financial return, and annual carbon savings. It consists of a single role of the average US household responsible for reducing GHG emissions at the household level.

2.2 Research design

Designers of an effective SG embedded with actions and intervention messages to reduce household GHG emissions need to deal with the challenge of knowledge production. We use a transdisciplinary (TD) approach to collaborate with social actors from industry, government, and community members into the research process to integrate the best available knowledge, reconcile values and preferences, and build support for knowledge production (Agusdinata and Lukosch, 2019). The SG is designed by a TD team including engineers, social scientists, climate scientists, modeling experts, software engineers, and social actors to identify intervention factors (e.g., messages, policies, cultural commitments) that help the household manage their household consumption practices. The RPG, a common type of SG, assists both the researchers and players with exploring solutions-oriented intervention and developing potential strategies to change the current FEW consumptions to become more sustainable. Technological and behavioral actions are modeled in the simulated gaming environment. The RPG's simulated environment provides a platform for the players to understand the changes that their actions cause to the environment. The RPG is modeled so that the costs, savings, and carbon reductions caused by the interventions are easily understandable to the general public. This method helps the researchers and players to prioritize interventions. Adopting a TD approach for game development alleviates the incongruence in needs and priorities between research teams and stakeholders.

2.2.1 Data collection

The study participants were emailed a document that briefly described the project and contained the information regarding different elements of the gameplay session. Due to the novel coronavirus, all gameplay sessions were online, and the Institutional Review Board (IRB) of Arizona State University (ASU) approved the study before the data collection (Appendix D). Therefore, all participants completed the gameplay session unsupervised and on their computers. The elements of the gameplay session were sequentially placed on a dedicated website. The first element of the study was a pre-survey that was designed using google forms, and the data collected was stored in an Excel spreadsheet (Appendix B). The pre-survey took approximately 10 minutes to complete. Once the participant completed the pre-survey, they were asked to see a tutorial about HomeRUN. The 7 min 37-second long video was hosted on YouTube and was embedded in the website.

After watching the tutorial, the participant continued to play the RPG. HomeRUN is designed using Unity and was embedded on the same website using Unity WebGL. The playtime is 35 minutes approximately and consists of 10 rounds, where each round represents a simulation of one year. The online version of HomeRUN was designed for a single player. At the start, the participant was asked to familiarize with the game for 1 minute. Before each round, a randomized IM (was flashed for 20 seconds, followed by 90 seconds of gameplay per round. The IM consists of three groups (reduction, social comparison, and impact-focused) of conservation messages and a baseline message. Each round, players have the option to adopt from the thirty-four simulated household actions. Six indulge and food actions, four water and wonder actions, and fourteen energy actions (Appendix A).

2.2.2 The gameplay session of HomeRUN

The currency used in HomeRUN is called gold, where one gold is approximately equal to 100 USD. A player will receive 40 golds in every round, which is about two-thirds of the annual savings of an average American family. There are three types of actions players can take: (1) household actions related to individual FEW sectors, (2) wonder action (altruistic behaviors such as offsetting carbon emissions), and (3) indulge (actions that people usually do for pleasure such as taking a vacation and eating out). The first two types of action are done by spending gold, while the third requires gold and carbon reductions. The carbon reductions are earned by doing the first two types of actions. All actions give players joy (positive psychological consequences of pro-environmental behavior (Hu et al., 2016)), and the player with the highest joy wins the game. The values for the technological and behavioral actions are taken from a tool developed by UC Berkeley, called cool California calculator (Calculator, 2017).

At the end of the round, the summary is shown in a bar chart for 1 minute. The carbon reductions are reflected in the perspective of taking an equivalent number of cars off the road. After the ten rounds, a summary of all actions was shown to the participants. The data collected from the HomeRUN gameplay session was emailed to dedicated

Gmail and Outlook addresses. The data was in text form and then converted to a Microsoft Excel spreadsheet. In the end, the participants were asked to complete a post-survey, which took approximately 7 minutes to complete (Appendix C). In total, the gameplay session took about 1 hour to complete. The data was analyzed using Microsoft Excel and Statistical Package for the Social Sciences (SPSS). The evaluation of the gameplay session is done using the quantitative data generated during the gameplay of HomeRUN and qualitative and quantitative survey data. The survey aims to gather demographics, gaming attitude, baseline knowledge, game design, flow experience, and feedback from the participants regarding their gameplay experience.

2.3 Comparative approaches

There are various methods in the literature (Shittu, 2020; Song, 2000) to study household resource consumption including system dynamics approach, Input-Output analysis, and regional assessment. System Dynamics is a tool to investigate and model complex dynamic problems in terms of stocks (the accumulation of things), flows (the motion of things), and feedback loops at any level of aggregation. The System Dynamics models are used to understand and anticipate changes over time in puzzlingly complex systems (Assunção et al., 2020). The IO analysis is a modeling technique that divides the economy into final demand and production and accounts for the direct and indirect interdependencies among different sectors (Tabatabaie and Murthy, 2021). The regional assessment involves aggregate statistics about the production, conversion, and distribution of resources and similarly aggregate accounts for final resources consumed by households, commerce, industry, and other sectors (Baynes et al., 2011). The comparison between these approaches is elaborated in the table 2.

Table 2 Comparison of Approaches on Household Resource Consumption

	system dynamics	Input-Output analysis	regional assessment
Methodology	Stocks, flows, and feedback loops	Macroeconomic analysis	Aggregate statistics
Data	Systems model	National household survey	Statistics of the region
Advantages	Deals with complex problems Deals with data-poor problems Broader information base	Empirical investigation Equilibrium economy Not concerned with demand analysis	Baseline impact Mitigation for future projects Supports regional development objectives
Disadvantages	One version of a situation at a time Ambiguous assumptions	Rigid model The number of inputs is not constant Restrictive model	Area-specific Linkages and boundaries are assumed
Policy implications	Insight and understanding of complex problems for planning	Policy impact analysis Interdependencies and linkages with industry, household, and government	Regional context to inform planning and management

The approaches discussed in the table 2, have certain strengths but for a study focusing on testing multiple hypothesis, these approaches are not as good as the serious game based approach. SG approach provides aplatform to answer different research questions and test multiple hypothesis in an enviorment that is convenient.

2.4 Players's values versus actions

Various scholars have argued that environmental problems are rooted in human values (e.g., Dunlap et al., 1983; O'neill et al., 2008; Gillroy, 2019; Gardener and Stern, 1996).

Human behavior is an essential contributor to the current sustainability and climate change problems and their solutions (De Groot and Steg, 2008). Environmentally significant behavior can reasonably be defined by its impact: the extent to which it changes the availability of materials or energy from the environment or alters the structure and dynamics of ecosystems or the biosphere itself (Stern, 1997). Some behaviors, such as clearing forests or disposing of household waste, directly or proximally cause environmental changes (Stern et al., 1992). Other behaviors are environmentally significant indirectly by shaping the context in which choices are made that directly cause environmental change (e.g., Rosa and Dietz, 1998; Liu et al., 2007).

Values reflect general goals that people strive for in life (Schwartz, 1992). It is generally believed that values influence behavior mostly indirectly, through more specific beliefs, attitudes, and norms (e.g., Feather, 1995; Bardi and Schwartz, 2003). This phenomenon has been further specified by the value-belief-norm (VBN) theory of environmentalism (Stern et al., 1999).

The VBN theory specifies that three types of value orientations, which are notably egoistic, altruistic, and biospheric value orientations, determine pro-environmental behavior. People with strong egoistic values will particularly value and consider consequences for their resources. In contrast, those with strong altruistic values will focus more on outcomes for other people. Finally, people with strong biospheric values will focus on consequences for nature and the environment. The VBN theory proposes that these value orientations affect ecological worldviews, that is, people's general beliefs about the relationship between humans and the environment, as reflected in the revised new ecological (environmental) paradigm (NEP) (Dunlap et al., 2000).

There is no apparent correlation between players' values and actions, as shown in the Table 3. RPG players are more likely to take actions with more benefits and lower costs, resulting in a better outcome in the gameplay session. Players not only consider instrumental costs and benefits of actions, such as financial costs, time, or functionality but are also more likely to take actions in the gameplay when they anticipate feeling good. Furthermore, players during the PRG consider intervention messages and social costs and benefits of actions. In order to measure values in a gaming simulation, the game has to be designed keeping in mind of the values. The designed game needs to have multiple scenarios to ensure that it can compare the result based on the players' values and the actions taken. Furthermore, the accounting system of the game needs to be revised, and the target players need to be from diverse populations.

Table 3 Correlations between players’ values versus actions taken

	Food Actions	Energy Actions	Water Actions	Wonder Actions	Indulge Actions
Biospheric	-0.09	-0.16	-0.01	-0.05	-0.18
Altruistic	-0.03	-0.00	0.07	0.11	-0.15
Egoistic	-0.20	-0.19	-0.09	-0.14	-0.08

The design of the game thereby should consider the ways of measuring values of players in a gaming simulation. The designed game needs to have multiple scenarios to ensure that it can compare the result based on the players' values and the actions taken. The accounting system of the game also needs to be revised, and the target players need to be from diverse populations.

2.5 Limitations

The limitations of this dissertation include; a homogenous pool of research participants, geographical scope, coronavirus restrictions, surveys administered before and after the gameplay session, approximate values of actions simulated, and unsupervised gameplay sessions of HomeRUN. The strength of the qualitative approach is that it encourages open-ended feedback, while a limitation is the lack of generalizability of the findings in larger populations. However, extensive quantitative data and research approaches are used in this dissertation. The research with university students as participants and not with actual households have implications for the results' generalization. The geographical scope of this study and its data – mainly from Tempe and US-focused – also require attention. Surveys are inflexible and lack depth. Despite the limitations, the focus of this study –supporting the conservation of food, energy, and water resources at households – is not compromised.

CHAPTER 3

DESIGN OF A SERIOUS SIMULATION GAME TO SUPPORT CONSERVATION OF FEW RESOURCES AT HOUSEHOLD LEVEL: EVALUATION OF FLOW EXPERIENCE DURING THE GAMEPLAY SESSION

3.1 Introduction

US households are essential in forming current and future food, energy, and water (FEW) nexus consumption impacts. The consumption of US households is very carbon-intensive; the carbon footprint of the lowest income group (less than 15K USD/year) is 2.3 times the world average (Feng et al., 2021). The high consumption has increased interest in research about household greenhouse gas (GHG) emissions (Hertwich, 2005; Reinders et al., 2003; Flood et al., 2018), and researchers highlight the importance of improving consumption for a sustainable future (Wang et al., 2019; Hartmann and Siegrist, 2017).

The sector-wise breakdown of FEW nexus consumption highlights the potential for conservation. The food sector emissions are 34% of total GHG emissions (Crippa et al., 2021). Direct GHG emissions from agriculture represent 10% to 14% of overall GHG emissions; when indirect emissions are added, the number rises to 17% to 32% (Bellarby et al. 2008; Kim and Neff, 2009; *FAOSTAT*, 2020). GHG emissions from food production were 16% of total US GHG emissions in 2013 (Boehm et al., 2018). Most household energy consumption is from indirect use – meaning the embedded energy in creating items like water, food, the house itself, and consumer goods (Adua, 2020). Direct energy use is responsible for just 23% of household GHG emissions (Jones and

Kammen, 2011). The residential water consumption in the US is higher than in developed countries at 130 gals/capita/day in 2015 (Dieter et al., 2018). The CO_2 embedded in the water use represents 5% of all US emissions (Griffiths-Sattenspiel and Wilson, 2009).

The households have insufficient knowledge and understanding of consumption impacts (Herrmann et al., 2018). The adverse climate change impacts of household consumption are often invisible in everyday lives (Røpke, 2009) partly due to the complex interaction between the FEW nexus. Thus, the intensity of household GHG emissions coupled with insufficient knowledge about the consumption impacts highlights the need for education about practical actions to reduce emissions.

3.2 Serious games

Serious games (SGs) are commonly defined as games that do not have entertainment or fun as their primary purpose (Michael and Chen, 2006), and they must include a practical dimension (Alvarez and Djaouti, 2011). Zyda (2005) describes SGs as mental contests played with a computer following particular entertainment rules to further government or corporate training, education, health, public policy, and strategic communication objectives. Duke and Geurts (2004) define simulation games where players enact a specific role in a simulated environment. Thus, all SGs share two attributes. First, simulated gameplay is designed to share knowledge and facilitate the exchange of ideas and data about the subject matter. Second, the purpose is more than fun.

SGs are widely used for development across application domains, including military (Veziridis et al., 2017), healthcare (Pilnick et al., 2018), resource management (Lorido-Botran and Bhatti, 2021), public policy (Ghaffarzadegan et al., 2011), strategic communication (Geurts et al. 2007), intervention study (Oberle et al., 2018), collaborative decision making (Mayer et al., 2005), sustainability (Learmonth et al., 2011), sports (Oliver et al., 2020), training (Baumgartner and Winter, 2014), learning (Lee et al., 2018), education (Landon-Hays et al., 2020), human performance engineering (Silverman, 2004; Fernlund et al., 2006) and game evaluation (Koltai et al., 2017) as illustrated in Figure 2. The different terms used for SGs are extensive: applied games, simulation games, serious simulation games, interactive and social simulations, collaborative games, gamified approaches, collective action games, gamification, virtual and augmented reality (VR/AR), and more. The characteristics and genre describe the process of SG design: a role-playing game (RPG), a computer-supported interactive simulation, a digital game, a board game, etc. SGs can be designed with different perspectives: i.e., the subject matter, the application area, the game's design, the game technology, the research or evaluation methodology, and the learning (Medema et al., 2016).

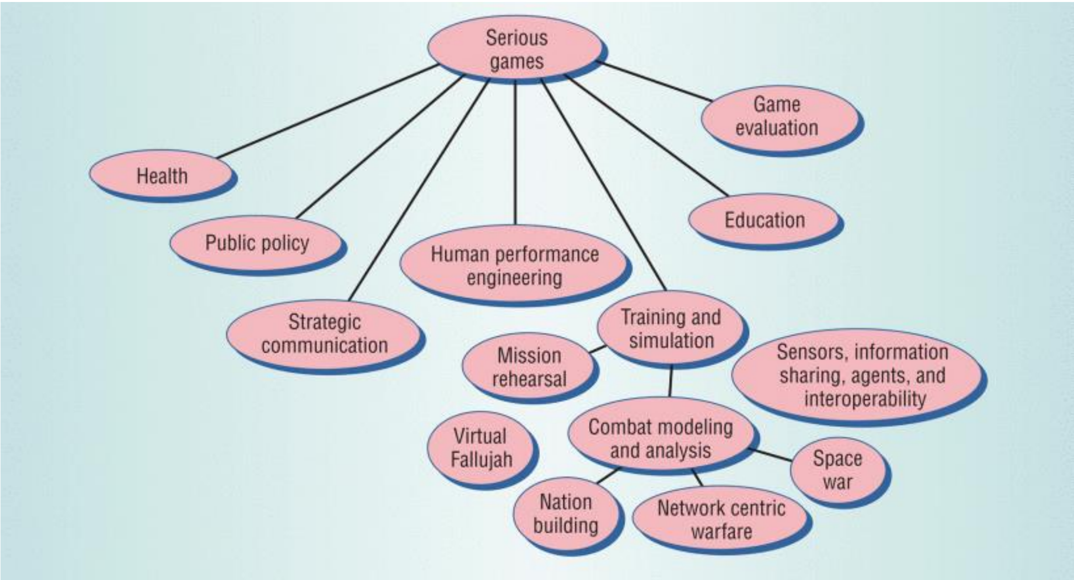

Figure 2 Broad application spectrum of SG (Zyda, 2005)

SGs are experiential and rigorous tools that facilitate players to gain insights and improve knowledge and behavior (Girard et al., 2013) and aid players to think and act in a safe and controlled environment (Dumblekar, 2004). Researchers are making games that tackle real dilemmas and improve real lives (McGonigal, 2011). However, proper training is needed to effectively design SGs with the ingenuity of entertainment games embedded with educational objectives (Zyda, 2005).

Mochizuki et al., (2021) introduce a game design framework to foster social learning and apply it to develop a FEW nexus game. The gameplay sessions of Nexus Game are crafted to promote social learning focused on understanding the underlying social-ecological system and encourage collaboration between stakeholders. They observed qualitative evidence of participants' cognitive learning by understanding the complexity of interconnections between social and ecological aspects of the FEW nexus and relational learning about the significance of collaboration at different governance levels.

3.2.1 Game design

A game used for research is designed to support a specific purpose through the true simulation of the actual event or process (Pan et al., 2017). HomeRUN simulates actions in values that are approximations of actual values. A practical game is a series of interesting choices (Morris and Rollings, 2000), and its design is a challenging task that requires a playful approach and a systematic solution (Fullerton, 2014). The fundamental aspect at the start of the design process of SG is to set the objectives and parameters. Greenblat (1988) has proposed seven questions to facilitate the design process. The questions are; (1) What is the subject matter? (2) What purpose is to be served? (3) Who are the likely players? (4) Who are the likely operators? (5) what is the probable context of use? (6) What resources are likely to be available to users? (7) what resources are available for development?

3.2.2 Flow experience

A well-thought-out SG design serves as the tool to answer different research questions (Mcmahon, 2009). During the game design process, one key consideration was ensuring that the participant's experience flow during the gameplay session of HomeRUN. Csikszentmihalyi (1975) theorized that flow is a positive psychological state that is challenging, intrinsically rewarding, and enjoyable. Flow is a state of concentration so focused that it amounts to absolute absorption in an activity. Its characteristics include: people typically feel strong, alert, in effortless control, unselfconscious, and at the peak of their abilities. Both a sense of time and emotional problems seem to disappear, and there is an exhilarating feeling of transcendence. The state of flow (Figure 3) can be controlled by setting ourselves challenges--tasks that are neither too difficult nor too simple for our abilities (Csikszentmihalyi, 1990).

Gameplay that fully engages the participants is characterized by flow theory. Games can be considered flow activities because they offer opportunities to go beyond the boundaries of ordinary experience (Csikszentmihalyi, 1990). Gameplay promotes intrinsic motivation, positive affect, and many aspects of the flow experience (Hoffman and Nadelson, 2010). Chang et al. (2017) concluded that flow experience is positively correlated to germane cognitive load. The term 'Germane cognitive load' means the work put into creating a lasting store of knowledge. Kiili et al. (2014) proposed a flow framework for analyzing and designing educational games and concluded that the flow experience reveals new ways to optimize learning effects and user experience.

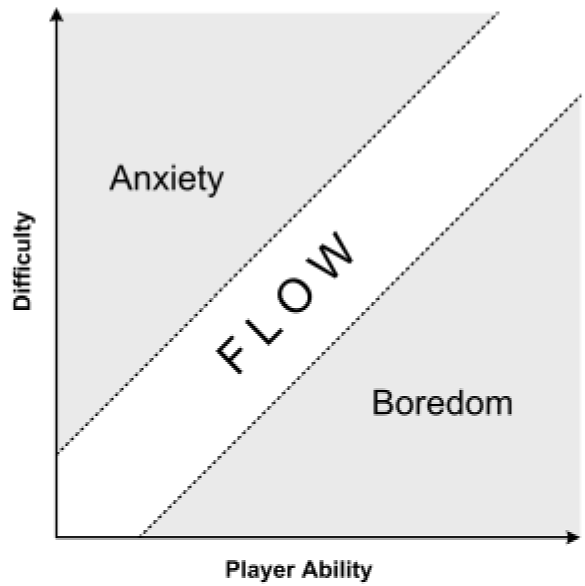

Figure 3 Flow for optimal gameplay (Csikszentmihalyi, 1990)

The flow experience from the gameplay of a serious game designed with explicit goals and challenges results in increased learning (Chan and Ahern,1999). A high flow experience is critical to increased knowledge and improved attitudes (Finneran and Zhang, 2005). Flow experience is important for participants in game-based learning research (Hamariet et al., 2016) and has been extensively connected with learning (Shernoff and Csikszentmihalyi, 2009; Skadberg and Kimmel, 2004) in different contexts, such as computer-based instructional environments (Wang and Hsu, 2014), online learning (Esteban-Millat et al., 2014; Shin, 2006) and game-based learning (Barzilai and Blau, 2014; Buil et al., 2018; Hamari et al., 2016). Research studies (Erhel and Jamet, 2019; Oliveira et al., 2019) exploring connections of game-based learning with the flow experience found a positive association. The flow experience positively affected players' learning behavior patterns, and the gaming exercise yielded more learning gains. A review article about the experience of flow in game-based learning by Perttula et al., (2017) noted that fun elements in the gameplay session are vital to players' engagement. Flow experience has a positive impact on performance enhancement and learning; however, future research should focus on the specific aspects related to the nature of serious games to establish the effect of flow in game-based learning.

3.2.3 The twelve elements of game design

This study adopts an RPG approach inspired by the twelve elements for simulation game design by Duke (1980). Following Duke's (1980) paradigm of game design, the RPG elements were developed to ensure the effectiveness of the game design. Roles are characters assigned to players with prescribed patterns of behavior. Players in the current version of HomeRUN assume the role of a person empowered to take/adopt actions to reduce GHG emissions. The game plot involves tensions and decision trade-offs between upfront costs vs. GHG emissions vs. behavioral choices. Households will take/adopt actions to mitigate their FEW GHG emissions. They base their decisions on information about activities regarding upfronts cost, financial return, and carbon reductions. They will also be receptive to interventions message related to the conservation of FEW resources. Rules govern what players should do in various circumstances, especially in cases beyond the game's scope. HomeRUN has visible, consistent, and well-communicated rules. A player can finish the game unsupervised without ambiguity. HomeRUN simulates the actions taken from the UC Berkley carbon calculator (Calculator, 2017) so that their value can easily be translated to real-world values.

This study focuses on designing an SG named HomeRUN (Role-play for Understanding Nexus) as a tool to foster knowledge about the impacts of household actions and as a research instrument to observe the in-game behavior of the participants for an intervention study. The design process was iterative, and testing was done at various stages of development to ensure that the gameplay session of HomeRUN fulfills its goal of answering multiple research questions. The game design of HomeRUN is meant to: (a) design and develop an effective and fun to play SG, (b) improve knowledge of participants about the household actions in terms of upfront costs, financial return, and GHG emissions; and (c) study the effectiveness of intervention messages for a reduction in GHG emissions. This study will answer the following research question. How to design an effective and fun SG to promote conservation of resources at the household level? The corresponding hypotheses are as follows:

Hypothesis 1: The participants of the gameplay session will consider HomeRUN as an effective and fun serious game to foster knowledge about the impacts of FEW nexus consumption at the household level.

Hypothesis 2: The participants will experience Flow during the gameplay session of HomeRUN.

3.3 Objectives and parameters of HomeRUN

The subject matter of HomeRUN is to identify the factors (news, policies, cultural commitments, hazards, etc.) that help homeowners manage their household consumption practices. The critical parameter of the SG is to educate/motivate households to change the FEW consumptions to have sustainable GHG emissions. The emphasis is on designing solutions-oriented actions easily understandable by the general public (with different cultural backgrounds). HomeRUN aims to identify and understand the factors that help households manage FEW consumptions and develop strategies to change the current FEW consumptions into more sustainable consumption. The gameplay will explore interventions and actions to assist the general public in adopting sustainable FEW consumptions. It will foster knowledge about the impact of household actions. The logo of HomeRUN is shown in Figure 4.

Figure 4 Logo of HomeRUN, an RPG for conservation of FEW Nexus resources

The intended players of HomeRUN are the general public, and the implementation mainly includes university students. The operators include sustainability scientists, Ph.D. students, graduate research students, teachers, policymakers, and FEW resource producers. HomeRUN is equipped for research and teaching purposes. The time frame for the gameplay session is one hour. It includes a briefing about the game, gameplay, and debriefing. HomeRUN is used for research, educational, and outreach activities. Players need a computer and internet connection to play the game.

3.4 The conceptual model for game design

The development of HomrRUN was an iterative process based on initial brainstorming and review of other SGs. The game was tested with students, games professionals, and information technology specialists. Suggestions, feedback, failures, shortcomings were integrated into the subsequent revisions of the game

3.5 Game description

HomeRUN simulates household actions regarding annual upfront financial cost, yearly financial return, and annual carbon savings. It consists of a single role of the average US household responsible for reducing GHG emissions at the household level. The game consists of ten rounds; before each round starts, an intervention message (IM) is randomly flashed (figure 5). The IM consists of three groups (reduction, social comparison, and impact-focused) of conservation messages and a baseline message. Each round, players have the option to adopt from the thirty-four simulated household actions. Six each indulge and food actions, four each water and wonder actions, and fourteen energy actions (figure 6).

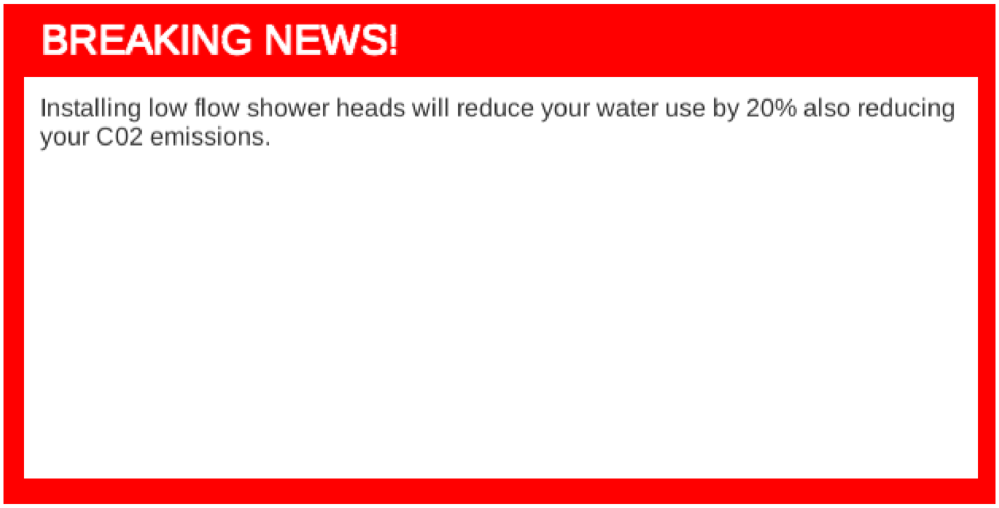

Figure 5 An example of IM for conservation of resources in HomeRUN

Players have the in-game currency gold to adopt the household actions; available gold is approximately equal to two-thirds of the average US household saving. Players have the option to adopt any of the simulated actions or do nothing. There are three types of actions players can take: (1) household actions related to individual FEW sectors, (2) wonder action (altruistic behaviors such as offsetting carbon emissions), and (3) indulge (actions that people usually do for pleasure such as taking a vacation and eating out). The first two types of action are done by spending gold, while the third requires gold and carbon reductions. The carbon reductions are earned by doing the first two types of actions, as shown in figure 7. All actions give players joy (positive psychological consequences of pro-environmental behavior (Hu et al. 2016)), and the player with the highest joy wins the game. The values for the technological and behavioral actions are taken from a tool developed by UC Berkeley, called cool California calculator (Calculator, 2017). The game data comprising players' actions is emailed to a dedicated email address as a text file.

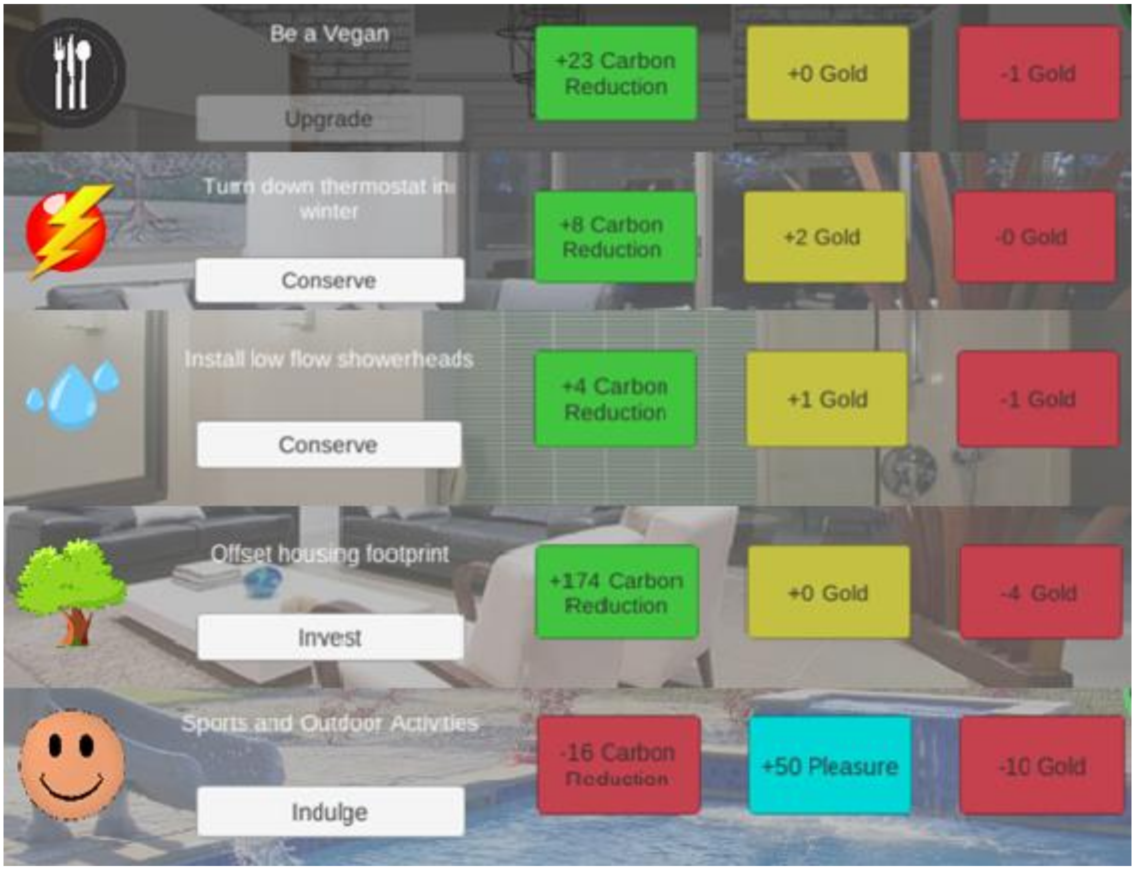

Figure 6 An example of Household actions in HomeRUN

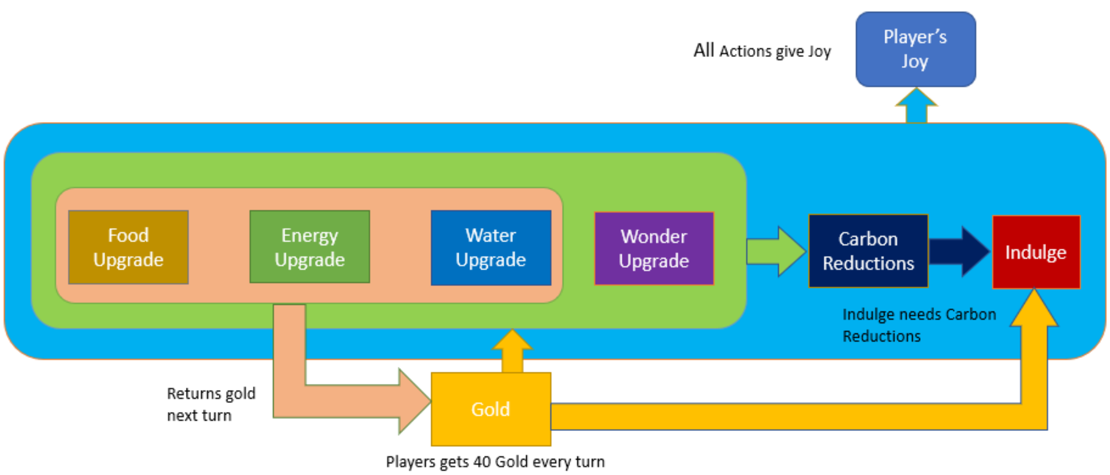

Figure 7 Conceptual Model of HomeRUN

3.6 Research design

An SG must be embedded in a carefully designed gameplay session for the study participants to utilize the potential fully. Figure 8 represents the flow diagram of the gameplay session of HomeRUN.

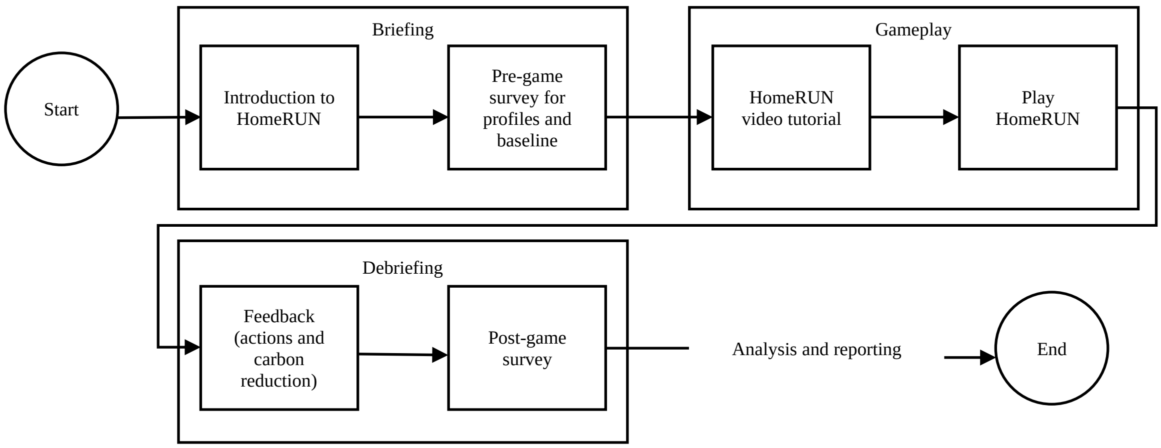

Figure 8 Gameplay session of HomeRUN

The study participants were emailed a document that briefly described the project and contained the information regarding different elements of the gameplay session (figure 8). Due to the novel coronavirus, all gameplay sessions were online, and the Institutional Review Board (IRB) of Arizona State University (ASU) approved the study before the data collection. All participants completed the gameplay session unsupervised and on their computers. The elements of the gameplay session were sequentially placed on a dedicated website. The first element of the study was to complete a pre-survey. The survey was designed using google forms, the data collected was stored in an Excel spreadsheet. The pre-survey took approximately 10 minutes to complete. Once the participant completed the pre-survey, they were asked to see a tutorial about HomeRUN.

The 7 min 37-second long video was hosted on YouTube and was embedded in the website.

Then the participant continued to play the RPG. HomeRUN is designed using Unity and was embedded on the same website using Unity WebGL. The playtime is 35 minutes approximately and consists of 10 rounds. The online version of HomeRUN was designed for a single player. At the start, the participant was asked to familiarize with the game for 1 minute. Before each round, a randomized IM (figure 4) was flashed for 20 seconds, followed by 90 seconds of gameplay per round. At the end of the round, the summary was shown in a bar chart for 1 minute. The carbon reductions of the players were reflected in the perspective of taking an equivalent number of cars off the road (figure 9). After the ten rounds, a summary of all actions was shown to the participants. The data collected from the HomeRUN gameplay session was emailed to dedicated Gmail and Outlook addresses. The data was in text form. A python code was written to convert it to a Microsoft Excel spreadsheet. After that, they were asked to complete a post-survey, which took approximately 7 minutes to complete. In total, the gameplay session took about 1 hour to complete. The data was analyzed using Microsoft Excel and Statistical Package for the Social Sciences (SPSS). The evaluation of the gameplay session was done using the quantitative data generated during the gameplay of HomeRUN and qualitative and quantitative survey data. The survey aimed to gather demographics, gaming attitude, baseline knowledge, game design, flow experience, and feedback from the participants regarding their gameplay experience. Contact the first author or corresponding author for the complete survey or to arrange its use.

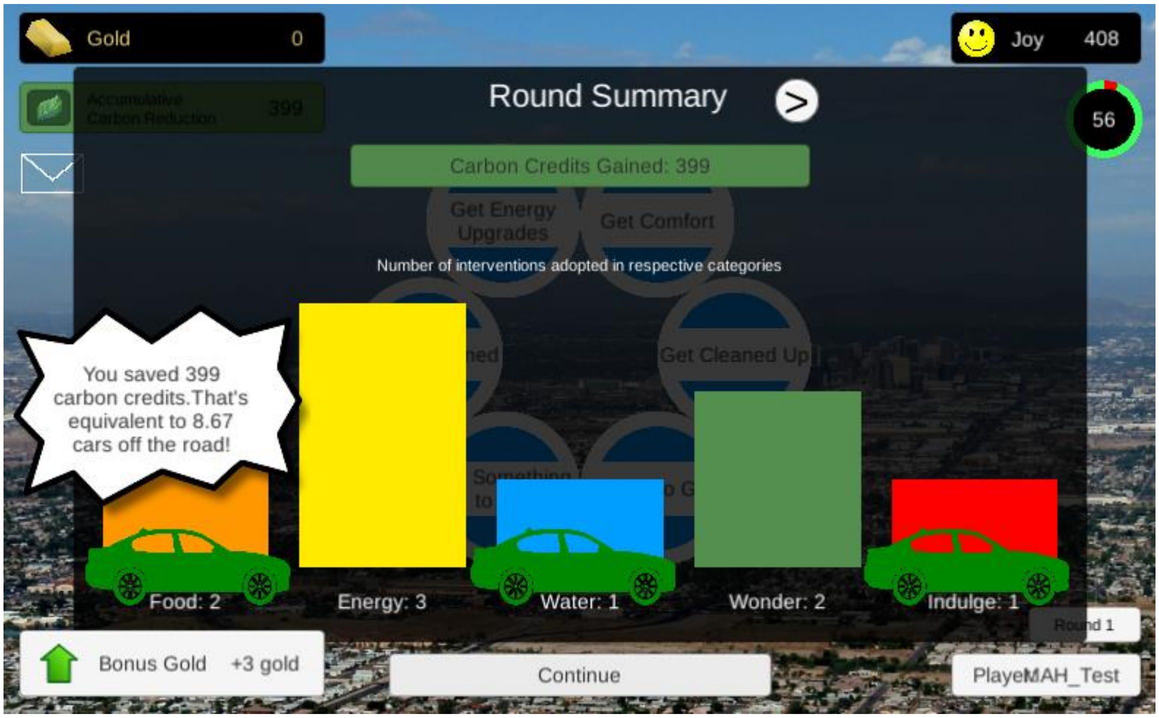

Figure 9 Feedback after each round

3.7 Results

Two hundred eighty-one college students participated in this study for extra credits. Half of the participants were males, and 48% were freshmen. Around one-third of the students were in natural sciences, followed by 23% in social sciences. The number of participants who completed the post-game survey was less than those who completed the pre-game survey. There were some multiple entries; only the first instances of the surveys were used for analysis.

There were several reasons for the less post-game survey response. Few gameplay sessions were not completed because of bugs in the gameplay of HomeRUN, and participants used inconsistent identifiers in both surveys. Furthermore, pre-game and post-game data were matched for each participant.

3.7.1 Participants' comments

There was a comments section to gather the descriptive experience of the participants in the post-game survey. Sixty-three participants replied to the post-game survey question "Remarks/ Comments/Suggestions about the complete RPG session." The responses were largely positive. Fifty-two percent of players used words like "fun," "interesting," "enjoyed," or "learned" in their comments on the game. Around 15% provided constructive feedback to improve graphics, interface, increasing actions, and tutorial.

3.7.2 Gaming attitude

The pre-game survey had three Likert-style (5-point) statements about participants' perceptions of navigation, work effects, and ability to learn games (Table 4). Around three fourth of participants agreed that they could teach themselves the things needed to know a game.

Table 4 Gaming attitude of the participants (Likert scale is 5 = Strongly agree to 1 = Strongly disagree)

Statements	Strongly agree	Agree	I don't know	Disagree	Strongly disagree
Given the opportunity to play a real-time strategy game, I am afraid that I might have trouble in navigating through it. (M= 2.7, S.D.=1.1)	4% [12]	21% [58]	24% [68]	38% [108]	12% [35]
Games help me relax and do my work better. (M=3.7, S.D.=1)	22% [62]	37% [104]	27% [77]	11% [31]	2% [7]
I could probably teach myself most of the things I need to know about games. (M= 3.9, S.D.=0.9)	24% [68]	49% [138]	17% [49]	8% [22]	1% [4]

3.7.3 Game design

The post-game survey focused on understanding the participants' perceptions about game design, impacts of FEW resource consumption, the educational value of HomeRUN, and flow experience. The results obtained from the post-game survey are presented below.

Table 5 Participants' perception about the game design (Likert scale is 5 = Strongly agree to 1 = Strongly disagree)

Statements	Strongly agree	Agree	I don't know	Disagree	Strongly disagree
The game is designed in an interesting and stimulating way. (M= 3.8, S.D.= 1)	21% [59]	55% [155]	8% [22]	12% [35]	4% [10]
I have a better understanding of GHG emissions because of Food Energy Water consumption after playing the RPG. (M= 3.9, S.D.=0.9)	24% [67]	58% [162]	9% [26]	7% [19]	2% [7]
The RPG provided me an insight into the complexity of Food Energy Water Nexus. (M=4, S.D.=0.9)	25% [71]	56% [158]	10% [28]	6% [17]	2% [7]
The feedback provided during the de-briefing session was useful. (M=3.8, S.D.= 0.9)	17% [48]	55% [154]	21% [59]	5% [14]	2% [6]
The use of RPG for education and training purposes is valuable. (M= 4.1, S.D.= 0.8)	33% [92]	54% [153]	8% [23]	3% [8]	2% [5]
I expect the insights gained through this RPG to help me in reducing GHG emission at my household in future. (M= 4, S.D.= 0.9)	27% [77]	54% [151]	10% [28]	6% [18]	2% [7]

The post-game survey had six Likert-style (5-point) statements about participants' perceptions of game design, resource consumption, the complexity of the actions, and SGs for education and training (Table 5). Three-quarters of the participants (76%) agreed that HomeRUN is designed in an interesting and stimulating way. Most participants

(82%) agreed that they have a better understanding of GHG emissions because of FEW consumptions after playing the RPG, and 79% at least agreed that the use of HomeRUN for education and training purposes is valuable.

3.7.4 Flow experience

Table 6 participants' perceptions about the flow experience (Likert scale is 5 = Strongly agree to 1 = Strongly disagree)

Statements (Flow element)	Strongly agree	Agree	I don't know	Disagree	Strongly disagree
I was challenged and I felt I could meet the challenge. (challenge–skill balance) (M= 3.6, S.D.= 1)	15% [42]	50% [141]	15% [42]	16% [46]	4% [10]
I did things naturally without thinking too much. (action–awareness merging) (M= 4, S.D.= 0.9)	26% [73]	56% [158]	8% [23]	9% [26]	0% [1]
I had a strong sense of what I wanted to do. (clear goals) (M= 4, S.D.= 0.9)	29% [82]	51% [143]	12% [34]	7% [19]	1% [3]
I felt I was on track towards my goals. (unambiguous feedback) (M= 4.1, S.D.= 0.8)	30% [84]	54% [152]	12% [35]	2% [7]	1% [3]
I was totally focused on what I was doing. (total concentration on task) (M= 3.9, S.D.= 1)	28% [78]	49% [139]	11% [32]	10% [28]	1% [4]
I felt I was in control of what I was doing. (sense of control) (M= 4.1, S.D.= 0.9)	31% [86]	50% [141]	10% [28]	8% [23]	1% [3]
It felt like nothing else mattered. (loss of self-consciousness) (M= 3.1, S.D.= 1)	10% [28]	22% [61]	38% [108]	25% [70]	5% [14]
I lost my normal sense of time. (transformation of time) (M= 2.9, S.D.= 1.1)	7% [19]	25% [71]	25% [71]	33% [92]	10% [28]
I really enjoyed what I was doing. (intrinsically rewarding experience) (M= 3.4, S.D.= 1)	13% [36]	41% [116]	27% [77]	14% [40]	4% [12]

The post-game survey had nine Likert-style (5-point) statements about participants' perceptions regarding the flow experience (table 6). Most participants (84%) agreed that they thought they were on track towards their goals, and 81% at least agreed that they felt they were in control of what they were doing. Around two-third (65%) at least agreed that they felt challenged by the gameplay of HomeRUN and could meet the challenge. Slightly more than half (54%) at least agreed to the statement that they enjoyed what they were doing.

3.8 Discussion

The open-ended feedback provided by the participant in the post-game survey was largely positive, describing the gameplay session of HomeRUN as fun and educational. Participants agree that gameplay was engaging, unique, and beneficial for learning purposes in general and specifically about conserving FEW resources at the Household level. Participants gained insights about the impacts of day-to-day actions on the environment from the simulated game household actions. They supported the use of HomeRUN for education and training. The interactive feature and feedback were welcomed. They provided constructive feedback, which is valuable for the development of new versions of HomeRUN. Few participants found rounds to be repetitive and suggested variation in household actions. Some participants recommended more time for each round and a practice round at the start of the game. Better interface, graphics, and collaborations with big gaming companies will increase the productivity of HomeRUN. Flow experience is reflected by participants' engagement in gameplay, a sense of gaining insight, a challenge of excelling in gameplay, and acknowledgment of the value of the game for education and training.

Gaming attitude (Table 4) was measured using three Likert-style items from Bonanno and Kommers (2008). The results indicate that most players can easily navigate games such as HomeRUN and teach themselves most of the things needed to excel in competitions. Furthermore, they agreed that games relax them and help them to perform better. Players achieve relaxation by realistically playing the games by immersing themselves in the virtual world (Pasch et al., 2009). The used scale needs multiple new items for future study as it has low internal consistency.

Game design (Table 5) was measured using six Likert-style items improvised from Kurapati et al. (2015). The results indicate that participants largely agree that the game design of HomeRUN is exciting and valuable for training and educational purposes. They are consistent with gaming literature; games compel fun (Chen and Michael, 2005) and reliable and effective research and education tools (Sudarmilah et al., 2018). Iten and Petko (2016) found a correlation between enjoyment and the motivation to continue being engaged with the game's subject matter. Participants primarily report a better understanding of GHG emissions from household FEW actions. They gained insight into the complexity of FEW nexus activities and how they will reduce GHG emissions at real-life homes in the future. SGs can be engaging, instructive (Garris et al. 2017), they provide a desirable learning experience (Bressler and Bodzin, 2013), and they stimulate interest in the subject matter while enhancing understanding and transfer knowledge capabilities (Chow et al., 2011). Johnson (2005) argues that the quality of the interactive gameplay is the most important feature of games that contributes to learning effectiveness. The results from game design coupled with participants' comments support the hypothesis that the participants of the gameplay session will consider HomeRUN as an effective and fun serious game to foster knowledge about the impacts of FEW nexus consumption at the household level.

The scale used to measure flow elements (Table 6) was outlined by Csikszentmihalyi (1990). All nine original items were used; however, Bressler and Bodzin's (2013) phrasing was used. The flow level experienced by the players was high (M = 3.66), and the experiences of elements are pretty consistent. Result supports the findings of studies done by (Kiili et al., 2014; Bressler and Bodzin, 2013; Csikszentmihalyi, 1990). Csikszentmihalyi (1990) reasoned that whenever people reflect on their flow experiences, they often mention all the nine flow elements. In general, high mean values of each element indicate that the gameplay of HomeRUN provides an appropriate environment for experiencing flow. The flow elements, unambiguous feedback, action–awareness merging, and clear goals scored the highest mean values. The flow element, the transformation of time, had the lowest mean value.

The statement for the flow element (unambiguous feedback) was that they felt they were on track towards their goals. The game design elements, steps of play, game rules, scenarios, and accounting are well connected with the role. The winning criterion of the gameplay of HomeRUN is to have the most joy, where joy is positively and significantly correlated to carbon reductions. The flow element (transformation of time) was that they lost their normal sense of time; it scored lowest, but the element (total concentration on task) was totally focused on what they were doing; had a high score. This comparison indicates that players were paying attention to the impacts of actions simulated in the game and the IMs being flashed at the start of each round. Two flow elements had a mean score of around three, but the overall score is still high. Csikszentmihalyi (1990) argued that people in flow temporarily tolerate a lack of stimulation if they believe stimulation will resume shortly.

HomeRUN is not comparable to most commercial games in terms of graphics, visual effects, and extended gameplay scenarios, yet it produced a high flow experience. The flow experience indicates that the subject matter resonates with the players, and they showed ownership of their achievements in HomeRUN. With repeated feedback during the gameplay, reducing GHG emissions at the household level is vital in achieving the flow experience. Therefore the results support the hypothesis that the participants will experience flow during the gameplay session of HomeRUN.

3.9 Conclusion

Conservation of FEW resources at the household level is vital for achieving a low carbon society goal. HomeRUN was designed from scratch to educate players about the impacts of household actions—the effectiveness increases by following a robust and rigorous design method. A comprehensive literature review of serious games connected to the game's subject matter provided valuable insights into the design process. HomeRUN was designed by first establishing the objectives and parameters, followed by selecting the genre, RPG. Csikszentmihalyi's (1990) theory of flow experience and Duke's (1980) twelve game design elements were core pillars of the game design. The game design was iterative, and HomeRUN was repeatedly tested with peers, developers, experts, and students. Each evaluation and testing resulted in more refined and robust gameplay. HomeRUN has the elements and capabilities to answer multiple research questions in a safe and controlled environment.

This paper presents the design of SG to facilitate the conservation of FEW resources at the household level. The results, coupled with participants' comments, reveal that the gameplay of HomeRUN was fun, engaging, facilitated learning, and provided insight into the impacts of household actions. The gameplay creates a high experience of flow for the participants of the study. A positive gaming attitude may be a predictor of flow experience. The clarity of rules and explicit goal of HomeRUN resulted in a high flow element unambiguous feedback score. HomeRUN is a model of reality, and specific aspects of reality have been left out or brought to a higher abstraction level to design a playable game.

The results of the gameplay sessions indicate that the participant of the study value the realism of HomeRUN as adequate with the game's goal. Future work may focus on the research related to the validity of games and add more household actions in HomeRUN after a thorough assessment of the relationship between games and reality. Studies may focus on gender as a predictor of flow experience and the relationship of flow experience with learning from the gameplay session. There should be a focus on gameplay sessions with actual households. These sessions could provide deeper insights into the effects of using a HomeRUN for fostering knowledge and as an intervention. A mobile version of the game may be developed for data collection with more significant segments of populations.

3.9.1 Limitations

The conclusion drawn from the results of this study needs to be considered by keeping in mind the limitations. First, the sample was obtained from university students; therefore, generalizing to other contexts should be made with extra care. Second, participants played without any social interaction during the game. Second, the sample's mean age may have an environmental bias. Age is inversely related to environmental concerns; in other words, younger people are more likely to engage in environmental behaviors (Wolters, 2014). The post-game survey was administered immediately after the gameplay session, and the participants were less than the pre-game survey.

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CHAPTER 4

CONSERVATION OF FOOD, ENERGY, AND WATER RESOURCES AT HOUSEHOLDS: EXPERIENTIAL LEARNING FROM THE GAMEPLAY SESSIONS OF A SERIOUS SIMULATION GAME

4.1 Introduction

Greenhouse gases (GHGs) keep a certain amount of heat in our planet's atmosphere; however, anthropogenic GHG emissions modify the planets' energy balance resulting in climate change (Pachauri et al., 2014). Household consumption is a considerable contributor to GHG emissions, responsible for over 20% of direct emissions and close to 80% when including indirect emissions: Food, housing, and mobility account for almost 75% of total household GHG emissions (Song et al., 2019). Population growth and rising economic prosperity are expected to increase demand for food, energy, and water (Bazilian et al., 2011) by 40%, 50%, and 35% respectively by 2030 (NIC, 2012). Households provide a unique prospect of achieving a low-carbon society by adopting a blend of technological actions and behavioral changes (Gram-Hanssen, 2013). Hence, they need knowledge about effective low-carbon choices to play a part in reducing household GHG emissions.

The next section of the paper discusses existing literature about learning from gameplay sessions of serious games (SGs) and presents the study hypothesis. Then, the gameplay session is briefly explained, followed by the process used to evaluate experiential learning from the gameplay sessions. In the end, results are reported, followed by a discussion about the findings in terms of experiential learning. Lastly, the study concludes by reflecting on the research question and lists future study areas.

4.2 Gameplay based learning

SGs are defined as games used for purposes other than mere entertainment (Susi et al., 2007) and incorporate the goals that include all aspects of education and at all ages (Michael and Chen, 2006). An SG is a mental contest played with a computer following particular entertainment rules to further government or corporate training, education, health, public policy, and strategic communication objectives (Zyda, 2005). The gameplay of SG is an appropriate activity in the context of learning about household actions as it simulates and creates realities with specific rules, roles, conditions, and assumptions (Dieleman and Huisingh, 2006). The gameplay session provides a platform for learning by doing without the negative consequences of household actions (Zhonggen, 2019). Furthermore, integrating knowledge-based information in a simulated gameplay session results in learning (Prensky, 2007). Thus the knowledge about the effectiveness of household actions can successfully be embedded in the gameplay session of an SGs.

The use of SGs to foster learning on environmental issues has been studied by several authors (Barreteau et al., 2007 (natural resource management issues); Eisenack and Reckien, 2013 (climate change); Fjællingsdal and Klöckner, 2019 (simulated ecosystems)). The gameplay session of an SG has the most significant potential of fostering learning over other methods (Prensky, 2001). Gameplay-based learning can be categorized into experiential and social learning. Experiential learning is a process whereby knowledge is created through experience transformation (Kolb, 1984). There are three types of learning outcomes linked with social learning: (a) cognitive - the acquisition of new or restructuring of existing knowledge – (b) normative - a shift in viewpoints, values, or paradigms – and (c) relational - an improved understanding of others' mind-sets and enhanced trust and ability to cooperate between stakeholders (Baird et al., 2014). Daré et al. (2014) catagerozies learning based on technical, behavioral, and organizational options to change the system, communication skills, beliefs, and values.

SGs have extensively been used as an alternative to traditional methods for fostering knowledge, awareness-raising, education, training, and research for sustainability-related issues (e.g., Carfì and Donato, 2018; Ahamer, 2006; DeVries, 1998; Mayer, 2009). The gameplay sessions of an SG create shared experiences, contribute to team building, provide experiential learning without the real world's consequences, support the possibility to create shared experiences, and allow play games with multicultural people (Dieleman and Huisingh, 2006). The gameplay sessions help test alternative solutions and generate positive mental energy for participants to engage in challenges (Frossard, 2013). Vogel et al. (2006) suggest that the application of SGs resulted in significantly higher cognitive gains and improved attitudes towards learning than traditional teaching techniques. The creation of immersive and engaging environments is a practical way in which participants can explore and learn.

Social learning from a gameplay session happens when a change in understanding—about the system, subject matter, agreement, and collective action—is achieved through interaction in collaborative and participatory settings (e.g., Reed et al.

2010; Muro and Jeffery, 2008; Den Haan and Van der Voort, 2018). Licorish et al. (2018) noticed the gameplay experience had the most substantial influence on classroom dynamics, engagement, motivation, and improved learning experience. In both actual and perceived aspects, the gameplay session is more effective in advancing knowledge than the traditional lecture-based method of teaching participants about climate change and the Arctic region ecosystems (Pfirman et al., 2020). The gameplay sessions of Nexus Game, an SG based on the Food, Energy, Water (FEW) nexus, provide qualitative evidence of cognitive learning focused on understanding the underlying social-ecological system and relational learning to promote collaboration between stakeholders (Mochizuki et al., 2021).

Role-playing games (RPGs), a genre of SG, have been used to educate environmental and sustainability issues (Stanitsas et al., 2019). An RPG about sustainability issues is designed with learning objectives about the system and its functioning and outcomes. The gameplay of such RPGs has embedded problem-solving knowledge, including negotiating with other stakeholders to resolve the problem (Voinov and Bousquet, 2010). RPGs favor the experiential learning cycle and are an effective process for long-term knowledge retention. The gameplay sessions of RPGs facilitate immersion, activate players' preconceptions even before the game starts, and promote deeper learning (Kikkawa, 2014).

The potential of SGs to foster gameplay-based learning is quite evident from the literature. Researchers focus on conceptualizing and quantifying gameplay-based learning about the subject matter of an SG designed to foster knowledge (e.g., Rodela et al. 2019; Ajloni and O'Toole, 2021; Vorderer and Ritterfeld, 2009). This attention on quantifying learning is essential to achieve the goals of SG. In a review, Ke (2016) examined 69 studies discussing gameplay-based learning, where half reported significant positive effects, and 18% reported no difference, and one study reported unfavorable results. Although the gameplay sessions of SG add to the knowledge of the participants; however, the challenge of quantifying learning still remains.

The research on gameplay-based learning has focused on gender as a factor influencing learning dissimilarities and results. Several studies have indicated that genders prefering different goals can affect the learning outcomes (Kapp, 2012; Kinzie and Joseph, 2008; Jakobsson, 2012). Men are focused on attaining achievements in games; thus, they prefer "performance" challenges. Women, in contrast, enjoy the learning relationship with peers in games, favoring the goals of self-pursuit. Yee (2006) maintained that the motivation from games is related to behaviors, and achievement is one of the critical elements of in-game motivation. The achievement goals in games trigger men's motivation to learn, thus exhibiting a more functional performance than women. However, Begy and Consalvo (2011) proposed a different view, where they pointed out that effective instructional design using digital games can also inspire learning motivation and performance in women. Hsu and Tsai (2013) further confirmed that digital games positively impact female learners to enhance their learning performance effectively with appropriate instructional guidance. It might imply that the learning performance and motivation from digital game-based learning can vary by gender, but adaptive instruction can provide positive advice.

Digital game-based learning focuses on learning and engagement, which affects the motivation and learning achievements of learners. Prensky (2007) pointed out that the ideal digital game-based learning involves high intensity and high engagement activities. Gender difference is further accentuated in these types of learning situations. Current studies on gender differences in digital game-based learning focus primarily on game types' preferences and comparison of learning methods. Few studies have analyzed the motivation and learning achievements concerning learning and engagement. Chung and Chang (2017) studied the impact of gender on motivation and learning achievements by looking at the relationship between engagement in digital games and learning. Studies on integrating digital games in subject learning have shown that this approach is particularly suitable for uninspiring difficult subjects because students generally lack the needed learning motivation for these subjects. The impact of gender on learning motivation and performance is investigated by probing into learners' engagement and learning in using this digital game. Results show that gender has no significant effect on learning achievement but causes substantial differences in learning motivation.

According to Riding and Grimley (1999), the performance of digital learning is differed by gender. One key reason lies in the different approaches adopted by men and women in receiving and process information. Riding and Grimley (1999) suggested that women tend to have a more complete understanding of information than men since women are willing to spend a long time processing new information and associate the newly received information with existing knowledge. On the other hand, men have a more shallow understanding of new information but can process more information than women. This gender difference in information processing is also reflected in the different attitudes towards digital game-based learning. Unlike women who prefer exploratory games, men prefer gameplay that involves strategy and direct instructions given by the system. In addition, women tend to adopt autonomous learning, while men see digital games as a medium for socializing and skills development. This skill explains why men are more engaged in digital game-based learning with a higher sense of participation and motivation.

There are significant cognitive learning differences between genders. Women tend to have a clearer understanding of the game content and objectives in the digital game-based learning process. Female learners perform better when they need to apply the knowledge learned to complete puzzles and quests. Meanwhile, digital games featuring a storyline and role-playing offer a guidepost for learning; male learners perform better in these types of games than their female counterparts. Wang and Wang (2008) found that male learners experience higher pleasure and satisfaction when playing Massively Multiplayer Online Role-Playing Games (MMORPGs), which highlight cooperative learning. This positive affectivity allows men to reach higher learning achievements from playing MMORPGs. Lowrie and Jorgensen (2011) showed that the level of cognitive perception differed by gender plays a role in the attitude towards digital game-based learning. Learning attitude is correlated to learning achievements.

This paper reports on using an SG named HomeRUN (Role-play for Understanding Nexus) to promote learning about the impacts of various actions on household GHG emissions. HomeRUN is designed to simulate household actions based on the data of an average American household (Agusdinata and Lukosch, 2019). The gameplay is focused on providing knowledge about household actions in terms of upfront cost, annual financial return, and an annual reduction in GHG emissions. This study is designed to address the following research question: How to quantify experiential learning from the gameplay sessions of HomeRUN? Multiple research studies (e.g., Von Haartman et al., 2017; Lukman et al., 2013; Zelezny et al., 2000; and Yuan and Zuo, 2013) showed that gender plays a role in attitudes towards sustainable development, where women tend to perform better than men do. Hence, we define the following three hypotheses:

> Hypothesis 1: The gameplay sessions of HomeRUN positively influences participants' perception of the impact of household actions.
>
> Hypothesis 2: The gameplay sessions of HomeRUN significantly foster experiential learning about the effectiveness of household actions.
>
> Hypothesis 3: Females learn significantly more than males from the gameplay sessions of HomRUN.

4.3 Methods

This study uses a multiple-choice questionnaire-based survey (pre-game and post-game) designed to quantify experiential learning from the gameplay session of HomeRUN. Den Haan and Van der Voort (2018) reviewed literature published from 2007 to 2018 that has reported learning using SGs. Eight out of nines studies used a similar design to evaluate learning.

US university students participated in this research for extra credit in their respective classes. An email was sent to the potential players briefly describing the project. This email contained information regarding different elements of the gameplay session, as shown in Figure 9. Due to the novel coronavirus pandemic, all gameplay sessions were online, and the Institutional Review Board (IRB) of Arizona State University (ASU) approved the protocol before the data collection. Participants completed the unsupervised gameplay sessions on their computers. The elements of the gameplay session were sequentially placed on a dedicated website. The first element of the gameplay session was to complete a pre-game survey. The survey was conducted via Google Forms, and the data collected was stored in a Microsoft Excel spreadsheet. The pre-game survey took approximately 10 minutes to complete.

Once the participants completed the pre-game survey, they were asked to watch a gameplay tutorial embedded in the website. The video (7:37 runtime) was hosted on YouTube. Then, the participants continued to play the RPG. The RPG is designed using Unity and was embedded on the same website using Unity WebGL. The RPG playtime is 35 minutes approximately and consists of 10 rounds. At the start of the RPG, the participants were provided 1 minute to familiarize themselves with the game elements. Before each round, a randomized intervention message (IM) was flashed for 20 seconds. Players were then given 90 seconds to perform household action during the round. At the end of the round, a bar chart summarizing the actions was flashed for 30 seconds. At the end of the play, a summary of all actions performed and subsequent carbon reductions achieved at the end of the play. Then, they completed a post-game survey, which took approximately 5 minutes. The HomeRUN gameplay session took about 1 hour to complete in total.

All participants completed the study unsupervised. The first entry was used for analysis in case of multiple responses to the survey by participants. Pre-game and post-game surveys were matched using email IDs, and the survey data of the participants who completed both pre-game and post-game surveys were used. The analysis was done using Microsoft Excel and Statistical Package for the Social Sciences (SPSS).

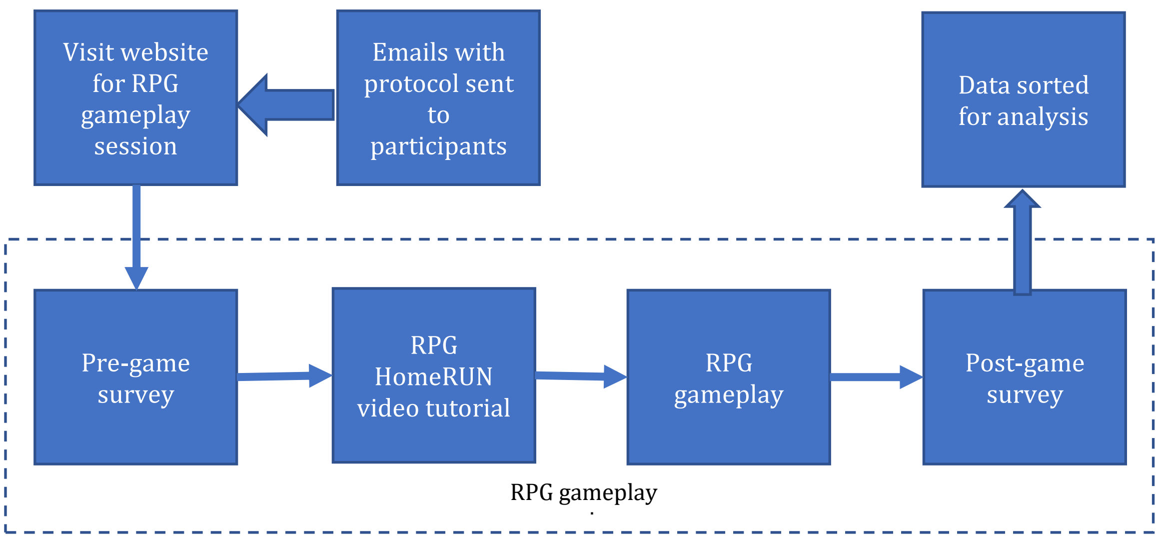

Figure 9 Flow diagram of the research protocol

4.4 Results

Figure 9 Flow diagram of the research protocol

In this section, the participants' demographics are provided, followed by the results of the survey questions. One hundred ninety-three US university students participated in this study for extra credits in their class. More than half (54%) of the participants were male. Around one-third (31%) of the students were in natural sciences, followed by 28% in engineering.

4.4.1 Game learning impacts

As depicted in Table 5, the post-game survey had Likert-style questions about participants' perceptions regarding the game design, resource consumption, complexity of the actions, and use of HomeRUN for education and training. Ninety-two percent of the participants at least agreed that HomeRUN is valuable for education and training purposes. Eighty-four percent of participants shared that they better understand the GHG emissions of the household actions simulated in the game, and they learned about the complexity of the FEW nexus. Eighty-one percent agreed that HomeRUN is an interesting and well-designed RPG.

Table 7 Participants' perception of learning from the gameplay session (Likert scale is 5 = Strongly agree to 1 = Strongly disagree)

	Strongly Agree	Agree	I Don't Know	Disagree	Strongly Disagree
The game is designed in an interesting and stimulating way.	23%	58%	4%	13%	2%
I have a better understanding of GHG emissions because of Food Energy Water consumption after playing the RPG.	25%	59%	8%	7%	1%
The RPG provided me an insight into the complexity of Food Energy Water Nexus.	26%	58%	9%	6%	1%
The use of RPG for education and training purposes is valuable.	32%	60%	5%	2%	1%

4.4.2 Participants' comments

Participants provided feedback (remarks/comments/suggestions about the complete RPG gameplay session) in the last question of the post-game survey. Some of the participants' written comments about learning are listed:

> "I had a nice game where I learned more things on how to save and conserve the environment. Thank you very much for the game."
>
> "I thought it was an interesting game to teach about how our everyday actions can affect our overall impact on the environment. I will take the information I learned into consideration when I am making my everyday decisions."
>
> "Thank you for this opportunity, I can learn more about RPG research, and it made me enjoy when I did this game."
>
> "Very interesting and educational"

The comments show that the participants could grasp the household interventions from the RPG gameplay session. Some participants provided critique too.

> "Very repetitive, otherwise very informative."
>
> "Collaborate with huge game companies and up the graphics. It would make it more interesting and engaging. Other than that, the game was informative."
>
> "I feel like the game is too fast-paced for a person to truly analyze if one were to play for a maximized "build." Over time I can see and recognize which actions are better for the game's future; however, I solely clicked the options without really giving much attention to it. Perhaps having a more extended time control in each round might be helpful.

With that being said, this game is good and can teach many people around the world about conserving our resources and maintaining a sustainable world. Given enough polish, I think this could be one of the better games that teach on sustainability."

4.4.3 Survey responses

A questionnaire-based survey was designed about the factual knowledge embedded in the RPG gameplay. The multiple-choice questions measure participants' knowledge about the upfront financial cost, financial return on investment, and carbon reductions of household actions. The survey was administered in pre-game and post-game design to participants of HomeRUN. Table 6, Table 7, and Table 8 present results related to learning and responses from 193 participants. A paired-samples t-test was conducted for all questions, and the Marginal Homogeneity Test was conducted to find statistical significance of group (female and male) responses.

Table 8 Food, energy, water, and indulge actions pre- and post-gameplay survey results

Question	Pre-game survey			Post-game survey			Paired samples t-test		Change in correct Answer, [%]	Marginal Homogeneity Test
	Mean	Standard Deviation	Correct Answer, [%]	Mean	Standard Deviation	Correct Answer, [%]	Correlation	P-Value		P-value
1. From the following options, which Food action reduces the most CO_2 equivalent per year?										
All	1.92	1.15	42	2.24	.91	47	**.305**	**.000**	**12**	
Female	2.13	1.10	52	2.42	.78	55	.189	**.034**	**6**	**.000**
Male	1.74	1.19	34	2.11	.96	40	**.337**	**.003**	**18**	
2. From the following options, which Energy action reduces the most CO_2 equivalent per year?										
All	1.79	1.29	46	2.20	1.09	55	**.248**	**.000**	**20**	
Female	1.96	1.24	52	2.18	1.12	55	.198	.191	6	**.000**
Male	1.65	1.33	43	2.21	1.07	54	**.329**	**.000**	**26**	
3. From the following options, which Water action reduces the most CO_2 equivalent per year?										

All	1.58	1.06	19	2.15	1.05	50	.102	**.000**	**163**		
Female	1.66	1.04	21	2.16	1.05	52	-.051	**.004**	**148**	**.000**	
Male	1.50	1.07	16	2.15	1.03	49	.149	**.000**	**206**		
4. From the following options, which Indulge action consumes the most CO_2 equivalent?											
All	2.37	1.03	67	2.50	1.02	77	**.170**	.192	15		
Female	2.37	1.01	65	2.46	1.03	74	**.233**	.544	14	.166	
Male	2.36	1.06	69	2.53	1.01	80	.142	.198	16		
5. From the following options, which Food action gives the most financial saving?											
All	2.11	1.06	47	1.82	1.11	33	**.272**	**.003**	**-30**		
Female	**2.04**	1.17	49	2.00	1.04	39	**.381**	.790	-20	**.003**	
Male	**2.16**	.96	44	1.68	1.16	29	**.221**	**.000**	**-34**		
6. From the following options, which Energy action gives the most financial saving?											
All	1.73	1.21	38	1.89	1.15	39	.132	.166	3		
Female	1.72	1.17	35	1.98	1.13	45	.087	.141	29	.195	
Male	1.74	1.23	41	1.81	1.16	35	.120	.668	-15		
7. From the following options, which Water action gives the most financial saving?											
All	1.66	1.17	31	1.98	1.16	47	**.165**	**.003**	**52**		
Female	1.55	1.16	25	2.00	1.17	49	.054	**.013**	**96**	**.004**	
Male	1.76	1.19	37	2.00	1.17	48	**.228**	.099	30		
8. From the following options, which Indulge action costs the most?											
All	2.36	1.18	76	2.53	.96	77	**.284**	.067	1		
Female	2.18	1.30	70	2.51	.98	76	**.224**	**.043**	**9**	.06	
Male	2.52	1.03	81	2.58	.90	79	**.344**	.598	-2		

Significant values are shown in bold. Least=1, intermediate= 2, most=3 I don't know=0.

Table 8 covers the results of eight questions based on the food, energy, water, and indulge actions available in HomeRUN. Each question's response could be one of the three household actions or "I don't know." Questions 1 and 5 are about interventions related to food. There was a slight improvement in the correct answers for Question 1 (42% to 47%) and a considerable decrease in Question 5 (47% to 33%). The 12% and -30% change in correct responses, respectively, is statistically significant (paired samples t-test, $p<0.004$). Questions 2 and 6 are about interventions related to energy. There was a considerable improvement in Question 2 (46% to 55%) and a slight increase in Question 6 (38% to 39%). The 20% improvement in Question 2 is statistically significant (paired samples t-test, $p<0.0001$). Questions 3 and 7 are about interventions related to water. There was considerable improvement in correct answers for Questions 3 (19% to 50%) and 7 (31% to 47%). The 163% and 52% improvement, respectively, is statistically significant (paired samples t-test, $p<0.004$). Question 4 and 8 are about indulge actions that add carbon emissions.

The first three questions ask about the actions which will reduce the most CO_2 equivalent per year. There is a positive percentage increase in the correct responses for both males and females. However, the increase is more for males (18%, 26%, and 206%) than females (6%, 6%, and 148%). The improvement is statistically significant for both males and females in Questions 1 and 3 and only for males in Question 2 (paired samples t-test, $p<0.04$). Questions 5, 6, and 7 ask about the intervention which will provide the most financial saving. The percentage of correct answers decreased in Question 5 and increased in Question 7 for both male and female participants. Whereas in Question 6, the percentage increased for females and decreased for males. The 34% decrease for males in Question 5, and 96% increase for females in Question 7 is statistically significant (paired samples t-test, $p<0.04$). Only the pre-game survey responses of Question 5 are statistically significant (independent samples t-test, $p<0.04$).

Table 9 Household actions pre- and post-gameplay survey results

Question	Pre-survey			Post-Survey			Paired samples t-test		Change in correct Answer, [%]	Marginal Homogeneity Test
	Mean	Standard Deviation	Correct Answer, [%]	Mean	Standard Deviation	Correct Answer, [%]	Correlation	P-Value		P-value
1. Which action from the dropdown menu below, you think would reduce THE MOST greenhouse gas emissions for the average American household?										

All	4.04	1.56	28	3.83	1.50	21	**.271**	.111	-25		
Female	**4.29**	1.40	31	3.88	1.44	21	-.007	.068	-32	.126	
Male	**3.84**	1.64	25	3.79	1.56	22	**.431**	.775	-12		
2. Which action from the dropdown menu below, you think would reduce THE 2nd MOST greenhouse gas emissions for the average American household?											
All	3.79	1.84	6	4.39	1.65	6	.036	**.001**	**0**		
Female	3.76	1.83	2	4.53	1.58	1	-.061	**.006**	**-50**	**.001**	
Male	3.84	1.88	9	4.32	1.68	11	.087	**.041**	**22**		
3. Which action from the dropdown menu below, you think would reduce THE 3rd MOST greenhouse gas emissions for the average American household?											
All	3.49	1.78	17	3.45	1.80	9	**.145**	.829	-47		
Female	3.40	1.91	7	3.47	1.76	5	.137	.785	-29	.901	
Male	3.50	1.68	23	3.40	1.83	11	.145	.672	-52		
4. Which of the following actions to reduce your greenhouse gases has the lowest cost per year?											
All	2.42	1.17	12	2.35	1.20	19	**.234**	.523	58		
Female	2.34	1.04	7	2.19	1.06	18	.205	.324	157	.424	
Male	2.49	1.27	16	2.45	1.26	19	**.240**	.803	19		
5. Which of the following actions to reduce your greenhouse gases is the MOST COST-EFFECTIVE (gives the most bang for your bucks?)											
All	3.37	1.40	16	3.21	1.42	20	**.416**	.133	25		
Female	3.45	1.37	15	3.23	1.49	23	**.610**	.123	53	.109	
Male	3.30	1.42	17	3.16	1.37	19	**.291**	.380	12		

Significant values are shown in bold. Questions 1 to 3: Least GHG emissions reduction=1, Most GHG emissions reduction=6; Question 4: Lowest cost=1 highest cost=5; Question 5: Least cost effective=1, Most cost effective=5

Table 9 covers the results of five questions based on the household interventions with mixed options from food, energy, and water interventions available in the RPG HomeRUN. Question 1 to 3 asks about the top-3 interventions from a list of six interventions from the RPG. There was no change in correct responses to Question 2, and it is statistically significant (paired samples t-test, $p<0.002$). Question 4 was about the lowest upfront cost of the household intervention, and Question 5 was the most cost-effective (in terms of return on investment) household intervention. There was 58% and 25% improvement in Questions 4 and 5, respectively.

Table 10 Intervention messages pre- and post-gameplay survey results

Statements	Pre-survey			Post-Survey			Paired samples t-test		Change in correct Answer, [%]	Marginal Homogeneity Test
	Mean	Standard Deviation	Correct Answer, [%]	Mean	Standard Deviation	Correct Answer, [%]	Correlation	P-Value		P-value
1. The average American household annually spends $10,776 on food.										
All	1.69	1.01	14	2.26	1.34	31	**.294**	**.000**	**121**	
Female	1.77	1.06	16	**2.57**	1.39	42	**.279**	**.000**	**163**	**.000**
Male	1.63	.96	11	**2.07**	1.27	23	**.310**	**.001**	**109**	
2. The average American household consumes 32,850 Kilowatt hours of electricity.										
All	1.57	.79	6	2.20	1.11	13	**.225**	**.000**	**117**	
Female	1.64	.86	8	2.28	1.07	13	.136	**.000**	**63**	**.000**
Male	1.52	.74	5	2.18	1.14	13	**.287**	**.000**	**160**	
3. The average American household consumes 6,600 Gallons of water per year.										
All	1.73	1.07	16	1.93	1.16	14	.035	.078	-13	
Female	1.89	1.19	22	1.94	1.12	11	-.005	.789	-50	**.049**
Male	1.58	.94	11	1.94	1.20	16	.090	**.012**	**45**	
4. If all households continue to consume the average levels of food, energy, and water, children that are currently 5 years old will live on Earth with a different climate.										
All	1.30	.70	80	1.72	.99	63	**.187**	**.000**	**-21**	
Female	1.24	.96	86	1.80	1.01	58	.150	**.000**	**-33**	**.000**
Male	1.33	.72	76	1.98	.99	65	**.236**	**.001**	**-14**	
5. If all households continue to use the average amount of food, energy, and water, the average American can expect to experience 2 days in a typical year in 2100 when the heat and humidity are so high that it will be unsafe to remain outdoors.										
All	1.35	.74	76	1.29	.70	83	-.015	.439	9	
Female	1.28	.70	82	**1.43**	.83	76	-.062	.206	-7	.480
Male	1.19	.77	71	**1.19**	.57	87	.061	**.018**	**23**	

Significant values are shown in bold. TRUE=1, I don't know=2, This message didn't appear on my screen=3, FALSE=4

The percentage of correct answers decreased in Questions 1 (25%) and 3 (47%). The percentage of correct answers increased in Question 2 for males (22%) and decreased for females (-50%) is statistically significant (paired samples t-test, $p<0.05$). The positive increase is considerably more in the females (157% and 53%) than males (19% and 12%) in Questions 4 and 5. Only the pre-game survey responses of Question 1 are statistically significant (independent samples t-test, $p<0.05$).

Statements 1 to 5 are based on the ten intervention messages that were flashed before the start of each round. Each statement, as shown in Table 10, had the following four responses, "True," "I don't know," "This message didn't appear on my screen," and "FALSE." Statements 1 to 3 are false, and the correct information was present in a single intervention message: "The average American household annually spends $1,351 on their electricity, $1,050 on their water bill, and $6,600 on food," which was displayed randomly before the start of a round for 20 seconds during the gameplay of HomeRUN. Performance on Statements 1 and 2 increased by 121% and 117%, respectively, and decreased by 13% on Statement 3. The improvement is statistically significant for Statements 1 and 2 (paired samples t-test, $p<0.0001$). Statements 4 and 5 were correct and were displayed as two separate intervention messages during RPG gameplay. The performance on Statement 4 decreased by 21%, and it increased by 9% on Statement 5. The performance is statistically significant for Statement 4 (paired samples t-test, $p<0.0001$).

The improvement for both males (109% and 160%) and females (163% and 63%) in Statements 1 and 2 are statistically significant (paired samples t-test, $p<0.0001$). The percentage of correct answers increased in Statements 3 and 5 for males (45% and 23%) and decreased for females (-50% and -7%). The improvement in male participants' responses is statistically significant (paired samples t-test, $p<0.02$). The percentage of correct answers decreased in Statement 4 for both males (-14%) and females (-33%). The decrease in male and female participants' responses is statistically significant (paired samples t-test, $p<0.002$). The post-game survey responses of Statements 1 and 5 are statistically significant (independent samples t-test, $p<0.05$).

4.5 Discussion

The experiential learning from the gameplay session of RPG was evaluated based on the participants' comments from the post-game survey and the comparisons of the percentage of correct answers from the pre-game and post-game survey. The participants overwhelmingly agreed (Table 7) that HomeRUN is an interesting and well-designed RPG, valuable for education and training purposes. They learned about the complexity of food, energy, water nexus. Furthermore, the gameplay session provided a better understanding of the GHG emissions of the household actions. The participants' comments acknowledge education and learning from the RPG gameplay session and the potential of RPG to be used as a tool to foster knowledge. They found HomeRUN exciting and fun to play. However, a few mentioned the game's repetitive nature, and there were a couple of suggestions to improve the graphics and feedback provided after the rounds. The results from Table 7, coupled with participants' feedback, support the first hypothesis that the gameplay sessions of HomeRUN positively influences participants' perception of the impact of household actions.

Tables 8, 9, and 10 show an increase in the percentage of correct answers in two-thirds (12/18) of the survey questions; furthermore, six out of twelve responses are statistically significant. The rate of correct answers decreased in five questions, and two out of five replies are statistically significant. The question (Table 3, question 2) where the percentage of the correct answers stayed the same is also statistically significant.

Hence, the results discussed above partially support the second hypothesis that the gameplay sessions of HomeRUN significantly foster experiential learning about the effectiveness of household actions.

The gender-wise results show that the rate of correct answers increased in twelve questions for males. The increase in eight of these questions is statistically significant. The rate of correct answers increased in eleven questions for females, and six of these are statistically significant. Males have improved more in questions about food, energy, and water consumption, and CO_2 reduction. In comparison, females have improved more in questions about financial savings. The questions, where males improve more than females, have a higher percentage of correct answers by females in the pre-game survey and vice versa. The Marginal Homogeneity Test was used to determine the statistical significance of pre-game and post-game answers by males and females. The results indicate that ten out of eighteen responses are statistically significant. Eight out of ten statistically significant responses show an increase in learning, and six show a positive rate of correct answers for males and two for females. However, there is not enough statistically significant difference in the performance of males and females to support or reject the third hypothesis that females learn significantly more than males from the gameplay sessions of HomRUN. It can be stated that the RPG gameplay sessions resulted in acquiring experiential knowledge about household action to conserve FEW nexus resources.

The context of HomeRUN is to provide a simulation of the financial and environmental impacts of household interventions. The target group includes household members of different backgrounds (i.e., policymakers, public administration, the general public, students, etc.) who may learn the effectiveness of the intervention implementation and advocate for the facilitation and implementation interventions in the future. HomeRUN can be used as an educational tool for any group of students who want to experiment with the use of household interventions and their impacts.

4.5.1 Concluding remarks

SGs are an efficient tool to promote knowledge with contextual and paradigm changes. They help players become increasingly efficient in achieving the goals/objective of the game. Experiential learning provides numerous opportunities for SG developers to obtain valuable insights into learning processes. This study reports experiential learning from the gameplay sessions of HomeRUN.

The experiential learning results from the gameplay session of the HomeRUN based on gender reveal that on all the questions where costs were involved, female participants had a better increase in the percentage of correct responses. In contrast, male participants performed better in the questions about GHG/CO_2 reduction and food, energy, and water resources consumption. Multiple studies report males learning more from games (e.g., Stege et al., 2011; Liu et al., 2013). However, Riemer and Schrader (2015) argue that female students reported a more positive attitude and higher perceptions of positive affective quality. It cannot be significantly stated that one gender demonstrated better than the other; however, male participants have performed slightly better.

Overall, the survey responses and participants' comments provide confidence that the RPG HomeRUN is an effective medium for experiential learning with diverse audiences. A few limitations of the study are essential while interpreting the results. First, post-game response rates are slightly lower than in the pre-game. However, only the responses of those participants were used for analysis who have completed both surveys, raising the possibility of selection bias. Second, although the participants in these evaluations were diverse, evaluations with the real household are needed. Third, although the pre-game and post-game comparisons show improved experiential learning, research should explore whether participants also improve their general understanding of synergies of food-energy-water nexus, complex systems, financial return, and GHG emissions reduction on adopting interventions and whether they can apply the understanding to problems other than the household GHG emission reductions. Finally, longitudinal follow-up studies should explore whether the experiential and cognitive learning impacts of HomeRUN endure, including whether participants changed their carbon footprints and behavior.

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CHAPTER 5

EFFECTIVENESS OF CONSERVATION MESSAGES TO REDUCE HOUSEHOLDS' GHG EMISSIONS: A SERIOUS-GAMING EXPERIMENT

5.1 Introduction

Household consumption is a significant contributor to greenhouse gas (GHG) emissions. It has been estimated to account for over 80% of total US direct and indirect emissions (Bin and Dowlatabadi, 2005). A typical US household has annual GHG emissions of 48 metric tons CO2e (Jones and Kammen, 2011). Food systems contribute between 19 to 29% of the total anthropogenic greenhouse gases (Vermeulen et al., 2012). Nearly 5% of total GHG emissions in the US come from the water sector (Griffiths-Sattenspiel and Wilson, 2009). Food, housing, and mobility account for almost 75% of total household GHG emissions, where about 82.3% of those emissions are produced domestically (Song et al., 2019). These facts highlight the opportunity for household actions to reduce GHG emissions by decreasing FEW resource consumption (Wilkinson, 2009). Achieving a net-zero global GHG emissions goal requires approximately 85% emissions reductions across all sectors over the next three decades (Rockström et al., 2017). Achieving this goal will likely require changes from high-emitting households in how they consume food, energy, and water (FEW) resources. For households, there are various options across heating, transport, food, and housing for behavior change that could decrease GHG emissions (Zajicek-Farber et al., 2012).

Behavioral change and technological upgrades have been recognized as central to any effective response to climate change mitigation to achieve net-zero GHG emissions (Allen et al., 2020; Carmichael, 2019). Potential for near-term reductions can be achieved through behavioral changes without needing new regulatory measures by altering adoption and using available technologies in US homes (Dietz et al., 2009). The change in energy use behavior and adoption of energy-efficient equipment is considered a successful policy (NRC, 2011). However, a transition to low-carbon and more efficient technologies critical for reducing GHG emissions cannot be accomplished without accounting for human behavior (Gram-Hanssen, 2013). Engaging and supporting the public in making behavioral changes require researchers, policymakers, and institutions to understand the types of interventions that effectively guide individuals towards low-carbon choices. There has been relatively little consideration of how this outcome might be achieved (Moore, 2012). Practical behavioral approaches need to impact the long-term changing habits and values and holistic involvement of individuals, systems, and social practices across all levels of society. People need to be engaged, informed, be willing to participate, and change their behavior for climate-change mitigation to take place (Moore, 2012).

5.2 Literature review

5.2.1 Intervention messages

A purposeful action by an agent to create change is called intervention (Midgley, 2000). An intervention is a precise set of events devised to put into practice action of known dimensions (Fixsen et al., 2005). The most effective interventions combine several policy tools to address multiple barriers to behavior change, use social marketing, use community-based approaches, and address multiple targets (Dietz et al., 2009). Intervention messages (IMs) have been used in many studies to initiate behavioral change. They have shown to be effective to change behaviors such as smoking, lack of exercise, or alcohol misuse (Miller et al., 1988; Fjeldsoe et al., 2009), to support climate mitigation policy (Klas et al., 2021), and to increase acceptance of climate change policy (Bertolotti and Catellani, 2014).

The messages about climate change are intended mainly to promote predefined behavior change in the recipient (e.g., messages that aim to reduce dairy and meat consumption) (Amelung and Funke, 2015). Formulating a compelling intervention message should be based on the evidence about how the recipients will take it. Text-based messages provide definitive and factual statements that can be agreed upon; however, providing facts in a message may not be sufficient and even ineffective if the target audience does not get the essence (Reyna, 2008). Understanding the values, norms, fears, and hopes of the target audience is essential for understanding a message. Messages focusing on providing information that will help audience members pursue personal and societal action may prove effective (Maibach et al., 2008). An IM can be considered effective within targeted populations and settings only if it is evaluated as having produced the anticipated results (Fixsen et al., 2005). In addition, an IM can only lead to behavior change if it is measurable (Bird, 2008).

The effects of different groups of IMs on shaping behavior to reduce GHG emissions have been examined by many studies (e.g., social comparison water messages by Brent et al., 2020; social comparison energy and water messages by Taylor et al., 2018; reduction food messages by Laestadius et al., 2016; ecological intervention messages by Shove, 2004). Anderson et al. (2017) found a positive effect on the durability of energy behavior change when normative feedback messages were continued over time. It found that messages displayed in the home about the electricity use and feedback resulted in significant savings over an 11-month intervention. Allcott (2011) studied the effectiveness of social comparison messages in over 600,000 US residences and concluded that the energy usage reduced by 2.0% to 6.3% when neighbors households' energy consumption was provided. A study of 810 Californians also shows that normative social influence caused the most significant change in residential energy behavior, even though the same respondents rated normative information as the least motivating (Nolan et al., 2008). Behavioral interventions are effective in decreasing energy use (Attari et al., 2010) people have greater willingness to save energy to mitigate climate change (Spence et al., 2011).

Tailored messages that induce dietary, behavioral change produce more positive results than a general message (Brinberg et al., 2000). A study by Whitehair et al. (2013) indicates that posted messages aimed at increasing awareness of food waste trigger a significant decrease in waste behaviors. A message resonating with the target audience's beliefs triggers a positive behavior. The framing and content of conservation messages encourage behavioral changes in sustainable water conservation (Addo et al., 2019). Households receiving information about water scarcity and specific water-saving strategies (e.g., low flow showers) are more likely to conserve water (Seyranian et al., 2015). However, a better understanding of the psychological drivers behind water consumption is still needed to efficiently frame conservation messages (Corral-Verdugo et al., 2003; Addo et al., 2019).

In a meta-review, Nisa et al. (2019) examined which interventions effectively promote climate change mitigation by individuals and households. They found that strategies of social comparison are among the most effective. A study of implications of social comparison messages in residential water and electricity use concludes that satiation is the critical determinant of the effectiveness (Taylor et al., 2018). Feedback messages based on real-time energy use data and user-friendly displays installed in various college dormitories on the Oberlin College campus coupled with an energy use competition resulted in an energy use reduction of 56% over two weeks (Petersen et al., 2007). Asensio and Delmas (2015) found that environmental and health-related messages affect household electricity consumption. It is, however, worth mentioning that the lasting effects of the messages are meager (Nisa et al., 2019).

5.2.2 Serious-gaming approach

The notion of serious games (SGs) implies applications in which games are used for purposes other than mere entertainment (Susi et al., 2007). The suitability and potential of the serious gaming approach as a method of experiment rest on the fact that games are an integral part of all known human cultures involving competitive exercises. The objective of games is to win by following a set of rules (Huizinga, 1955). The goal of an SG includes teaching, training, and informing for all users (Michael and Chen, 2006). The gameplay approach can be applied to a broad range of application areas such as public policy, defense, corporate management, sustainable development, healthcare, urban landscaping, training, and education (Zyda, 2005).

Game-based learning in simulated SGs is considered to create the most significant potential for learning over other media (Gee, 2004; Prensky, 2001; Squire, 2008). The creation of immersive and engaging environments is a practical way in which players can explore and learn. Current technologies in the development of SGs allow players to experiment with realistic simulations using animations, graphics, and an interactive environment that effectively explains course content and develops players' skills (Deshpande and Huang, 2011). The gameplay of SGs engages the user in a pedagogical journey and positively impacts the players' analytical skills, strategic skills, comprehension, understanding, recollection capabilities, and increased social skills such as collaboration, negotiation, and shared decision-making (Mitchell and Savill-Smith, 2004).

What is unique about SGs is that they allow players to experience impossible situations in the real world for reasons of safety, cost, and time (Corti, 2006). They are designed and tailored to explore the underlying problem or address specific issues and are explored as a method to establish social learning on sustainable natural resources management and urban planning (Furber et al., 2018; Medema et al., 2016). SGs can be designed as an intervention study by constructing opportunities for reflection about the game's subject matter (Rodela et al., 2019). They fit well with the learning-by-doing approach by offering stakeholders a place to negotiate, deliberate, exchange perspectives used in decision-making, and learn about the trade-offs between decisions in the safe experimentation environment of a game (Mayer, 2009). SGs, used as intervention study tools, can trigger learning about the subject matter and change behavioral practices (Flood et al., 2018).

SGs have become increasingly popular as an educational tool in schools, as a training device for professionals, and as a means which may add entertainment to teaching and training, making the learning experience more fun and motivating. Gaming is particularly popular with teenagers (Rideout et al., 2010), and they have a growing influence on family consumption choices (Ritch and Brownlie, 2016). Many SGs include opportunities for socialization (Levine and Vaala, 2013; Squire, 2008; Van Eck, 2006), typically using teams or as role players addressing different issues. Participants of collaborative games communicate with their peers as they navigate the game, hence, developing players' social skills (Kirriemuir and McFarlane, 2004). Studies confirm that simulation games help players increase their awareness of real-world issues and comprehend course subjects (Hirose et al., 2004; Philpot et al., 2005). Simulated SGs are progressing because of growing interest in their application in various areas such as in education and training and consultation, counseling, and shaping behaviors (Peters and Van de Westelaken, 2014).

SGs can be designed to simulate real-world scenarios to understand a specific problem and its solution better. Purposefully designed SGs with specific goals are established methods for education and research (Czauderna and Guardiola, 2019). A well-thought-out game design serves as the tool to answer different research questions

(Mcmahon, 2009). Rodela et al. (2019) point that SGs, when used as interventions to foster change, need to provide robust evidence of the effectiveness.

The current research using IMs for resource conservation is either about the effectiveness of a single group of messages or is about the single consumption sector. Theories of environmental decision-making by individuals and households are emerging, but they are primarily in the energy area. However, simultaneous consideration of FEW resources consumptions is still lacking. The comparison between the effectiveness of different IM groups in a single experiment has not been adequately researched. The literature encourages that SG with an appropriately designed gameplay is suited for studying the effectiveness of IMs to facilitate a reduction in household GHG emissions. Therefore, this research is utilizing an SG named HomeRUN (Role-playing for Understanding Nexus). HomeRUN simulates an average US household and introduces behavioral and technological household actions that facilitate households to reduce GHG emissions. As an experimental method for improving an understanding of practical environmental sustainability challenges, a serious game-based approach is appropriate because it offers opportunities to obtain first-hand experiences that may be otherwise too costly, difficult, or dangerous to do in real-world scenarios (Squire, 2002; Corti, 2006; Madani et al., 2017). By analyzing the actions taken by players responding to different types of conservation in the gameplay, this study aims to better understand the role of intervention messages to reduce GHG emissions in households.

The literature shows that there is a gap about comparing multiple intervention messages within a single experiment and SGs provide an efficient tool to study this gap. This study seeks to answer the following two questions:

1. How effective are intervention messages for conservation in a simulated SG environment designed to facilitate a reduction in GHG emissions at a household level?

2. Which group of intervention messages for conservation are the most effective?

The primary hypothesis is that the players, being exposed to messages in gameplay, will attempt to reduce their GHG emissions by taking actions provided to them, mimicking the actions they will take in the real world. In addition, it is hypothesized that the first action taken by the players in a round will be directly related to the intervention message received. Hence, we define the following two hypotheses:

Hypothesis 1: Players exposed to social comparison messages will engage in gameplay, resulting in a statistically significant reduction of GHG emissions.

Hypothesis 2: The intervention messages directly and significantly influence the first action taken by the players in the gameplay.

The remainder of the paper is structured as follows. Section 3 describes the SG design and gameplay session. In Section 4, we present the results of gameplay data analysis. The discussion in section 5 provides critical highlights from the results, policy implications, and study limitations. The study concludes with a summary of the research and a definition of future work.

5.3 Methods

5.3.1 HomeRUN game as a representation of the real-world setting

This research has developed HomeRUN to shape the behaviors of households for sustainable consumption (Agusdinata and Lukosch, 2019). Role-playing game (RPG) comprises an interestingly diverse genre, with two key attributes; player's role that improves with experience and a well-defined storyline (Rollings and Adams, 2003). RPG encourages higher-level mental stimulation on top of the chance to explore the depths of their empathy (Sundberg, 2016). The gameplay sessions of RPG; facilitate behavior consistent with the actions of the specified role (Nelson and Norton, 2005) and help in learning, planning, applying, visualizing, and reflecting (Podleschny, 2008). The gameplay of HomeRUN was explicitly designed to introduce IMs before each round to study their effects randomly.

The gameplay of HomeRUN has ten rounds, where each round represents a simulation of one year. The game's currency is gold, where one gold is approximately equal to the US $100. Thus, a player will receive 40 golds in every round, which is about two-thirds of the annual savings of an average American family. There are three types of actions players can take: (1) household actions related to individual FEW sectors, (2) wonder action (altruistic behaviors such as offsetting carbon emissions), and (3) indulge (actions that people usually do for pleasure such as taking a vacation and eating out). The first two types of action are done by spending gold, whereas the third action requires gold and carbon reductions. The carbon reductions are earned by doing the first two types of actions, as illustrated in figure 10. All actions give players joy (positive psychological consequences of pro-environmental behavior (Hu et al. 2016)), and the player with the highest joy wins the game. The values for the technological and behavioral actions are taken from a tool developed by UC Berkeley, called cool California calculator (Calculator, 2017).

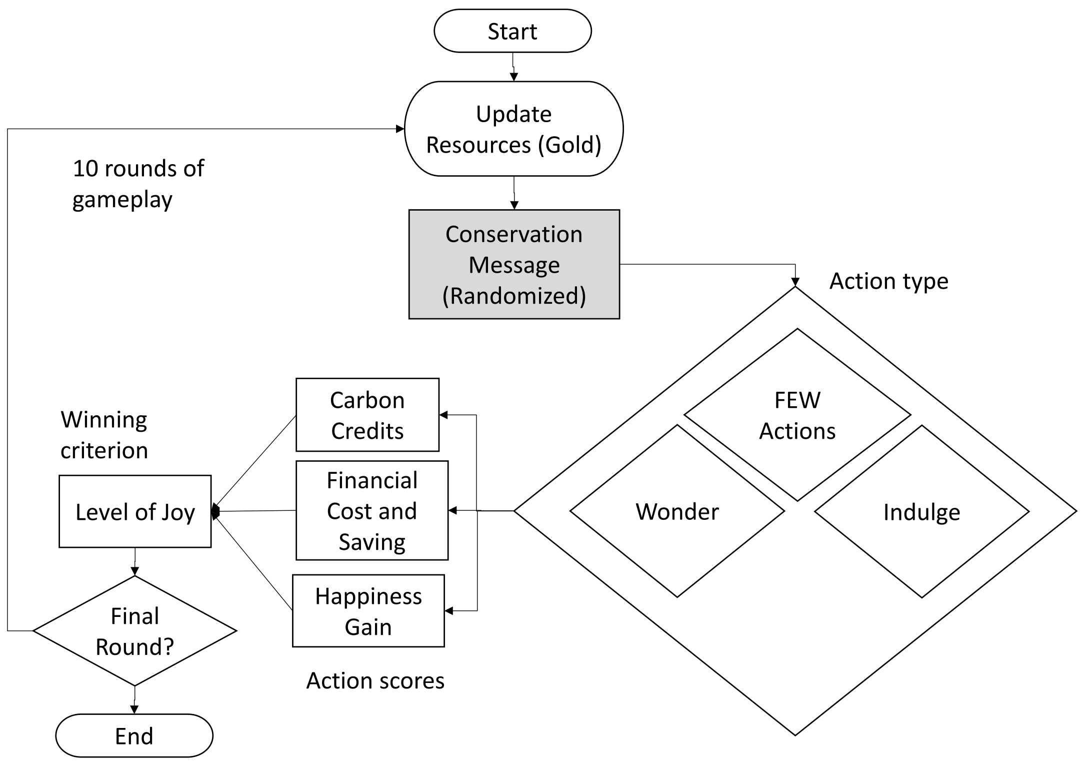

Figure 10 Flow diagram of the gameplay session of HomeRUN

5.3.2 HomeRUN options of household actions

HomeRUN simulated thirty-four household actions. There are six indulge and food actions, four water and wonder actions, and fourteen energy actions. Figure 11 shows some of the options as they appear in the HomeRUN user interface.

Figure 11 A screenshot of HomeRUN interface showing options of household actions

5.3.3 Intervention messages

In the gameplay session of HomeRUN, ten IMs were flashed randomly (Figure 12) before the start of each round for 20 seconds, as shown in Table 11. There are four groups of messages: (a) reduction messages, (b) social comparison messages, (c) sector-wise impact messages, and (d) baseline message.

Table 11 Intervention messages used in the HomeRUN

Intervention conservation messages groups	Message content
Reduction messages	
Reduction Food Measure (RFM)	Cutting your meat consumption in half can reduce your total household contribution to climate change by 10%.
Reduction Water Measure (RWM)	Installing low-flow showerheads will reduce your water use by 20%, also reducing your CO_2 emissions.
Reduction Energy Measures (REM)	Changing your compact fluorescent lightbulbs (CFL) to Light-emitting diodes (LEDs) can reduce your CO2 emissions from electricity use by 3%.
Social comparison messages	
Social Comparison Energy (SCE)	Last round, your energy use was 20% more than the average game player.

Social Comparison Food (SCF)	Last round, your food consumption was 20% more than the average game player.
Social Comparison Water (SCW)	Last round, your water consumption was 20% more than the average game player.
Baseline message	
Baseline Message (Base)	Have a good game!
Impact-focused messages	
Economic Impacts (EI)	The average American household annually spends $1,351 on their electricity, $1,050 on their water bill, and $6,600 on food.
Health Impacts (HI)	If all households continue to use the average amount of food, energy, and water, the average American can expect to experience 2 days in a typical year in 2100 when the heat and humidity are so high that it will be unsafe to remain outdoors.
Ecological Impacts (Ecl)	If households continue to use the average amount of food, energy, and water, we can expect climate change to reduce insect numbers and decrease insect-eating bird populations by 2050.

Figure 12 An example of intervention conservation message shown at the start of the round in the gameplay of HomeRUN

5.3.4 Study participants

One hundred and fifty-seven university students in the US participated in this study for extra credits. Half of the participants were female, and slightly more than half were freshmen (54%). Around one-third of the students were in natural sciences (34%), followed by engineering (28%) and social sciences (21%). One-third of participants had liberal political views (34%), and almost half of the participants identified as Democrats (47%). Only 13% of the participants had conservative political views, and 15% identify as Republicans.

The study participants were emailed a document that briefly described the project and contained the information regarding different elements of the gameplay session. Due to the novel coronavirus, all gameplay sessions were online, and the Institutional Review Board (IRB) of Arizona State University (ASU) approved the study before the data collection. All participants completed the gameplay session unsupervised and on their computers. The elements of the gameplay session were sequentially placed on a dedicated website. The first element of the study was to complete a pre-survey. The survey was designed using google forms, the data collected was stored in an Excel spreadsheet. The pre-survey took approximately 10 minutes to complete. Once the participant completed the pre-survey, they were asked to see a tutorial about HomeRUN. The 7 min 37-second long video was hosted on YouTube and was embedded in the website.

Then the participant continued to play the RPG. HomeRUN is designed using Unity and was embedded on the same website using Unity WebGL. The playtime is 35 minutes approximately and consists of 10 rounds. The online version of HomeRUN was designed for a single player. At the start, the participant was asked to familiarize with the game for 1 minute. Before each round, a randomized IM (figure 13) was flashed for 20 seconds, followed by 90 seconds of gameplay per round. At the end of the round, the summary was shown in a bar chart for 1 minute. The carbon reductions of the players were reflected in the perspective of taking an equivalent number of cars off the road. After the ten rounds, a summary of all actions was shown to the participants. The data collected from the HomeRUN gameplay session was emailed to dedicated Gmail and Outlook addresses. The data was in text form. A python code was written to convert it to a Microsoft Excel spreadsheet. After that, they were asked to complete a post-survey, which took approximately 7 minutes to complete. In total, the gameplay session took about 1 hour to complete. The data was analyzed using Microsoft Excel and Statistical Package for the Social Sciences (SPSS). The evaluation of the gameplay session was done using the quantitative data generated during the gameplay of HomeRUN. The surveys aimed to gather demographics, gaming attitude, baseline knowledge, game design, flow experience, and feedback from the participants regarding their gameplay experience.

5.4 Results

5.4.1 Relative effect of intervention messages

Hypothesis 1: Players exposed to social comparison messages will engage in gameplay, resulting in a statistically significant reduction of GHG emissions.

Table 12 Mean carbon reduction for each intervention message

Message	Mean Total Actions	Mean Carbon Reductions, [10*mtCO_2e/yr]
SCE (Energy)	15.6	434
SCF (Food)	15.7	419
RFM (Food)	14.8	394
HI (Health)	15.2	387
Base (Baseline)	14.5	384
SCW (Water)	15.1	384
REM (Energy)	14.1	380
EI (Ecological)	14.5	372
RWM (Water)	14.3	367
EcI (Economic)	13.8	365

Association of the message is indicated in between parentheses.

The data of all players was merged together for analysis. The raw gameplay data was restructured from carbon reductions attained per round to carbon reductions attained after being exposed to a specific intervention message. The mean of total actions taken and carbon reductions attained after being exposed to each IM and correlation between them is shown in table 12. Mean carbon reductions per IM were 389, and mean actions were 14.8. The exposure to social comparison energy message resulted in the most carbon reductions (M=434), whereas the exposure to the economic impact message produced the least carbon reductions (M=365). The exposure to only three IMs produced more than mean carbon reductions.

The comparison of different groups (impact, reduction, baseline, and social comparison) of IMs are shown in Table 13. The exposure to social comparison messages produced the most carbon reductions (M= 412), followed by the reduction message (M=380), whereas impact-focused messages (M=375) yielded the lowest carbon reductions. Only the social comparison messages group had above-average carbon reductions.

Table 13 Mean carbon reduction for each group of intervention messages

	Mean total actions	Mean Carbon reductions, [10*mtCO_2e/yr]
Social Comparison messages		
SCE	15.6	434
SCF	15.7	419
SCW	15.1	384
Mean	15.5	412
Reduction messages		
RFM	14.8	394
REM	14.1	380
RWM	14.3	367
Mean	14.4	380
Impact-focused messages		
HI	15.2	387
EI	14.5	372
EcI	13.8	365
Mean	14.5	375
Baseline message		
Base	14.5	384

A repeated-measures ANOVA determined that mean carbon reductions differed significantly across ten intervention messages assuming sphericity ($F(9, 1404) = 2.072$, $p < .03$). A post hoc pairwise comparison using the Least Significant Difference showed that only ten pairwise comparisons are statistically significant, as shown in Table 14. The mean carbon reductions of social comparison energy message are statistically significant when compared to seven out of the nine remaining IMs.

Table 14 Statistically significant pairwise comparison of mean carbon reductions

Pair-wise Comparison	P-value
Social Comparison Food	
SCF and RWM	.017
SCF and EI	.040
SCF and EcI	.006
Social Comparison Energy	
SCE and EcI	.001

SCE and SCW	.012
SCE and RWM	.002
SCE and EI	.005
SCE and HI	.023
SCE and Base	.019
SCE and REM	.011

The exposure to social comparison energy and food messages resulted in the most carbon reductions, whereas the exposure to social comparison water message produced slightly less than mean carbon reductions. Hence, the first hypothesis is partially supported.

5.4.2 Immediate effect of intervention messages

Hypothesis 2: The intervention messages directly and significantly influence the first action taken by the players in the gameplay.

The affiliation of the first action taken by the players at the start of each round, after being exposed to the intervention message, is shown in Table 15. The energy group had the highest percentage of the first action after being exposed to eight IMs, whereas the food group had the hightest percentage after being exposed to tow IMS (RFM and SCF).

Table 15 Percentage of first action for each action group

Intervention Message	Food	Energy	Water	Wonder	Indulge
REM (Energy)	10%	61%	4%	19%	6%
RFM (Food)	40%	35%	4%	15%	6%
Base	11%	48%	8%	24%	9%
HI	21%	48%	7%	18%	5%
EI	19%	50%	4%	24%	3%
RWM (Water)	10%	43%	29%	17%	2%
SCE (Energy)	11%	57%	6%	22%	4%
SCF (Food)	42%	39%	4%	13%	2%
SCW (Water)	8%	39%	29%	17%	6%
EcI	19%	52%	5%	18%	6%

A repeated-measures ANOVA determined that mean actions differed significantly across five groups of actions assuming sphericity ($F(4, 36) = 31.126$, $p < .001$). A post hoc pairwise comparison using the Least Significant Difference showed that 14 out of the 20 pairwise comparisons are statistically significant. The energy group is statistically significant against all other comparisons. Hence, the second hypothesis is fully supported.

5.5 Discussion

5.5.1 Key highlights

The game data analysis revealed that the exposure to social comparison energy, social comparison food, and reduction food message IMs resulted in the top three carbon reductions respectively. The remaining messages yielded less than mean carbon reductions. Social comparison energy message yielding the most carbon reductions; is in line with previous studies (e.g., Allcot, 2011; Taylor et al., 2018) and indicates that energy use has significant potential to reduce GHG emissions (Attari et al., 2010; Spence et al., 2011). The exposure to social comparison water message produced slightly less than mean carbon reductions. The low carbon reduction perhaps is because three out of the four water actions available in HomeRUN had negligible carbon reductions. Furthermore, emissions from water use are linked with energy use. In a contrast to the finding of Addo et al. (2015), reduction water message was not that effective and yielded second to last carbon reductions.

Comparing carbon reductions from the four message groups show that only social comparison messages yielded more carbon reductions than the mean. This strengthen the finding of a meta-review by Nisa et al. (2019) that social comparison interventions are the most effective in promoting environmental friendly actions by household. The results from the comparison of message groups further supports the first hypothesis that social comparison messages result in significantly more carbon reductions. Exposure to reduction and impact-focused messages had fewer carbon reductions than that of the baseline message.

The actions simulated in HomeRUN belong to five groups, and the first action taken at the start of each round is generally from the energy group. The highest frequency for energy actions is 61% in response to the exposure to REM, followed by 57% for SCE. There two instances where food actions had the highest response, 40% after being exposed to RFM and 42% for SCF. The increase in first action related to food after being exposed to the food specific message endorses the finding of Whitehair et al. (2013). In the rounds where SCW and RWM were flashed, the water actions were at least three times more than the eight other rounds. The reducation water message made 43% of the palyers to choose the first action from the water group, thus, confirming the findings of Seyranian et al., (2015) that households receiving specific water-saving startigies conserve more water. The Impact messages yielded the best response in terms of energy actions after energy specific messages thus agreeing to the findings of Asensio and Delmas (2015). Hence, tairlored IMs, in general, have a significant effect on the choices players make during the gameplay (Brinberg et al., 2000) and the use of SG facilitated the process of testing the efficacy of IMs in targeted population (Fixsen et al., 2005; Bird, 2008).

5.5.2 Policy implications

The results of this study point to some opportunities for policy design and actions. First, the strong effect on social comparison messages, especially on energy and food consumption, should be further capitalized. For example, electricity utility companies can intensify sharing information about their customers' relative resource use level to affect more sustainable consumption. Similarly, municipalities can encourage their citizen to reduce food wastes by a targeted message comparing solid waste production among neighborhoods using trash collection data as a proxy.

Second, our results demonstrate a strong influence of message type on the first action taken. When a message related to energy appears, for example, players tend to respond to the message by taking action associated with energy consumption. It seems that the IM focuses the attention of the participant and directs action. This result suggests that policymakers and utilities can send a periodic reminder message that would encourage conservation behavior.

Third, our results indicate that promoting water conservation based on carbon emissions impact is not effective. People do not directly associate water usage with emissions and further research is required to understand the drivers of behind water consumption (Corral-Verdugo et al., 2003).

5.5.3 Study limitations

The study has some caveats that should be kept in mind while interpreting the results and drawing conclusions. First, the effects of intervention messages for conservation are studied using the simulated environment of SG rather than actual households. Households differ considerably in income, consumption patterns, and their contribution to climate change (Feng et al., 2009). Second, the game participants are university students, which may prove a barrier to generalize findings. Third, some of the actions simulated in HomeRUN may be overlapping food, energy, and water groups. However, the results generate valuable insights into the effectiveness of intervention conservation messages.

5.6 Conclusion

It has been established that sustainable food, energy, and water resource consumption can significantly reduce GHG emissions. Successful nudging for such behaviors, however, requires an intimate knowledge of messaging that resonates with households. In the study, we experimented using the HomeRUN to assess the effectiveness of different intervention messages for conservation. Despite some limitations, the results of this study increase understanding of the role intervention messages can play to support conservation efforts in reducing households' GHG emissions. It is evident that social comparison messages have the most significant effect on reducing GHG emissions. The gameplay is also significantly affected by the messages as the participants' first actions are directly related to that of the message.

SGs offer an exciting and flexible platform for behavioral experiments. SG design aligns well with principles and concepts within behavior analysis with applied and basic research possibilities. We demonstrated that a serious gaming environment and an appropriately designed gameplay concept could reveal valuable insights into consumption behaviors that may be too costly and impractical to obtain in a real-world setting. The gaming setting can be used as a precursor to gauge the performance of alternative policies and inform a selection and full-scale implementation of the best policy.

For future work, this study can be extended by playing the game with actual house owners, comparing results with measuring the emission of households for 5 to 10 years. The game can be adapted to target the younger population segment, especially the youth.

CHAPTER 6

CONCLUSION

6.1 Conclusion

This dissertation has studied the design and development of an SG, HomeRUN, for supporting the conservation of FEW resources at households. It has been recognized that sustainable consumption of food, energy, water resources in households can significantly reduce total GHG emissions. Successful nudging for such behaviors, however, requires an intimate knowledge of messaging that resonates with households

The findings show that SGs promote knowledge about household actions in terms of financial and carbon savings. The gameplay sessions of HomeRUN are fun and create an experience of flow. Social comparison messages are most effective in steering household consumption towards sustainability. A rigorous game design process and an unambiguous vision of the game are essential for developing an effective SG. SG is an efficient tool to promote knowledge with contextual and paradigm changes. SGs assists players to become increasingly efficient in achieving the goals/objective of the game.

The answers to the dissertation's research questions are summarized as follows. Conservation of FEW resources at the household level is vital for achieving a low carbon society goal. HomeRUN was designed from scratch to educate players about the impacts of household actions. HomeRUN was developed by first establishing the objectives and parameters, followed by selecting the genre, RPG. Csikszentmihalyi's (1990) theory of flow experience and Duke's (1980) twelve game design elements were core pillars of the game design. The game design was iterative, and HomeRUN was repeatedly tested with peers, developers, experts, and students. Each evaluation and testing resulted in more refined and robust gameplay.

The results, coupled with participants' comments, reveal that the gameplay of HomeRUN was fun, engaging, facilitated learning, and provided insight into the impacts of household actions. The gameplay creates a high experience of flow for the participants of the study. Experiential learning offers numerous opportunities for SG developers to obtain valuable insights into learning processes. This study reports experiential learning from the gameplay sessions of RPG HomeRUN. Female participants demonstrated more understanding in questions about the financial saving of household actions.

In contrast, male participants performed better in the questions about GHG/CO_2 reduction and food, energy, and water resources consumption. It cannot be significantly stated that one gender demonstrated better than the other; however, male participants have performed slightly better. The results of this study increase understanding of the role intervention messages can play in reducing households' GHG emissions. Social comparison messages have the most significant effect on reducing GHG emissions. During the gameplay session, the participants' first action in each round is significantly and directly related to the message flashed before the start of the game.

The methodological contribution of the dissertation is to show that SGs offer a useful approach for interdisciplinary studies; on fostering learning and interventions to steer household consumption. An appropriately designed gameplay concept can reveal valuable insights into consumption behaviors. HomeRUN has the elements and capabilities to answer multiple research questions in a safe and controlled environment.

The gaming setting can be used as a precursor to gauge the performance of alternative policies and inform a selection and full-scale implementation of the best policy.

6.2 Post-post-game survey

The experiential learning by the players during the gameplay session was quantified because of the pre and post-game survey. In order to find out that the learning was long-lasting, a post-post-survey was sent three months after the gameplay session to the players. Longitudinal studies require time and are often quite expensive, resulting in only a small group of subjects, which makes it difficult to generalize results (Caruana et al., 2015). Some players drop out of the study, shrinking the sample size and decreasing the collected data. In some cases, this can influence the results of the longitudinal study. If the final group no longer reflects the original representative sample, the validity of the experiment is compromised. A longitudinal study can provide a wealth of information on a topic and costly and difficult to carry out (White and Arzi, 2005).

As shown in the table 16, the number of correct answers increased only in question number four (which indulge action consumes the most CO_2 equivalent) compared with both pre and post-game surveys. The comparison with post-game and post-post-game surveys reveals an increase in the correct answers in two questions: four (CO_2 emissions from indulge action) and five (financial saving from food action). The comparison with the pre-game and post-post-game surveys reveals an increase in three questions: three (CO_2 reduction from water action), four (CO_2 emissions from indulge action), and seven (financial saving from water action). The players participating (N=81) in the post-post-game survey are almost half of the pre-game and post-game survey participants. The decreased number of participants makes it difficult to compare results. However, in future work, it is recommended that the post-post-game survey should be matched with the earlier surveys, and analysis should be done only using the same participants' data.

Table 16 Food, Energy, Water, and Indulge Actions Pre- Post- and Post-post-gameplay Survey Results

Question	Pre-game survey	Post-game survey	Post-post-game survey
	Correct Answer, [%]	Correct Answer, [%]	Correct Answer, [%]
1. From the following options, which Food action reduces the most CO_2 equivalent per year?	42	47	41
2. From the following options, which Energy action reduces the most CO_2 equivalent per year?	46	55	29
3. From the following options, which Water action reduces the most CO_2 equivalent per year?	19	50	33
4. From the following options, which Indulge action consumes the most CO_2 equivalent?	67	77	78
5. From the following options, which Food action gives the most financial saving?	47	33	39
6. From the following options, which Energy action gives the most financial saving?	38	39	30
7. From the following options, which Water action gives the most financial saving?	31	47	42
8. From the following options, which Indulge action costs the most?	76	77	70

6.3 Future work

HomeRUN is a model of reality, in which specific aspects of reality have been left out or brought to a higher abstraction level to design a playable game. For future work, this study may be extended by playing the game with actual house owners with long-term consistent follow-ups. It will allow comparing results with measuring the emission of households for 5 to 10 years for deeper insights into the effects of using a HomeRUN for fostering knowledge and as an intervention. A modified version of the game can educate high school and college students about conserving household resources. Such modification may include comparison of different actions taken and their impact. A mobile version of the game, which is accessible through phones, may be developed for data collection with more significant segments of populations.

6.3.1 Climate change and mitigation

Adding a climate change and mitigation module to the current SG may be considered (see section 1.3.5). The new module requires an extensive review on literature related to climate change and mitigation practices. As previously introduced in Chapter 1, social and behavioral change is recognized for climate change mitigation and adaptation; changing household behavior is a low-cost yet under-utilized strategy that could be successful if implemented effectively, drawing on research evidence (Vandenbergh et al., 2010). Faber et al. (2012) conclude that there are options for behavior change that could decrease GHG emissions. In particular, the synthesis report constituting the final product of the Fifth Assessment Report of IPCC is structured around four topics which may be used to add a module in the RPG in the form of a pulse. A pulse is an event introduced during the gameplay to focus players' attention on a single aspect of the problem (Duke, 1980).

This new module of climate change and mitigate could be helpful in addressing research questions that this study have not answered but of high importance in the field.

Relevant questions may include: (a): What are people's perceptions about the future climate change risks, impacts, adaption, and mitigation? (b): How do different intervention messages related to future climate change impacts correlate with homeowners' consumption behaviors? (c): How to conceptualize and measure learning impacts resulting from the gameplay?

The IPCC synthesis report may extensively be used to refine the current version of household actions. The changes could be made so that the intervention messages can be tested effectively. The answer for part 'a' requires a change in the pre-game survey analtic hierarchy procsess (AHP) question; the changes will indicate players' current perceptions of climate change adaptation, mitigation, and sustainable development. The gameplay should also be changed to answer part 'b'. New Intervention messages may be adopted from the synthesis report published by IPCC. Two more types of IMs may be introduced. Dynamic IM (an IM where trends are mentioned, e.g., more and more people are using reusable cups for to-go coffee in this shop) and visual IM.

Demographic analysis should be done with the dependent variable as an annual reduction in GHG emissions. The same should be done for the value orientations and perceptions about climate change. A meta-analysis by Hornsey et al. (2016) reports that political affiliation is the largest demographic correlate of climate change belief. People who intend to vote for more liberal political parties are more likely to believe in climate change than those who align themselves with relatively conservative political parties. The results of the demographic analysis should be validated with the literature.

Insights from part ‘a’ may be used to change the interventions and round structure during the gameplay. The changes which may be made to the game include a change in costs related to household interventions because of the impacts of climate change. Post-game survey should be changed to help answer part ‘c.’ The RPG gaming session should be conducted at various international universities. The intended players may include university students, researchers, and faculty. The study should aim to play the RPG with around 100 players.

6.3.2 Optimization of household actions

Further research may focus on optimizing the carbon reductions based on the actions tailored for individual households. The gameplay may be linked with carbon calculators to use place-specific data for a better simulation. The optimization can be based on available resources and specific preferences of actions or approximate carbon reductions. The mixed-integer linear optimization (MILP) model needs to be developed. The model may maximize carbon reductions but is restricted by the number of interventions it can use. The model should use the actions from cool climate-carbon calculator. In the end, it prints a round by round list of optimized household actions. This list of actions is based on the preferences of households related to the respective resource sector. The model should optimize, round by round, actions adopted by the household and provide the list of actions with the best value for money and carbon reductions. This way, families will have a list of actions, know the upfront cost to adopt them, and pay back both financial and carbon dioxide equivalent reductions annually. The optimized list gives households, towns, and cities a map of household actions to reduce GHG emissions based on their preferences about individual sectors of food, energy, and water. The optimization can help households plan and see the returns of their investment and effort to reduce GHG emissions. Whereas decision-makers can understand the preferences of their localities and plan/tax/incentivize/promote options that already resonate with the residents, hence lowering GHG emissions efficiently with inputs from the most important stakeholder, i.e., households. From the research point of view, we may remove indulge options from the game and the restriction to match several actions with the gameplay to see the maximum amount of carbon reduction in the average savings of an average household and other demographics.

The improvement which can happen is to make a tool that first calculates the AHP weights from the pairwise comparisons made by the individual household. The household to play the RPG to adopt them to their households. After that tool, the AHP preferences form the questionnaire and then the list of interventions adopted by the families. These will then be fed to the MILP model, providing an optimized list of household actions and the carbon emissions saved because of the actions of the families.

6.4 Reflections and lessons learned

This research study was carried out for five years. Critical reflections and lessons learned during the course of this study are discussed here for future scholars.

At the start of research that uses SG, it is imperative to understand the game design process. There is a need to consult with the SG experts before starting the design process. The consultation with experts and prototype testing needs to be carried out frequently for a game with minimum bugs. We did this process, but we didn’t focus much on the research questions that the gaming simulation is going to answer. Extensive literature research coupled with expert interviews provides a flexible platform for researchers to carry out a study that will use SG as a research tool. Scholars need to put a lot of focus on clearly defining the subject matter of the intended game. A clear and concise subject matter of the game helps to articulate the purpose of the game.

The subject matter and purpose of the game provide a ground to find the right game design framework. Scholars can find a better game design choice if they are clear about the gameplay sessions' research questions. Furthermore, the game design choice may be refined based on the intended player, the context of the use of the game, and the resources available to the scholars. Quality time spent selecting a proper game design facilitates a smoother progression of research and better insight from the research design. Scholars have to decide the technical aspects of their game once they know what kind of game design they will follow. A computer-based game needs extra resources, specifically people with knowledge and expertise, to build a game envisioned by the designers. This research started with a prototype game using cards and board; during the testing of the prototype, it was revealed that accounting is a hassle, and it affects the game flow. Therefore, we decided to simulate the game using a computer and then make a mobile version. We had difficulty finding and communicating the game design parameters to the software engineers working on creating a game simulation.

The key lessons from the technical side of online game are data collection, stable game build, and clear reperesentation for a diverse audience. We had troubles with data collection, firewall issues, and unstable versions of the game. We learned that rather than making an application and installing it on computers to play, it is much better to make an online version that can be played on a browser. Furthermore, it is also essential to have multiple methods to save and recover the data collected from the gameplay session. An idea about the research questions and data analysis needed may help design the data's output in a form that may be readily used for analysis.

If I have to go back in time and start this research again, I will focus more on the research questions at the start of the design process. The literature review may be summarized to be used later on. The fact that we had to communicate with software engineers to develop an online version cost a lot of time, resources, and data. I would learn unity programing and develop the game myself.

6.5 Closing remarks

I have been fascinated with the concept of strategic sustainability since 2009, my first year of Master's education at Blekinge Institute of Technology, Karlskrona, Sweden. Games are a part of my life, and the opportunity to research by designing a game was a blessing in disguise. This study has laid a path to research by developing an SG and using it as a tool to answer multiple research questions. The findings are appropriate given there is a pressing need to identify and implement measures to mitigate climate change. The novel coronavirus pandemic added to the challenges, and yet the utility of SG was not much affected. My genuine wish is that this dissertation provides insights and motivations for future research on the topic.

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APPENDIX A

SIMULATED HOUSEHOLD ACTION

A SIMULATED HOUSEHOLD ACTION

HomeRUN simulated thirty-four household actions as shown in Table 14. There are six each indulge and food actions, four each water and wonder actions, and fourteen energy actions.

Table 17: Household actions simulated in the RPG

In-game actions	Carbon reductions, [$mtCO_2e/yr$]	Financial return, [$/yr]	Capital cost, [$/yr]
Indulge			
Take a summer trip overseas	-4.9	0	1776*
Go luxury clothes shopping	-1.1	0	200*
Have a fancy dinner with wine and steak	-0.1	0	500*
Spending time with family and friends outside	-1.5	0	4000*
Install swimming pool	-4.5	0	8000*
Sports and outdoor Activities	-1.6	0	1000*
Wonder			
Offset Housing Footprint	17.36	0	347
Offset Shopping Footprint	24.62	0	492
Offset Transportation Footprint	11.8	0	236
Purchase Green Electricity	3.9	0	78
Water			
Install Low Flow Toilet	0	18	520
Install water efficient landscaping	0	15	833
Install Low Flow Faucets	0	5	20
Install Low Flow Showerheads	0.4	94	30
Food			
Be a Vegan	2.3	0	95
Eat 2150 instead of 2500 calories a day	1.1	573	0
Reduce your meat consumption by 50%	0.8	179	0
Reduce your dairy consumption by 50%	0.3	0	129
Reduce your food waste by 20%	0.4	400	0
Go Organic	0.2	0	418
Energy			
Install PV Panels	3.9	1290	31341
Install Solar Hot Water Heater	0	5	2500
Install Tankless Water Heater	0	204	500
Practice Eco-Driving	1.4	439	0

Turn Down Thermostat in Winter	0.8	174	0
Turn off Lights	0.1	24	0
Turn Up Thermostat in Summer	0.1	17	0
Use Rechargeable Batteries	0.2	626	52
Buy a More Efficient Vehicle	2.33	441	2000
Buy an Electric Vehicle	9.6	2613	15000
Change your lightbulbs from compact fluorescent (CFLs) to Light Emitting Diodes (LEDs)	0.1	42	10
Line dry clothing	0.2	50	0
Print double sided	0.3	16	0
Manage Computer Use	0.2	63	0

Negative carbon reductions represent that the actions consume carbon reductions, * represents one-time cost.

APPENDIX B

PRE-GAME SURVEY

B PRE-GAME SURVEY HOMERUN

A Role-Playing Game to reduce Greenhouse Gases emissions at household level
* Required

Q 1: Enter your school email *
You must enter the same email in the game and post survey too.

____

Q 2: Are you over 18 years old? *
If Yes, then please proceed after signing the consent form. If no, then please close the survey
____ Yes
____ No

Consent
Title of research study: Climate Change Mitigation via Reducing Household Food, Energy and Water Consumption: A Quantitative Analysis of Interventions and Impacts of Conservation

Investigator: Datu Buyung Agusdinata, School of Sustainability, Arizona State University
Phone: (480) 965 5738
Email: bagusdin@asu.edu

Why am I being invited to take part in a research study?
We invite you to take part in a research study because you are a consenting adult, willing to voluntarily participate.

Why is this research being done?
The purpose of the study is to understand household consumption patterns of food, energy, and water resources, and to understand the best way to reduce household consumption of these resources.

How long will the research last?
We expect that individuals will spend 1-1.5 hours participating in the proposed activities.

How many people will be studied?
We expect about 75-200 people will participate in this research study.

What happens if I say yes, I want to be in this research?
Voluntarily participating and consenting adults (18 years or older) will be asked to engage with an interactive, computer gaming scenario to examine household consumption patterns and possible ways to reduce household consumption of food,

energy, and water resources. They will be asked to fill a short pre survey (10 minutes) before the play (35 minutes). Game results will be analyzed to understand preferences for different kinds of changes to reduce household consumption and the feedback and relationships among preference selections. After gameplay a post survey (5 minutes) will be filled and then after three to six weeks a post post survey (3 minutes) will be sent. You are free to decide whether you wish to participate in this study. Instead of being in this research study, your choices may include:

What happens if I say yes, but I change my mind later?
You can leave the research at any time it will not be held against you.

Is there any way being in this study could be bad for me?
There are no known risks from participating in this study. Your data will be completely confidential, meaning we will not keep a record of your identifying information in association with the information about your household consumption. Your participation is voluntary and you can withdraw from the study at any time.

Will being in this study help me in any way?
We cannot promise any benefits to you or others from your taking part in this research. A possible benefit is the opportunity to share experiences and opinions. We hope you will have fun and learn something new by participating in this gaming exercise.

What happens to the information collected for the research?
The information that is obtained in connection with this study will be anonymous; we will not record your identifying information in connection with the information you provide, so there will be no way to link your responses back to you individually. No recordings of identifiable personal information will be kept in association with your responses. Data (the results from the gaming activity) will be stored on a secure Arizona State University campus server using numerical codes to identify gaming sessions and participants, with no identifiable personal information associated with your responses. Records will be kept for the required minimum of three years retention after the completion of the final report. Federal IRB regulations require the retention of records for three years after the completion of the final report. Information will not be released to any outside agency or entity; only persons on the research team trained to reliably protect participant confidentiality will be given access to the data collected in association with this project. Email ids will be asked (not a must, a participant can decline) for participation in a post post survey, but the analysis of post post survey will be a population based and will not be linked to the previous sessions.

What else do I need to know?
This research is being funded by National Science Foundation Award no. 1639342.

Who can I talk to?
If you have questions, concerns, or complaints, talk to the research team at

Datu Buyung Agusdinata, School of Sustainability, Arizona State University
Phone: (480) 965 5738
Email: bagusdin@asu.edu

This research has been reviewed and approved by the Social Behavioral IRB. You may talk to them at (480) 965-6788 or by email at research.integrity@asu.edu if:
• Your questions, concerns, or complaints are not being answered by the research team.
• You cannot reach the research team.
• You want to talk to someone besides the research team.
• You have questions about your rights as a research participant.
• You want to get information or provide input about this research.

Q 3: I understand the above information and consent to participate in this research *
_____ I consent
_____ I do not wish to participate in this research

Q 4: We would like to get back to you in 2 weeks' time to follow up. If you agree, please provide your email address below.
e.g. myname@asu.edu
____

Beliefs Intro: Now we will ask you about the things you find important and your beliefs in your daily life.

Q 5: Please indicate which of these items below are a general goal in your life. Use the scroll bar at the end to see all the options *

	-1(opposed to my values)	0 (not important)	1	2	3	4	5	6	7 (extremely important)
Respecting the earth: harmony with other species									
Unity with nature: fitting into nature									
Protecting the environment: preserving nature									
Preventing pollution: protecting natural resources									
Equality: equal opportunity for all									
A world at peace: free of war and conflict									
Social justice: correcting injustice, care for the weak									
Helpful: working for the welfare of others									
Social power: control over others, dominance									
Wealth: material possessions, money									
Authority: the right to lead or command									
Influential: having an impact on people and events									
Ambitious: hardworking, aspiring									
Pleasure: joy, gratification of desires									
Enjoying life: enjoying food, sex, leisure, etc.									
Self-indulgent: doing pleasant things									

Q 6: On a scale of 1 (totally disagree) to 7(totally agree) please indicate how closely you identify with the statements below *

	1 (totally disagree)	2	3	4	5	6	7 (totally agree)
Acting environmentally friendly is an important part of who I am							
I am the type of person who acts environmentally friendly							
I see myself as an environmentally friendly person							

Q 7: Please state how strongly you agree or disagree with the following statements about water. *

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Totally disagree
I feel morally obliged to not waste water							
I would feel guilty if I did not conserve water							
I would feel proud to conserve and not waste water							

Q 8: Please state how strongly you agree or disagree with the following statements about food. *

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Totally disagree
I feel morally obliged to not waste food							
I would feel guilty if I did not take actions to reduce the environmental impacts of the food I buy							
I would feel proud to not waste food and reduce impacts of the food I buy							

Q 9: Please state how strongly you agree or disagree with the following statements about energy. *

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Totally disagree
I feel morally obliged to not waste energy							
I would feel guilty if I did not take actions to reduce the environmental impacts of my energy use							
I would feel proud to not waste energy and reduce impacts of the energy I use							

Q 10: Please read the following scale carefully

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment moderately favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation

	Extremely less important	Very strongly less important	Strongly less important	Moderately less important	Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance	
A	9	7	5	3	1	3	5	7	9	B

Now assign the intensity of importance to the following comparisons. Use the scroll bar at the end to see all the options *

	9	7	5	3	1	3	5	7	9
Food Availability vs. Energy Availability									
Food Availability vs. Water Availability									
Energy Availability vs. Water Availability									
Food Affordability vs. Energy Affordability									
Food Affordability vs Water Affordability									
Energy Affordability vs. Water Affordability									
Food Impacts vs. Energy Impacts									
Food Impacts vs. Water Impacts									
Energy Impacts vs. Water Impacts									

CO_2 statement Greenhouse gas emissions are the chemicals in the air that cause the climate to change - such as Carbon Dioxide and Methane. Please indicate whether you believe the following statements are true or false about greenhouse gas emissions in the average Americans daily life.

Q 11: What is your best estimate of the percent range of the average American household's greenhouse gas emissions that come from growing, transporting, and preparing the food they eat? *
____ 0-9%
____ 10-30%
____ 31-50%
____ 51-70%
____ 71% and above
____ I don't know

Q 12: What is your best estimate of the percent range of the average American household's greenhouse gas emissions that come from electric power and natural gas used in our homes ? *
____ 0-14%
____ 15-30%
____ 31-45%
____ 46-60%
____ 61-75%
____ Over 75%
____ I don't know

Q 13: From the following options, which Food action reduces the most CO_2 equivalent per year? *
____ Be a Vegan
____ Reduce your meat consumption by 50%
____ Reduce your food waste by 20%
____ I don't know

Q 14: From the following options, which Energy action reduces the most CO_2 equivalent per year? *
____ Install Solar Hot Water Heater
____ Turn Down Thermostat in Winter
____ Buy a More Efficient Vehicle
____ I don't know

Q 15: From the following options, which Water action reduces the most CO_2 equivalent per year? *
____ Install Low Flow Showerheads
____ Install water efficient landscaping

_____ Install Low Flow Toilet
_____ I don't know

Q 16: From the following options, which Indulge action consumes the most CO_2 equivalent? *
_____ Have a fancy dinner with wine and steak
_____ Go luxury clothes shopping
_____ Take a summer trip overseas
_____ I don't know

Q 17: From the following options, which Indulge action costs the most? *
_____ Have a fancy dinner with wine and steak
_____ Go luxury clothes shopping
_____ Take a summer trip overseas
_____ I don't know

Q 18: From the following options, which Food action gives the most financial saving? *
_____ Be a Vegan
_____ Reduce your meat consumption by 50%
_____ Reduce your food waste by 20%
_____ I don't know

Q 19: From the following options, which Energy action gives the most financial saving?*
_____ Install Solar Hot Water Heater
_____ Install PV Panels
_____ Buy a More Efficient Vehicle
_____ I don't know

Q 20: From the following options, which Water action gives the most financial saving? *
_____ Install Low Flow Showerheads
_____ Install water efficient landscaping
_____ Install Low Flow Toilet
_____ I don't know

Q 21: Please respond to the following statements *

	True	False	I don’t know
The average American household annually $10,776 on food.			
The average American household consumes 32,850 Kilowatt hours of electricity.			
The average American household consumes 6,600 Gallons of water per year.			

If all households continue to consume the average levels of food, energy and water, children that are currently 5 years old will live on an earth with a different climate.			
If all households continue to use the average amount of food, energy and water, the average American can expect to experience 2 days in a typical year in 2100 when the heat and humidity are so high that it will be unsafe to remain outdoors.			

Q 22 (a): Which action from the dropdown menu below, you think would reduce THE MOST greenhouse gas emissions for the average American household. *
____ Turn down your thermostat 10 degrees when using the heat in the winter
____ Reduce your food waste by 20%
____ Change your lightbulbs from compact fluorescent (CFLs) to Light Emitting Diodes (LEDs)
____ Turn off your lights
____ Install low flow shower heads
____ Use rechargeable batteries

Q 22 (b): Which action from the dropdown menu below, you think would reduce THE 2nd MOST greenhouse gas emissions for the average American household. *
____ Turn down your thermostat 10 degrees when using the heat in the winter
____ Reduce your food waste by 20%
____ Change your lightbulbs from compact fluorescent (CFLs) to Light Emitting Diodes (LEDs)
____ Turn off your lights
____ Install low flow shower heads
____ Use rechargeable batteries

Q 22 (c): Which action from the dropdown menu below, you think would reduce THE 3rd MOST greenhouse gas emissions for the average American household. *
____ Turn down your thermostat 10 degrees when using the heat in the winter
____ Reduce your food waste by 20%
____ Change your lightbulbs from compact fluorescent (CFLs) to Light Emitting Diodes (LEDs)
____ Turn off your lights
____ Install low flow shower heads
____ Use rechargeable batteries

Q 23 (a): Which of the following actions to reduce your greenhouse gases has the lowest cost per year? *
____ Reduce your dairy consumption by 50%
____ Install a photovoltaic solar panels

_____ Buy a more efficient vehicle
_____ Buy an electric vehicle
_____ Install low flow showerheads

Q 23 (b): Which of the following actions to reduce your greenhouse gases is the MOST COST-EFFECTIVE (gives the most bang for your bucks?) *
_____ Reduce your dairy consumption by 50%
_____ Install a photovoltaic solar panels
_____ Buy a more efficient vehicle
_____ Buy an electric vehicle
_____ Install low flow showerheads

Q 24: I can contribute to a better environment by eating low carbon foods. *
_____ Strongly agree
_____ Agree
_____ Somewhat agree
_____ Neither agree nor disagree
_____ Somewhat disagree
_____ Disagree
_____ Strongly disagree

Q 25: Please indicate your level of agreement with the following statements *

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
When humans interfere with nature, it often produces disastrous consequences.					
The so-called "ecological crises" facing humankind has been greatly exaggerated.					
The balance of nature is very delicate and easily upset.					
Humans are severely abusing the environment.					

Q 26: How strongly do you agree or disagree with these statement *

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
Humans have the right to modify the natural environment to suit their needs.					
If things continue on their present course, we will soon experience a major ecological catastrophe.					
Plants and animals have as much right as humans to exist.					
Humans were meant to rule over the rest of nature.					

Q 27: We will now ask some questions about climate change. Please note the extent you agree or disagree. *

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
Climate change is part of a natural cycle beyond human control.					
We can't stop climate change because it is part of a natural cycle beyond our control.					

Q 28: Again - please note the extent you agree or disagree. *

	Strongly disagree	Disagree	I do not know	Disagree	Strongly disagree
Climate change is not going to happen.					

People will be able to adapt to climate change.					
I worry about climate change.					
Climate change will cause problems for people.					
Climate change is NOT likely to be a serious problem					

Q 29: How strongly do you agree with the following statements? *

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Totally disagree
I think it is useful to reduce energy use to reduce environmental problems.							
I can take on responsibility for the environment and/or for other people by turning down my heat in the winter							
I can contribute to the reduction of environmental problems by using my own solar energy as much as possible							
I think I can contribute to reducing environmental problems by reducing energy use.							

Gaming Attitude

This part of the survey contains a number of statements about gaming. There is no “right” or “wrong” answer. For each statement, select the column that represents how you feel about that statement.

	Strongly disagree	Disagree	I do not know	Agree	Strongly agree
Given the opportunity to play a real-time strategy game, I am afraid that I might have trouble in navigating through it.					
Games help me relax and do my work better.					
I could probably teach myself most of the things I need to know about games.					

Q 31: To which gender do you most identify? *
_____ Male
_____ Female
_____ Non-binary/Third gender
_____ Prefer to self-describe
_____ Prefer not to answer

Q 31 (a): If you chose "Prefer to self-describe" above then please self-describe

____

Q 32: What year of college are you in? *
_____ First year of undergraduate
_____ Second year of undergraduate
_____ Third year of Undergraduate
_____ Fourth or Fifth year of undergraduate
_____ Enrolled as masters student
_____ Enrolled in professional degree (JD, MD)
_____ Enrolled as PhD graduate student

Q 33: What is your major? *
_____ Undeclared
_____ Humanities
_____ Natural Sciences
_____ Social Sciences
_____ Engineering

Q 34 (a): If you chose "Humanities, Natural Sciences, Social Sciences or Engineering" above then please enter specific major

____

Q 35: In politics TODAY, do you consider yourself a Republican, Democrat, or independent?
____ Republican
____ Democrat
____ independent
____ No preference
____ I Don't know

Q 36: How would you describe your political views ? *
____ Very conservative
____ Conservative
____ Moderate
____ Liberal
____ Very liberal
____ I don't know

Q 37: What is your race or origin? *
____ White
____ Hispanic, Latino, or Spanish origin
____ Black or African American
____ Asian
____ American Indian or Alaska Native
____ Native Hawaiian or Other Pacific Islander
____ Some other race or origin

We thank you for your time taking this survey. Please turn your attention back to the game facilitator and prepare to play our game.

APPENDIX C

POST-GAME SURVEY

C POST-GAME SURVEY HOMERUN

A Role-Playing Game to reduce Greenhouse Gases emissions at household level
* Required

Q 1: Enter your school email *
Please enter the same email you have entered in the Pre Survey and the game.

____

Q2: Statements
Please indicate your agreement or disagreement with the following statements

	Strongly agree	Agree	Undecided	Agree	Strongly agree
The game is designed in an interesting and stimulating way.					
I have a better understanding of GHG emissions because of Food Energy Water consumption after playing the RPG.					
The RPG provided me an insight into the complexity of Food Energy Water Nexus.					
The feedback provided during the de-briefing session was useful.					
The use of RPG for education and training purposes is valuable.					
I expect the insights gained through this RPG to help me in reducing GHG emission at my household in future.					

Q3: Statements
Please indicate your agreement or disagreement with the following statements

	Strongly agree	Agree	Undecided	Agree	Strongly agree
I was challenged and I felt I could meet the challenge.					
I did things naturally without thinking too much.					
I had a strong sense of what I wanted to do.					
I felt I was on track towards my goals.					
I was totally focused on what I was doing.					
I felt I was in control of what I was doing.					
It felt like nothing else mattered.					
I lost my normal sense of time					
I really enjoyed what I was doing.					

Q 4: From the following options, which Food action reduces the most CO_2 equivalent per year? *
____ Be a Vegan
____ Reduce your meat consumption by 50%
____ Reduce your food waste by 20%
____ I don't know

Q 5: From the following options, which Energy action reduces the most CO_2 equivalent per year? *
____ Install Solar Hot Water Heater
____ Turn Down Thermostat in Winter
____ Buy a More Efficient Vehicle
____ I don't know

Q 6: From the following options, which Water action reduces the most CO_2 equivalent per year? *
____ Install Low Flow Showerheads
____ Install water efficient landscaping

_____ Install Low Flow Toilet
_____ I don't know

Q 7: From the following options, which Indulge action consumes the most CO_2 equivalent? *
_____ Have a fancy dinner with wine and steak
_____ Go luxury clothes shopping
_____ Take a summer trip overseas
_____ I don't know

Q 8: From the following options, which Indulge action costs the most? *
_____ Have a fancy dinner with wine and steak
_____ Go luxury clothes shopping
_____ Take a summer trip overseas
_____ I don't know

Q 9: From the following options, which Food action gives the most financial saving? *
_____ Be a Vegan
_____ Reduce your meat consumption by 50%
_____ Reduce your food waste by 20%
_____ I don't know

Q 10: From the following options, which Energy action gives the most financial saving?*
_____ Install Solar Hot Water Heater
_____ Install PV Panels
_____ Buy a More Efficient Vehicle
_____ I don't know

Q 11: From the following options, which Water action gives the most financial saving? *
_____ Install Low Flow Showerheads
_____ Install water efficient landscaping
_____ Install Low Flow Toilet
_____ I don't know

Q 12: Please respond to the following statements *

	True	False	I don't know	This message didn't appear on my screen
The average American household annually $10,776 on food.				
The average American household consumes 32,850 Kilowatt hours of electricity.				

The average American household consumes 6,600 Gallons of water per year.				
If all households continue to consume the average levels of food, energy and water, children that are currently 5 years old will live on an earth with a different climate.				
If all households continue to use the average amount of food, energy and water, the average American can expect to experience 2 days in a typical year in 2100 when the heat and humidity are so high that it will be unsafe to remain outdoors.				

Q 13 (a): Which action from the dropdown menu below, you think would reduce THE MOST greenhouse gas emissions for the average American household. *
____ Turn down your thermostat 10 degrees when using the heat in the winter
____ Reduce your food waste by 20%
____ Change your lightbulbs from compact fluorescent (CFLs) to Light Emitting Diodes (LEDs)
____ Turn off your lights
____ Install low flow shower heads
____ Use rechargeable batteries

Q 13 (b): Which action from the dropdown menu below, you think would reduce THE 2nd MOST greenhouse gas emissions for the average American household. *
____ Turn down your thermostat 10 degrees when using the heat in the winter
____ Reduce your food waste by 20%
____ Change your lightbulbs from compact fluorescent (CFLs) to Light Emitting Diodes (LEDs)
____ Turn off your lights
____ Install low flow shower heads
____ Use rechargeable batteries

Q 13 (c): Which action from the dropdown menu below, you think would reduce THE 3rd MOST greenhouse gas emissions for the average American household. *
____ Turn down your thermostat 10 degrees when using the heat in the winter
____ Reduce your food waste by 20%
____ Change your lightbulbs from compact fluorescent (CFLs) to Light Emitting Diodes (LEDs)
____ Turn off your lights
____ Install low flow shower heads

____ Use rechargeable batteries

Q 14 (a): Which of the following actions to reduce your greenhouse gases has the lowest cost per year? *
____ Reduce your dairy consumption by 50%
____ Install a photovoltaic solar panels
____ Buy a more efficient vehicle
____ Buy an electric vehicle
____ Install low flow showerheads

Q 14 (b): Which of the following actions to reduce your greenhouse gases is the MOST COST-EFFECTIVE (gives the most bang for your bucks?) *
____ Reduce your dairy consumption by 50%
____ Install a photovoltaic solar panels
____ Buy a more efficient vehicle
____ Buy an electric vehicle
____ Install low flow showerheads

Q 15: Remarks/ Comments/Suggestions about the complete RPG session
____
____
____
____
____
____

APPENDIX D

ASU IRB

D ASU IRB

APPROVAL: EXPEDITED REVIEW

Buyung Agusdinata
GFL-SOS: Faculty and Researchers
-
Datu.Buyung.Agusdinata@asu.edu

Dear Buyung Agusdinata:

On 3/5/2020 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Climate Change Mitigation via Reducing Household Food, Energy and Water Consumption: A Quantitative Analysis of Interventions and Impacts of Conservation using Role Playing game.
Investigator:	Buyung Agusdinata
IRB ID:	STUDY00011584
Category of review:	
Funding:	Name: National Science Foundation (NSF), Grant Office ID: FP00007376, Funding Source ID: 1639342
Grant Title:	FP00007376;
Grant ID:	FP00007376;
Documents Reviewed:	• Debriefing.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Homeowners pre survey.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • HomeRUNTutorial5-16-19.mp4, Category: Other; • HRP-502a - TEMPLATE CONSENT SOCIAL BEHAVIORAL.pdf, Category: Consent Form; • HRP-503a - TEMPLATE PROTOCOLSOCIAL BEHAVIORAL-1.docx, Category: IRB Protocol;

	• INFEWS_ProjectDescription.pdf, Category: Sponsor Attachment; • Post Post survey.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Post Survey New.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • recruitment script.pdf, Category: Recruitment Materials; • Students pre survey.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);

The IRB approved the protocol from 3/5/2020 to 3/4/2025 inclusive. Three weeks before 3/4/2025 you are to submit a completed Continuing Review application and required attachments to request continuing approval or closure.

If continuing review approval is not granted before the expiration date of 3/4/2025 approval of this protocol expires on that date. When consent is appropriate, you must use final, watermarked versions available under the "Documents" tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc: Muhammad Adnan Hanif