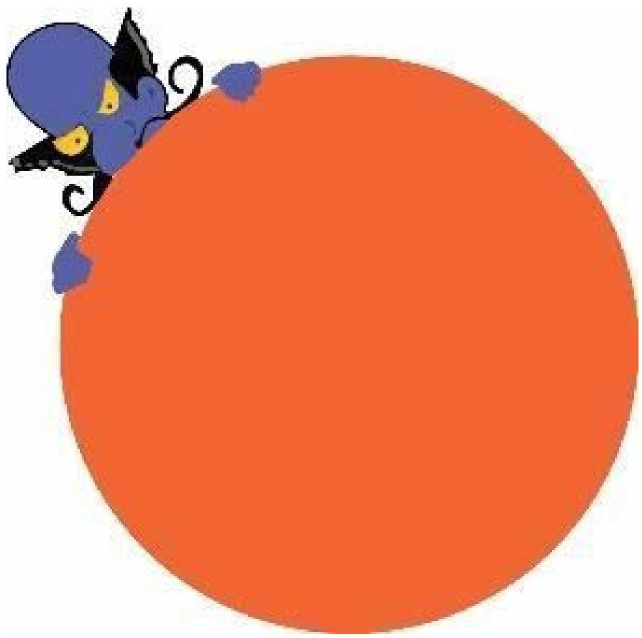
Purposeful Play: Serious, pervasive, energy games bridge the energy-efficiency gap



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DRAFT

1) Play invites exploration;

2) Play builds relationships;

3) Play motivates achievement.

Kristy Cunningham, Michigan State University

Executive Summary

Global warming trends and climate change create a compelling context for evaluating existing building stock in the USA. Currently, buildings use almost 40% of all energy produced and are responsible for 38% of all greenhouse gas emissions. Although research shows that energy efficiency is the cheapest method to provide Americans with electricity, studies identify barriers preventing owners and occupants from adopting energy efficiency measures despite their cost-saving potential. This failure to adopt energy- and cost-saving behaviors is known as the *energy efficiency gap* (Chapter 1).

Research on the energy efficiency gap notes the failure of households and government agencies to take full advantage of cost-effective energy-conserving opportunities, and discusses the structural and behavioral barriers to closing the energy efficiency gap. The research shows that consistent results on energy-efficiency programs' effectiveness are elusive, and suggests that the ultimate cause of difficulties in measuring and addressing the energy efficiency gap might be *heterogeneity of needs* in the target demographic. Specifically, different issues are relevant to different consumers and consumer groups, making one-size-fits-all efforts effective only to a limited audience and less effective to other audiences. This dissertation contends that *games* have the potential to address the heterogeneity in consumer agency comprising of varying interests, needs, preparedness and resources, by harnessing game characteristics such as designed flexibility, voluntary participation, community-building, competition, incentives, pleasure motive, and skill-building. In addition, games can provide necessary triggers to create engagement. *Pervasive games* in particular make ordinary life action part of game play. Chapter 3

addresses the methodology and data collection in order to study the hypotheses that "playing a public or targeted, interactive, pervasive game can lead to awareness and learning about energy-savings; can engender willingness to engage in energy-saving behavior; willingness to make energy saving investments; and lead to energy-savings in homes and schools." A short history of energy games is outlined in order to contextualize the design of *pervasive energy games* for this research (Chapter 2).

An opportunity to test the contention of games' potential to address the heterogeneity of needs emerged in 2014 with the Georgetown University Energy Prize (GUEP), a nationwide competition open to American cities with populations between 5,000 and 250,000 people. At the initiative of this dissertation's author, and in partnership with North Dakota State University and two local utilities (Cass County Electric Cooperative and Xcel Energy), the City of Fargo, ND, entered the GUEP competition in 2014. Under the leadership of this dissertation's author, the project team organized under the name "efargo." Of the fifty cities that successfully achieved GUEP semifinalist status, and the ten finalist cities, Fargo emerged the winner of the Georgetown University Energy Prize, successfully reducing municipal and residential energy use in the City (Chapter 8).

Serious pervasive energy games that include building- and behavior-based approaches were researched, planned, designed and implemented by this dissertation's author and the efargo team. From 2015-2018, data was collected prior to, during and after the implementation of two pervasive energy games. The first game, the *efargo game,* was a pervasive energy game open to public participation; it was implemented once in Spring 2016 over an 8-week game period and a 1-week kick-off period. The efargo game was designed to allow gamers to act on energy saving behaviors in their homes through game play (Chapter 4).

The second game, the *efargo Energy Challenge,* was a targeted pervasive energy game implemented in elementary and middle schools. Four design iterations of the efargo Energy Challenge were implemented and tested from 2016-2018. All the iterations asked participating schools to complete various educational and energy-saving (fixing) activities over a 3-6 week period in their schools. The game design, game tools, reporting structures and timeline were refined in response to feedback from teachers and students every year (Chapter 6). Ongoing data collection through surveys, game play and energy-use tracking in partnership with the utilities, provided the information for assessing the games (Chapters 5, 7 and 8).

The following hypotheses were tested:

1. Playing a serious pervasive energy game leads to awareness and learning about energy-savings was confirmed.
2. Playing a serious pervasive energy game can engender a willingness to engage in energy-saving behavior showed positive results.
3. Playing a serious pervasive energy game can engender a willingness to make energy-saving investments was confirmed.
4. Playing a serious pervasive energy game can lead to energy savings showed positive results.

All four hypotheses were supported by positive findings.

The dissertation concludes (Chapter 9) with concepts for future games frameworks that may address limitations, and provide an opportunity to do further research on unaddressed concepts, successful, unsuccessful, and inconclusive results.

1.0 Introduction: Why play games?

Summary

With reference to relevant background literature, this chapter describes the overall context in which this dissertation is situated, and outlines the specific needs which the work seeks to address. Specifically, the chapter cites the urgency of global climate change and the need to respond through large-scale energy-saving actions. It identifies the energy-efficiency gap (i. e., the failure of end-users to adopt energy- and cost-saving behaviors). It explains the dissertation's focus on games as a means of overcoming the energy-efficiency gap.

The chapter establishes a specific focus on the state of North Dakota, and specifically the city of Fargo, deriving from the state's extreme cold-climate conditions, its population trends characterized by cyclical growth and shrinkage, the strong presence of the fossil fuels industry, and energy costs that are nearly the lowest in the nation. North Dakota and Fargo in particular are thereby positioned as in need of experimental ideas addressing issues of energy efficiency and energy-use reduction.

1.1 The climate change problem: Why play games?

Long-term temperature observations are consistent and widespread evidence of a warming planet. Global annual average temperature has increased by more than 1.2oF for the period 1951-2010. Further temperature records indicate that recent global average temperatures are much higher and are rising faster than any time in the past 1700 years. With high confidence, the likely range of the human contribution to the global mean temperature increase over the period 1951-2010 is 1.1oF to 1.4oF (United States Global Change Research Program, 2018). Also with high confidence, the likely contributions of natural forcing and internal variability to global temperature change over the same period are minor. The global influence of natural variability such as El Niño events and recurring patterns of ocean-atmosphere interactions is limited to a small fraction of observed climate trends even though it impacts temperature and precipitation regionally over periods of months and years. The magnitude of climate change will depend primarily on the greenhouse gases (GHG) emitted globally. With significant reduction in GHG emissions the global average temperature rise could be limited to 3.6oF. Even stabilizing GHG emissions at current levels would cause at least an additional 1.1oF warming over this century (United States Global Change Research Program, 2018, Ch. 2).

Of all sectors, buildings have the largest share of energy use in the United States (U. S. Energy Information Administration, 2020b). They consequently have a large role to play in efforts to reduce energy use and impact global warming trends. In the United States, buildings consume almost 40% of all energy produced (U. S. Energy Information Administration, 2019), over 74% of all electricity produced (U. S. Energy Information Administration, 2020a) and are responsible for producing over 36% of CO_2 emissions (U. S. Energy Information Administration, 2018) (Table 1.1, Table 1.2, and Table 1.3). Over the lifetime of buildings, 80-90% of this energy use is in operations (heating, cooling, lighting, and devices) whereas only 10-20% is in embodied energy (manufacturing and demolition) (Ramesh et al., 2010) for a code-compliant building for its time of construction. As a result, investments in reduction of operational energy use of buildings can have a large impact on reducing building energy use, global warming trends and resultant climate change.

Table 1.1. U. S. Energy Use by End-Use Sector, 2019 totals
(After U. S. Energy Information Administration, 2020b)

End-Use Sector	Consumption (trillion Btu)	% of Total Energy
Buildings (Residential and Commercial)	39,400	39.32%
Industrial	32,575	32.51%
Transportation	28,283	28.22%
total	100,215	100%

Table 1.2. U. S. Electricity Use by Sector, 2019 totals

End-Use Sector	% of electricity consumption
Buildings (Residential and Commercial)	74.40%

Industrial	25.40%
Transportation	0.20%
total	100%

Table 1.3: Carbon Dioxide Emissions for U. S. Buildings, 2018 totals (After U. S. Energy Information Administration, 2018), Figure 4,Energy-related CO2 by end-use sectors, 1990-2018]

End-Use Sector	Total CO2 emissions (million metric tons)	Percent of Total
Buildings (Residential and Commercial)	1,908	36.21%
Other sources	3,361	63.79%
Total	5,269	100%

1.1.1 Urban large-scale actions

Per Raman (2009), estimated population growth will result in a proportionate 40% demand growth for new building stock, and 70% of the existing building stock will still be functional in 2050. As of 2018, an estimated 55% of the world's population lives in urban areas, a proportion expected to increase to 68% by 2050 (United Nations, 2018). Seto et al. (2014) project that urban areas are responsible for 67%-76% of global energy use and 75% of carbon emissions. The urban heat island effect results in daytime temperatures that are 0.9-7.2oF higher and night time temperatures that are 1.8 - 4.5oF higher than rural areas. Cities with larger and denser populations have larger temperature differences, and the urban heat island effect is projected to strengthen in the future as population densities and structures grow (United States Global Change Research Program, 2018). It follows that the existing building stock in cities needs urgent and immediate attention.

Creutzig et al (2015) argue that urban interventions have the potential to reduce global energy use by 26%. Kousky & Schneider (2003) argue that even though greenhouse gas emissions are seen as a global problem, municipalities control major factors impacting greenhouse gas emissions (such as land use policy, urban morphology, building regulations, transit and waste). Globally, the problem and opportunity is of such magnitude and complexity that action at the scale of single structures in the built environment is insufficient; actions at larger scales must be tested. These conditions present an opportunity for impacting global energy use and carbon emissions by acting at the city scale (Hoornweg et al., 2011). Actions at the city scale may allow perceptible shifts to occur in globally significant problems while simultaneously addressing and engaging local cultures, connected systems, and infrastructures that can act as cohesive wholes.

1.1.2 Fast population growth in North Dakota[1] and related poor performance measures

Tremendous changes are occurring throughout North Dakota, in and beyond the Bakken oil fields (Figure 1.1; Figure 1.2). Studies estimate the range of recoverable oil in North Dakota at twenty-five times more than the volume estimated in 1995 (U. S. Geological Survey, 2008). Even assuming the smallest estimate, the cycle of oil boom and bust (due to instability in oil prices) could persist for decades. In the 2010-2018 period, population growth in the Bakken oilfield city of Williston, ND was estimated at 70% (United States Census Bureau, 2019). Estimates that include temporary workers are as high as 30,000 people for a town that was 12,512 in 2010, constituting more than 100% growth (Dalrymple, 2016). Compared to the phenomenal growth in the western part of the state, the record-breaking growth in eastern North Dakota is less frenzied. In the 2010-2018 period, eastern North Dakota cities like Fargo, West Fargo and Grand Forks grew 18.2%, 41.4%, and 7.6% respectively (United States Census Bureau, 2019).

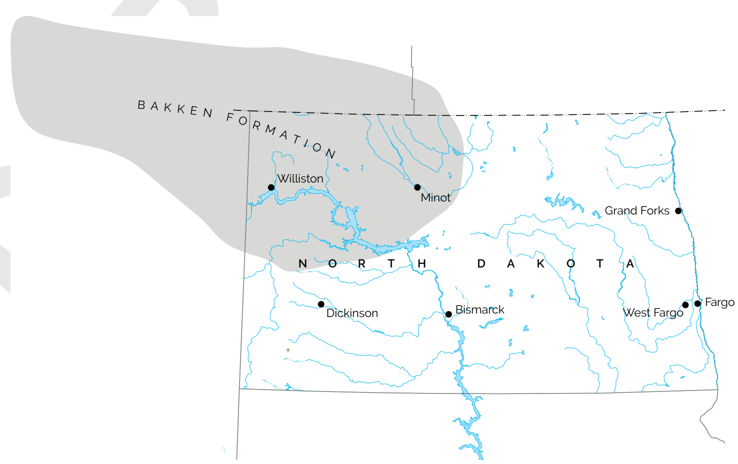


Figure 1.1: Bakken Formation in North Dakota

1 Fargo, North Dakota was the domicile of the author for part of the timeline of this dissertation and the test site for the research conducted in this dissertation.

Figure 1.2: North Dakota Oil Boom (accessed from nationalgeographic.com on 5/7/2016)

According to the U. S. Energy Information Administration (2017a, 2017b, 2017c), North Dakota ranks the second highest in total energy expenditures per capita overall ($7,087 per capita in 2017), third highest in total energy consumed per capita overall (813 MBtu in 2017) and the highest in residential energy consumption estimates per capita (91.5 MBtu).

Given North Dakota's cold-climate conditions, its remarkable population growth and shrinkage cycles, the strong presence of the fossil fuels industry, and energy costs that are nearly the lowest in the nation, it is not surprising that the state is tied for fifth-last in in the number of energy-use reduction related programs (N. C. Clean Energy Technology Center, n. d.). Due to these difficult circumstances, North Dakota provides an urgent need and a relevant test bed for experimental ideas addressing issues of energy efficiency and energy use reduction.

Yet, despite considerable challenges, due to the fast growth in the economy and low employment, there is an environment of optimism, an energized population, and a collective sentiment of planning for the post-oil future, as evidenced by the adoption of the Go2030 plan as policy by the City of Fargo with large-scale citizen participation (City of Fargo, 2014). The magnitude of opportunities and problems in North Dakota and in the City of Fargo requires deliberate action. Actions at the scale of one-structure-at-a-time, and even one-neighborhood-at a-time, though necessary, do not tap into the current cultural ethos of an optimistic and engaged citizenry.

1.2 The case for energy efficiency

Energy efficiency in buildings is a rich area for potential innovation in process, tools and strategies. Energy efficiency is the cheapest method to provide Americans with electricity (Molina, 2014). Energy efficiency offers a vast, low-cost energy resource for the U.S. economy, but only if the nation can craft a comprehensive and innovative approach to unlock it; if executed at scale, such a program could reduce end-use energy consumption in 2020 by 9.1 quadrillion BTUs, roughly 23 percent of projected demand, potentially abating up to 1.1 gigatons of greenhouse gases annually (Granade et al., 2009). Though energy efficiency is a much-needed and necessary strategy to reduce energy use, the energy efficiency gap as defined by Hirst & Brown (1990) needs to be addressed. Especially in a state like North Dakota where incentives are the third-lowest in the country, a policy-based approach, though necessary, does not address the financial investments that existing buildings will need, to improve performance.

1.2.1 What is the energy efficiency gap?

Despite the fact that energy-saving measures have cost-saving potential, several studies identify barriers preventing owners and occupants from pursuing them. Hirst & Brown (1990), in coining the term “energy efficiency gap,” note the failure of households, businesses, manufacturers and government agencies to take full advantage of cost-effective energy-conserving opportunities. They identify behavioral barriers under the control of occupants, including attitudes towards energy efficiency, the perceived risk of energy-efficiency investments, and barriers that were not under the control of the occupants such as information gaps, and misplaced incentives.

Causes of the energy efficiency gap are difficult to pinpoint and consistent results on energy-efficiency programs’ effectiveness are elusive. Information programs alone have limited effects on energy consumption (Abrahamse et al., 2005; Stern, 1985; Stern & Aronson, 1984). Combining energy-use reduction information with comparison information for consumers produces results

(Schultz, Khazian, & Zaleski, 2008), and a social/informational comparison approach can be effective (Ayres, Raseman, & Shih, 2013). Financial incentives may not be significant or effective (Joskow & Marron 1992; Arimura, Li, Newell, & Palmer, 2012; Auffhammer, Blumstein, & Fowlie, 2008; Rivers & Jaccard, 2011).

Because games accommodate heterogeneous audiences, allowing people to play based on interests and motivations, they suggest a potential way to bridge the energy efficiency gap and reduce energy use. Games can accommodate heterogeneity through design flexibility, allowing game players to act based on abilities, make decisions based on needs, and play meaningfully and enjoyably (Harteveld, 2011).

Jaffe & Stavins (1994) define the optimal level of energy efficiency as "that which is consistent with efficient overall resource use, including efficient use of government resources." They identify market and non-market factors related to the limited success of energy-efficiency initiatives. Market factors include (1) information that has public good attributes that can be used by many people without compensation to the creator of the information; (2) the act of adoption is a source of information for which the initial adopter is not compensated; (3) when the adopter of the energy efficiency measure is a different entity than the energy bill payer, it is likely to not have optimal diffusion (split incentives) or there is a gap in the communication of information between the provider, adopter, and payer. Non-market explanations identified include (1) uncertainty about future energy prices make actual savings and return on investment hard to calculate; (2) qualitative attributes of efficient technologies make them less desirable; (3) although energy efficiency measures might be cost-effective, this does not mitigate the unaffordability of these measures for a percentage of individual investors. Finally and most importantly, Jaffe & Stavins (1994) note that there is a real inertia in adoption behavior and attribute it to one or more of market and nonmarket causes.

Fleiter, Schleich, & Ravivanpong (2012) identify several barriers to achieving energy efficiency for small and medium-sized businesses. They analyze businesses through case studies and surveys to identify the following barriers: (1) high initial investment costs, (2) lack of capital, (3) lack of access to capital, (4) disruption of core production process, and (5) quality of energy audits and auditors.

Head & Hunt (2014) identify clear barriers to adoption of efficiency measures. They find that 48% of Americans think their homes are already energy-efficient and therefore do not consider improving efficiency a priority, or do not think it is possible to become more efficient. Allcott & Greenstone (2012), even as they argue against the magnitude of the energy efficiency gap claimed by engineering-based studies, acknowledge that due to consumers' access to imperfect information, energy use may increase in various settings due to investment inefficiencies. They state that because consumers are heterogeneous in the degree of their investment inefficiencies, it is crucial to design targeted policies. They argue that "[p]olicy evaluations must therefore consider not just how much a policy increases energy efficiency, but what types of consumers are induced to become more energy efficient. Welfare gains will be larger from a policy that preferentially affects the decisions of consumers subject to investment inefficiencies" (Allcott & Greenstone, 2012, 5). They add that targeted policies have the potential to generate larger welfare gains than general subsidies or mandates. In general, they conclude that this area is ripe for rigorous empirical research which should utilize randomized controlled trials and quasi-experimental techniques to estimate the impacts of energy efficiency programs on heterogeneous consumer types.

1.2.2 What has been done to address the energy efficiency gap?

Synthesizing large category groups for the gap are (1) financial (unaffordability of the adoption costs, lack of incentives); (2) informational (lack of accurate and customized information from reliable resources, lack of how-to, misinformation), and (3) behavioral (inertia in adoption, attitudes towards energy efficiency, perceived risks). Gillingham & Palmer (2014) outline and discuss three primary approaches to addressing energy efficiency: information strategies, economic incentives, and energy efficiency standards. Information strategies include low- or no-cost energy audits for households; product labels such as Energy Guide or Energy Star certification for buildings and the Energy Star label for products; and public disclosure of buildings' energy use.

Financial incentives in the form of rebates, tax incentives, and low-cost loans are used to encourage energy-efficient purchase and use behavior. Documented concerns about the effectiveness of such approaches in reducing energy use include the requirements for funding sources, a rebound effect which reduces energy savings, and the use of programs by free-riders who avail themselves of the subsidy but would have bought the efficient product without the program (Joskow & Marron, 1992). Studies report mixed cost-effectiveness of such programs, i.e., that programs' cost-effectiveness compared to estimated costs by utilities is not significant (Arimura, Li, Newell, & Palmer, 2012; Auffhammer, Blumstein, & Fowlie, 2008; Rivers & Jaccard, 2011).

In the United States, building energy codes and standards are used as a mechanism to pursue energy efficiency. Studies cited by Gillingham & Palmer (2014) show that the effectiveness of building efficiency standards have mixed results. Among the studies cited by Gillingham & Palmer (2014), Jaffe & Stavins (1995) find no evidence that building codes have any effect on average state efficiency levels, while Aroonruengsawat, Auffhammer, & Sanstad (2012) find a significant effect of building codes on residential per capita electricity consumption, ranging from 0.3-5%, and Jacobsen & Kotchen (2013) find that Florida's statewide energy code (implemented in 2002) "appears to have caused a 4% decrease in annual electricity consumption and a 6% decrease in annual natural gas consumption."

In summary, research shows that the causes of the energy efficiency gap are difficult to explain and pinpoint, and consistent results on energy-efficiency programs' effectiveness are elusive. Recent studies include growing evidence that "behavioral anomalies may influence investment decisions, and such anomalies, ranging from self-control problems to reference dependent preferences to biased beliefs and inattention, are becoming a commonly cited explanation for the energy efficiency gap" (Gillingham & Palmer, 2014). It is becoming increasingly clear that heterogeneity might be the ultimate cause of difficulties in measuring and addressing the energy efficiency gap. Different issues are relevant to different consumer groups making one-size-fits-all efforts effective only to a limited audience and less effective to other audiences. Heterogeneity presents researchers with both an opportunity and a challenge (Gillingham &

Palmer, 2014).

1.3 Why are games a potential solution?

This dissertation contends that games provide a potential answer for bridging the energy efficiency gap and reducing energy use because of their ability to accommodate a heterogeneous target audience through game design, allowing people to enter and play the game based on their own needs, interests, motivations, goals and resources (agency/ability). Game and play characteristics include "voluntary participation, an avenue to do satisfying work, ability to succeed based purely on skill, knowledge development in the game, ability to have social connection with others, [and] the chance to be part of something meaningful" (McGonigal, 2011), i. e., the play motivation in human beings (Huizinga, 1962). These characteristics can be instrumental in engaging gamers in the game and its goals. Fogg (2009) discusses the need for "triggers" or "nudges" as a component of persuasion or behavior shift given the presence of motivation and ability, which may be varied in the audience. This project argues that games may serve as a trigger or nudge to audiences of varied abilities, resources, preparedness and interests, when designed with the necessary attention to the concepts of Reality (agency or ability of gamers), Meaning (the motivations of gamers) and Play (competition, skill-building, fun and other aspect of play) (Harteveld, 2011). This allows gamers flexibility where people have the ability to take actions based on their abilities (Reality), make decisions based on their needs (Reality) and play the game as is most meaningful (Meaning) and enjoyable (Play) to them. Ferri & Coppock (2013) argue that gaming can promote "active, responsible forms of citizenship, awareness-raising on key sociocultural and political issues and the promotion of more participative urban design and development processes." Taking into consideration that gaming can promote active, responsible forms of citizenship (Poplin, 2011; Poplin, 2012; Ferri & Coppock, 2013), games may also be able to create an active and aware community with regards to energy issues and their larger impacts.

1.3.1 Play and games

Huizinga, establishing play as an essential human quality and need, argues that "the great archetypal activities of human society," such as language, myth, and ritual, "are permeated with play from the start." (Huizinga, 1962, 4). Hejdenberg (2005) relates the psychology of games to Abraham Maslow's hierarchy of human needs and discusses how games fulfill higher needs, such as esteem, cognition, self-actualization and transcendence. Play is the unstructured, purposeless participation in an activity for the sake of pleasure and entertainment such as children at play, while games are structured, have rules and incentives, participants (gamers or gamer groups) that identify with each other, make decisions about how to use their resources, hold secrets and have purpose (as in achieving a goal or level of winning against the gamers/ gamer groups). In other words, games are systems with various components creating an environment with interactions (Erickson, Ganz, Wagner, Kolos, & Li, 2011).

McGonigal traces game-play back three thousand years to the Histories by Herodotus, where alternating days of game-play and days of eating helped an ancient civilization escape famine for eighteen years (McGonigal, 2011). McGonigal argues that the essential human attributes of games, such as voluntary participation, escape from all that is real and ordinary, an avenue to do satisfying work, ability to succeed based purely on skill, have social connection with others, and the chance to be part of something meaningful, are essential to happiness and positive emotions. A total of 2.3 billion gamers worldwide are expected to generate $137.9 billion in revenues from digital games in 2018 (Wijman, 2018). McGonigal asks "[i]nstead of teetering on the tipping point between games and reality, what if we threw ourselves off the scale and tried something else entirely? What if we decided to use everything we know about game design to fix what's wrong with reality?" (McGonigal, 2011, 7). McGonigal's work ultimately contends that games due to their attributes have the ability to engage and motivate the citizenry towards helping themselves and at the same time through their actions have an impact on serious issues such as global warming and climate change. Such games that are not intended to be played primarily for amusement are termed Serious Games (Abt, 1970).

Gaming can promote "active, responsible forms of citizenship, awareness-raising on key sociocultural and political issues and the promotion of more participative urban design and development processes" (Ferri & Coppock, 2013, 120). Poplin argues that "games can potentially enable easier and joyful learning processes and bring playfulness into the process of public participation" (Poplin, 2011, 3). In her extensive work in playful participation in urban planning and the design of the Next Campus game, she establishes the basic elements of a game as (1) the game environment; (2) the game objects (in this case actual buildings and events); (3) Goals (most satisfactory urban planning solution); (4) Rules that include resources and consequences; (5) Player (in this case an individual) and (6) the map, physical model and digital model of the game that I am collectively calling game tools.

Overlapping qualities of urban and serious games, Serious Urban Games are "playful, organized practices, taking place in urban environments with some kind of technological/digital support and serving social purpose" (Ferri & Coppock, 2013). Adding qualities of immersive and big urban games, and following Poplin's game elements, these game characteristics emerge that can make a game design particularly suited to addressing the financial, informational and behavioral barriers of the energy efficiency gap.

1.3.2 The community as an ecology of games

Long (1958), based on a year of field study in the Boston metro area, proposes that "the local community can be usefully conceptualized as an ecology of games." He notes that games provide goals to gamers, sense of structure, the sense of being on a team, and determinate roles and strategies and tactics to achieve those goals. In making the local community analogous to a game, Long contends that games are not trivial but quite the opposite. He contends that "man is a game-playing and a game-creating animal … and that it is through games or activities analogous to game-playing that he achieves a satisfactory sense of significance and a meaningful role." He posits politics, banking, contracting, journalism, civic organizations, and ecclesiastics as interconnected, albeit different, games sharing a common locality where each game has well-established goals, known and understood ways to behave and a set of strategies and tactics for gamers. Long links all the games of the locality into the social game as the integrator of all games where social acceptance or recognition is the goal. For Long, the importance is in the linking together of various constituencies and their games to make possible cooperative actions, (vaguely) shared aspirations and common goals.

1.4 Games and Fargo

Within this context, and triggered by a national competition,[1] this dissertation's author established a partnership called efargo between North Dakota State University, the City of

1 See Chapter 3.

Fargo, and local utilities in 2014. The partnership positioned the locality of Fargo as an ecology of games with several interconnected games and gamers as actors of note, The University (through the efargo research group) provided design, scholarship, research, production and implementation. The utilities provided information and connection to their customer bases while positioning their participation as a positive sign of the need to reduce utility costs for their customers. The City provided permissions, resources, structure and partnerships with personnel in various existing frameworks within the community. Several collaborators with shared goals such as public schools, area business groups, area nonprofits, church groups, environmental activist, community volunteers came together to provide events, spaces, schedules and opportunities for the efargo team to implement the idea that the community could come together to achieve shifts in energy use for the City while playing games. As a central part of the efargo effort and this research, this dissertation's author and the efargo team designed and implemented games enabling people to act on buildings to reduce energy use as part of game play. This dissertation describes the research background, game design, implementation, and data collection structures and concludes with the results of these efforts.

2.0 Background: Serious Pervasive Energy Games

Summary

This chapter briefly defines serious games, pervasive games, and energy games, and briefly outlines a history of serious energy games. It argues for the relevance of serious pervasive energy games as a method of closing the energy-efficiency gap based on a literature search of the outcomes of serious pervasive energy games. It also discusses the gaps in the design, research and outcomes of serious pervasive energy games. It concludes with a discussion of some of the gaps that this dissertation seeks to study.

Portions of this chapter incorporate and adapt previously published material (Srivastava, 2019b). Both works originate from the research effort to have a comprehensive documentation of Serious Energy Games.

2.1 Introduction

The world of Energy Games, a subcategory of Serious Games, may be able to provide game solutions to serious problems such as global warming and climate change due to their ability to engage people on their own terms. Energy Games are designed and deployed with the serious purposes of impacting energy waste and use, with the goal of promoting energy efficiency, energy use reduction and other pro-environmental education, engagement, and behavior changes related to energy use. Here, such games are referred to as Serious Energy Games (SEGs). SEGs typically target purposes of information delivery, behavior programs, and social interaction (Mazur-Stommen & Farley, 2013). Categorizations of SEGs are introduced in order to provide an overview of their history, typologies, locations, gamers, designers, platforms and purposes. As a further subset of games, this chapter also discusses Serious Pervasive Energy Games (SPEGs), and provides the context in which the SPEGs for this dissertation have been designed, implemented and analyzed. This overview also identifies the gaps for developing SPEGs aimed at addressing energy use reductions.

2.2 Serious Games

> "Games may be played seriously or casually … Serious … games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. This does not mean that serious games are not, or should not be, entertaining. We reject the somewhat Calvinistic notion that serious and virtuous activities cannot be 'fun.' … The term 'serious' is also used in the sense of study, relating to matters of great interest and importance, raising questions not easily solved, and having important possible consequences." (Abt, 1970, 9-10)

In 1970, Abt defined Serious Games as those meant for educational purposes, specifically for removing gaps in educational practices and experimental games (Abt, 1970). The definition of Serious Games has evolved to include fun games with non-entertainment goals (Michael & Chen, 2006). Serious Games may be of many different types including but not limited to Persuasive Games, Social Games, Simulation Games, and Pervasive Games. Deterding et al. (2011) identify serious pervasive games at the intersection of serious games (i. e., games used in non-game contexts for serious purposes) and games that are extended beyond entertainment (Figure 2.1).

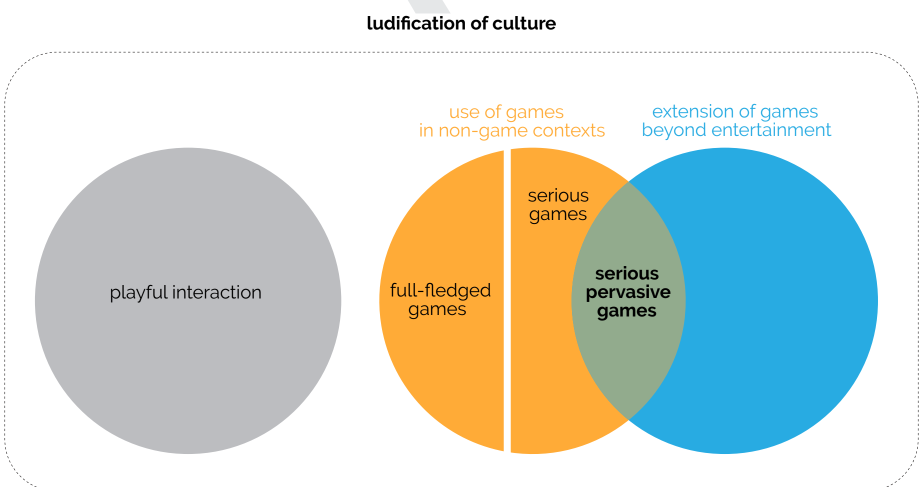


Figure 2.1. Ludification of Culture (after Deterding et al., 2011).

Within Ratan and Ritterfield's database (Ratan & Ritterfield, 2009) of Serious Games, the two largest categories are games for education (constituting the largest category, at 63% of the total), and games for social change (the next highest group in Serious Games, comprising

14% of the total). Games aimed at protecting the environment are included in the education and social change categories. Within the category of Serious Games aimed at protecting the environment, Serious Energy Games, or SEGs, have (serious) goals of impacting energy use through outcomes such as educating gamers about energy issues and creating behavior change towards energy-use reduction. Games that impact energy use in cities and buildings (sometimes collectively referred to as the built environment) may be able to contribute to solutions for the climate change crisis. These games may create structures where gamers can design sustainable cities or neighborhoods, or they may teach about how individual buildings (typically homes) use or waste energy, or they may nudge people towards changing energy-use behaviors and cause energy savings. According to Ritterfield et al games for social change and those which focus on problem solving are potential areas of development (Ritterfield, Cody, & Vorderer, 2009). Energy games that aim to change energy use behavior and address the serious problem of the energy efficiency gap would fall into this category.

2.2 Serious Energy Games

In order to better understand the impacts and potential of Serious Energy Games, a systematic, online, keyword-based search was conducted which included academic literature and sources beyond academic literature such as game reviews, articles, and information which are typically hosted on non-scholarly online gaming magazines. Thus, the keyword search included websites, conferences, game review portals such as blogs, game reports, game competitions and gaming industry publications (Ecogamer, n. d., Games4Sustainability, n. d., BoardGameGeek, n. d., Anderson, 2009). Table 2.1 shows the keywords (and keyword phrases or combinations) utilized intermittently over a four year period to complete the searches.

Table 2.1. Keywords (Srivastava, 2019b).

energy games, serious energy games, pervasive games, pervasive energy games, persuasive energy games, educational energy games, immersive energy games, urban energy games, simulation energy games, social energy games, civic energy games, energy efficiency games, digital energy games, energy board games, architectural energy games, architecture + energy saving games, fun energy games, forms of energy games, energy games for students, energy games for science, energy conservation games, energy efficiency games, energy-saving games, renewable energy games, energy games for k-12, open access energy game, energy games for elementary schools (also search middle schools, high schools), energy conservation games, energy games for building owners, energy games for building lessors or renters, online energy games, multi-player energy games, single-player energy games, two-player or dual-player energy games, energy games for kids

In secondary searches, the word “games” in the above list was substituted with “race”, “play”, “competition”, “program” and “prize,” in order to distinguish games from other types of activities such as competitions or prizes that include some component of gaming.[1]

2.2.1 Organizing Serious Energy Games

The search returned 474 game results (Figure 2.2). 247 of the 474 results are focused primarily on energy issues such as energy production, energy sources, energy efficiency and energy-use behavior. 172 of the results address broader environmental subject matter, such as water, global warming, climate change, air quality, and resiliency, of which energy might be a minor concern or indirect consequence. Another 55 results simultaneously address broader environmental issues while also including energy issues.

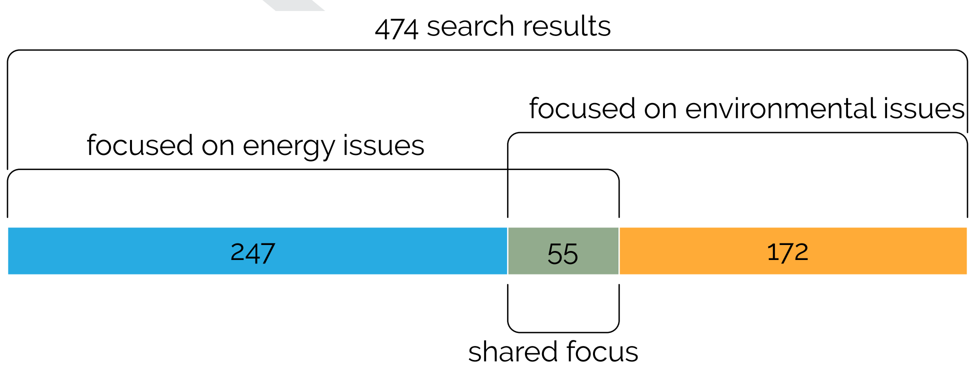


Figure 2.2. Subject Matter Focus of Keyword Search Results.

The keyword search results were further analyzed to identify whether they were games, or

1 Findings are discussed in Srivastava (2019b).

were instead examples of gamifications, competitions, or other entity (Figure 2.3). Gamifications include “the use of game design elements in non-game contexts” (Deterding et al., 2011, 9). Competitions are a subset of games: while the purpose of playing games is typically enjoyment (particularly having fun as an immediate reward), competitions incorporate elements of games with delayed rewards for a pro-social or pro-environmental purpose (Vine & Jones, 2016). Of the 474 unique search results, 318 are games; 76 are challenges or competitions; 31 are publications about energy-related games, competitions, prizes, gamifications or programs; 28 are tools or systems to reduce energy use with a game component or sub-set; 16 are gamifications of existing efforts; and 5 are prizes (competitions with a large incentive) with game characteristics.

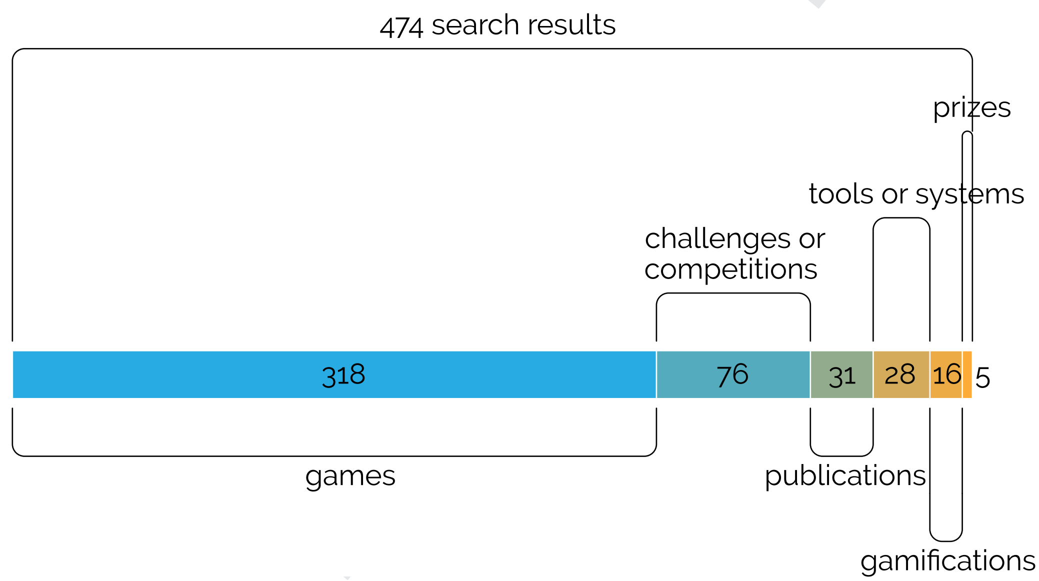


Figure 2.3. Games as a subset of Search Results.

The competitions, prizes, gamifications, programs, and prizes are excluded from further analysis, leaving the 318 games that specifically relate to either energy issues or environmental issues with energy as a considerable part of those broader considerations. Of these 318 games, three sub-categories emerged (Figure 2.4) that allowed for further narrowing down of games to consider in this research.

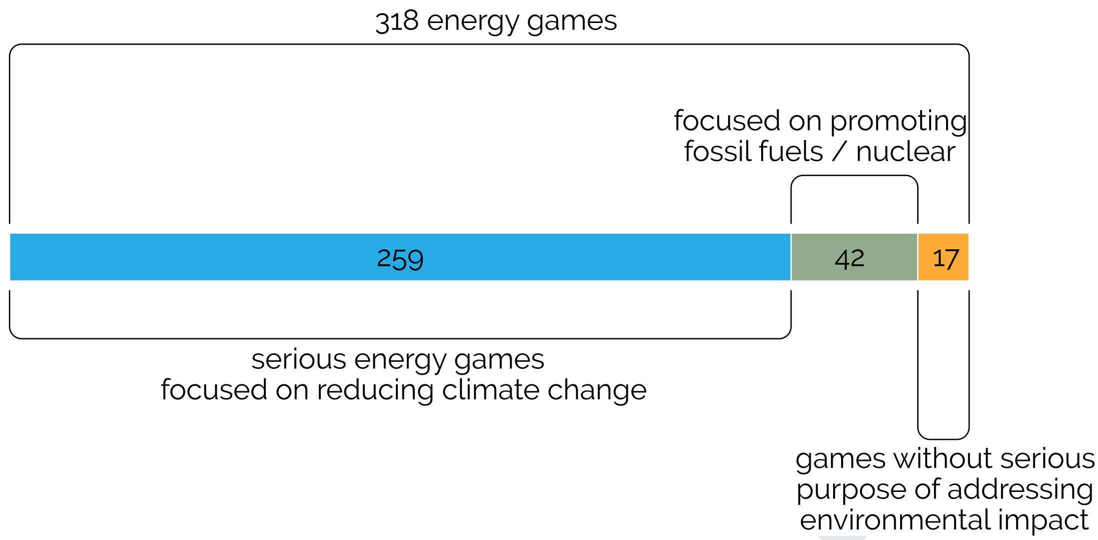


Figure 2.4. Sub-categories of energy games.

The first subcategory, representing the majority of energy games, are Serious Energy Games (259 games) focused on reducing climate changes due to energy use. In general, the purpose of these games is educating about and creating awareness of energy waste, teaching about energy efficiency and causing energy use reduction. These games may also educate gamers about energy production, resources, transportation and use in order to teach about environmental impacts. The second subcategory (42 games) includes games with similar strategies for education related to promote fossil fuels energy production, resources, transportation and use (and in one game, nuclear) fuels for commercial purposes (Anderson, 2009). For example, the purpose of the game Alaska Pipeline was to "refute the attacks on the pipeline and then get the permit to build it. ... The game's underlying purpose is [was] to educate and create support for the Alaska Pipeline to be built" (Alaska pipeline: The energy crisis game, n. d.). According to the Alaska Historical society, "In this game, environmental protection is obviously a losing strategy" (Pipeline Games, 2013). These games were excluded from this analysis since their goals, albeit serious, were not aligned with the purpose of this dissertation.

The final subcategory of games that emerged were those (17 games) that had environmental issues or energy issues as the narrative, story or setting but did not have the serious purpose of addressing environmental impact due to energy use. At times, the purpose of these games was entirely unrelated to environmental or energy issues. For example, both MIT CleanStart: Simulating a Clean Energy Startup and the Energy Crisis Game are games about management skills. Similarly, Who Left theLights On is a logic puzzle. These games were also excluded from this analysis of Serious Energy Games.

Further, of the 259 Serious Energy Games found, 132 of the games are solely focused on larger environmental issues such as large scale energy production and transportation. The remaining 95 games which are focused solely on energy consumption, education, behavior, energy reduction, and energy efficiency (Figure 2.5). and 32 games that focus on energy efficiency and environmental issues were finally narrowed down for inclusion. Thus, a total of 127 games are the background reference for this dissertation (Table 2.2).

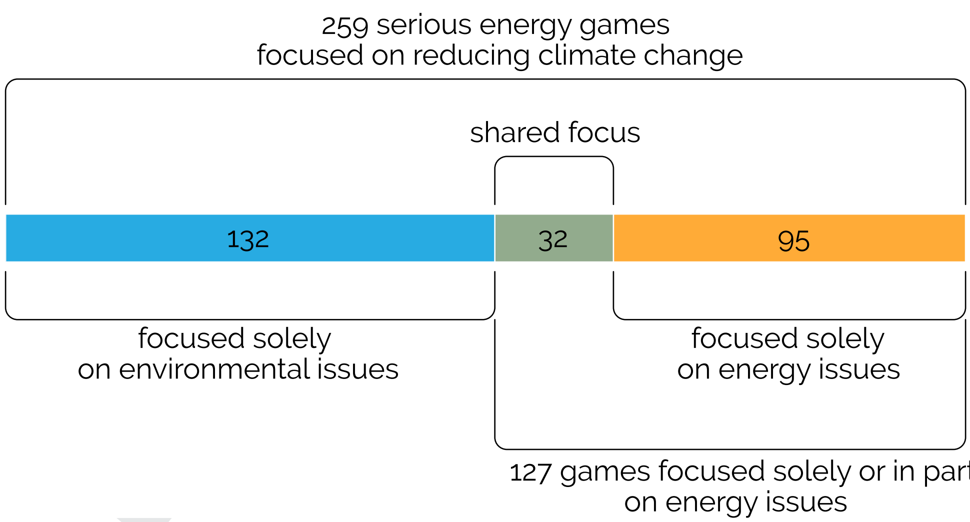


Figure 2.5. Subject matter focus of Serious Energy Games (after Srivastava, 2019b)

Table 2.2: Games (Srivastava, 2019b).

No.	Name	Year (if known)	Published Reference(s) or Game Links
1	2020 Energy	unknown	Bourazeri, Pitt, & Arnab (2017, 4); Flor & Lavrova (2016); A serious game about energy efficiency, renewable energy and sustainable development (n. d.)
2	A Day Full of Energy	2006	A day full of energy (n. d.); A day full of energy: Presenters' notes (n. d.)

No.	Name	Year (if known)	Published Reference(s) or Game Links
3	Age of Energy	2015	Whalen & Kijne (2019); New IoT project for Manchester (2017); Biparva (2015); Age of energy (n. d.)
4	Agents Against Power Waste	2010	Svahn & Waern (2014)
5	BIM (Building Information Modeling) Game	2009	Yang (2009)
6	Brainergy	2011	Lawton (2011)
7	Carbon Footprint Reduction Game	unknown	Using gamification to reduce energy use (2014); Grossberg et al. (2015, 17)
8	CityOne	2010	Bourazeri, Pitt, & Arnab (2017, 3)
9	CityOPT	2014	Audrain et al. (2016); Gamification motivates consumers ... (2017); Santinelli et al. (2016)
10	Clarkson Energy Choices Board Game	2009	Energy choices board game (2009)
11	Climate Policy (modification of CO2)	2015	Castronova & Knowles (2015)
12	Climway (ex Clim City)	2008	Wu & Lee (2015); Katsaliaki & Mustafee (2012); Sanchez Burbano et al. (2018, 228-229); Clim'Way (n. d.)
13	Collapsus	2011	Raessens (2019); Barrios-O'Neill & Hook (2016); Collapsus (n. d.)
14	Conserving Energy	unknown	Conserving Energy (n. d.)
15	Copenhagen Challenge	2009	Liarakou et al. (2012); EU-India cooperation on climate change (2009); This game has green message for children (2009); Copenhagen challenge: A game on climate change awareness (n. d.)
16	Dropoly	2012	Ashe (2012); Playing with energy (2012); What we do at Dropoly (n. d.); Grossberg et al. (2015, 39); Markham (2013)
17	ecoGator	2014	Johnson et al. (2017, 257, 262); Peham, Breitfuss, & Michalczuk (2014)
18	Electric Eddy Energy Saving Game	2015	Bringing electrical science to life (2015)
19	ElectroCity	2007	Katsaliaki & Mustafee (2012); Coakley & Garvey (2015, 139); Liarakou et al. (2012); ElectroCity (n. d.)
20	EnerCities	2009	Yang, Lin, & Liu (2017, 886); Johnson et al. (2017, 252, 254, 255, 259, 261); Harteveld & Drachen (2015, 487-488); Knol & De Vries (2011); De Vries & Knol (2011); EnerCities (n. d.)
21	EnerGAware / Energy Cat:The House of Tomorrow	2015	Casals et al. (2017); Casals et al. (2016); Energy cat: The house of tomorrow (n. d.)
22	Energetika	2011	Energetika (n. d.)
23	Energie-Spar-Spiel (Energy Saving Game)	1981	Energie-spar-spiel (n. d.)
24	Energize	2010	Energize (n. d.)
25	Energuy	2008	Liarakou et al. (2012); Energuy (n. d.)
26	Energy Activities with Energy Ant	1975, 2010	Energy activities with energy ant (n. d.)

No.	Name	Year (if known)	Published Reference(s) or Game Links
27	Energy and Global Warming	unknown	Energy and global warming (n. d.)
28	Energy Chickens	2013	Bourazeri, Pitt, & Arnab (2017, 4); Grossberg et al. (2015, 39-40); Orland et al. (2014); Coccia et al. (2013); Energy chickens: Plug load energy behavior change game (n. d.)
29	Energy Choices	2013	Scarlatos, Tomkiewicz, & Courtney (2014)
30	Energy City (FilamentGames)	2009	Franciosi & Mehring (2015); Energy city (n. d.) (b)
31	Energy City (Lightcycle Retourlogistik und Service)	2009	Energy city (n. d.) (a)
32	Energy Crisis	1977	Energy crisis (n. d.)
33	Energy Czar	1980	Energy czar (2017)
34	Energy Flows	2013	Energy flows (n. d.)
35	Energy Hogs	unknown	Yang, Lin, and Liu 2017: 886; Wood et al 2014: 1219-1220, 1222; Energy hog (n. d.)
36	Energy in Motion	unknown	Energy in motion (n. d.)
37	Energy Light Online Game	unknown	Energy light online game (n. d.)
38	Energy Meter Madness	unknown	Energy meter madness (n. d.)
39	Energy Mover	1995	Energy mover (2014)
40	Energy Ninjas	unknown	Energy ninjas (n. d.)
41	Energy Quest	unknown	Energy quest (n. d.) (b)
42	Energy Quest (Weldon Productions)	1977	Board game: Energy quest (n. d.); Energy quest (n. d.) (a)
43	Energy Safari	2016	Gugerell & Zuidema (2017); Play!UC: Playing with urban complexity (n. d.)
44	Energy Saving Online Game	unknown	Energy saving online game (n. d.)
45	Energy Smart House	2007	Energy smart house (n. d.)
46	Energy Sources	unknown	Label the energy sources (n. d.)
47	Energy Street, Energy Conservation	unknown	Energy street, energy conservation (n. d.)
48	Energy Systems	1979	Energy systems (n. d.)
49	Energy Transition Game	unknown	Verhagen, Johansson, & Jager (2017)
50	Energy Wars: The Green Revolution	2015	Energy wars (2015)
51	EnergyLife	2011	Gamberini et al. (2012); Spagnolli et al. (2011); Gamberini et al. (2011); Björkskog et al. (2010)
52	EnergyVille	2007	Flor & Lavrova (2016); Liarakou et al. (2012); Joubert & Roodt (2009); Energyville (2016)
53	ERG: The Energy Resource Game (J. Taylor)	unknown	ERG: The energy resource game (n. d.)

No.	Name	Year (if known)	Published Reference(s) or Game Links
54	ERG: The Energy Resources Game (Wolf & Laessig)	1973	Wolf & Laessig (1973)
55	Eskom Energy Planner	2013	Barrios-O'Neill & Hook (2016); Grossberg et al. (2015); Serious games: Eskom energy planner (2013)
56	Find the Power Bandit	unknown	Help find the power bandit (n. d.)
57	Fossil Fuels	unknown	Fossil Fuels (n. d.)
58	From the Generating Station to Your Home	2001	From the generating station to the home (2001)
59	Future Voltage	1989	Benders & de Vries (1989)
60	Game of Energy	2015, 2016	Schleicher (2016)
61	Genius (Total Solar Expert)	unknown	Genius serious game (n. d.)
62	Get Plugged In	unknown	Get plugged in (n. d.)
63	Ghost Hunter	2014	Banerjee & Horn (2014); Johnson et al. (2017, 254, 262)
64	Go Goals! (Sustainable Development Goals - Playing and Building the Future)	unknown	Go goals! (n. d.)
65	go2Zero (City Zen Project)	2016-17	Bekebrede, Van Bueren, & Wenzler (2018); GO2Zero (n. d.)
66	Green My Place (Save Energy Project)	2010	Cowley & Bateman (2017); Alhadeff (2010)
67	GreenPlay (Apolis Planeta)	2015-17	Csoknyai et al. (2019); Hamwi, Legardeur, & Lizarralde (2016); Green play (2015)
68	GreenSight City	2011	Leggett (2011)
69	Humans and the Environment	unknown	Humans & the environment (n. d.)
70	Hungry Mice	unknown	Hungry mice (n. d.)
71	iChoose -or- Cool Choices Game	2012	Ro et al. (2017)
72	IdleWars	2015	Tolias et al. (2015) (a), Tolias et al. (2015) (b)
73	Interactive House	unknown	Interactive house (n. d.)
74	Join the Lorax	2009	Join the Lorax and help protect the earth from global warming activity book (2009)
75	Kukui Cup Project (Makahiki)	2011	Brewer, Lee, & Johnson (2011); Grossberg et al. (2015, 26-31, 67); Johnson et al. (2012); Lee, Xu, Brewer, & Johnson (2012); Johnson et al. (2017, 256)
76	Lâchez Prise (Let Go)	2004	Lâchez prise (n. d.) (a); Lâchez prise! (n. d.) (b)
77	Last Car, the Game of the Energy Crisis	1981	Last car, the game of the energy crisis (n. d.)
78	Le Réflexe Planétaire (The Planetary Reflex)	2003	Alvarez & Michaud (2008, 27); Le réflexe planétaire (n. d.)
79	Let's Make It Go	2013	Let's make it go (2017)
80	Lolly vs. The Energy Monkeys	2004	Grossberg et al. (2015, 72)

No.	Name	Year (if known)	Published Reference(s) or Game Links
81	Ludwig	2014	Ludwig (2014); Wernbacher et al. (2012)
82	Meltdown: The Nuclear Energy Conflict Game	1987	Meltdown: The nuclear energy conflict game (n. d.)
83	Mindergie	2014	Kalz et al. (2015); Borner et al. (2014)
84	Mission Lighting	2008	Liarakou et al. (2012); D'Andrea, Ferri, & Grifoni (2010, 624); Mission lighting (n. d.)
85	Mission Possible	2014	Mission possible (2018)
86	Mobility	unknown	Mobility (2016)
87	My2050 Calculator (UK)	unknown	Chilvers & Longhurst (2016); Brown (2014, 389); DECC 2050 calculator (n. d.)
88	Mysusthouse	2006	Ellahi, Zaka, & Sultan (2017); Katsaliaki & Mustafee (2012)
89	NEPS (national energy policy simulator)	1988	Dolin & Susskind (1992)
90	Nexus! Challenge	2013	Nexus! Challenge (n. d.)
91	Nico the Ninja	unknown	Nico the ninja: A ninja's quest to save energy (n. d.)
92	OFFSET!	unknown	Play OFFSET! (n. d.)
93	Plan it Green: The Big Switch	2013	Coakley & Garvey (2015, 139); Liarakou et al. (2012); Plan it green: The big switch (n. d.)
94	Pollution Simulator	2006	Sanchez Burbano et al 2018 228, 230
95	Power Agent	2008 (first tried in 2007)	Gustafsson, Katzeff, & Bang (2009); Grossberg et al. (2015, 14, 48); Johnson et al. (2017, 255, 261-262)
96	Power Explorer	2009	Gustafsson, Bang, & Svahn (2009); Yang, Lin, & Liu (2017, 887); Skamnioti (2014); Johnson et al. (2017, 255, 261-262)
97	Power Grid	2004	Dahlin, Fenner, & Cruickshank (2015); Power grid (n. d.)
98	Power House	2011	Bourazeri, Pitt, & Arnab (2017, 3-4); Johnson et al. (2017, 257, 261-262); Flor & Lavrova (2016); Reeves et al. (2015); Grossberg et al. (2015, 40-42); Jaffe (2014)
99	Power Matrix	2013	Bourazeri, Pitt, & Arnab (2017, 3); De Simón-Martín et al. (2016); Flor & Lavrova (2016); Power your world: Siemens energy introduces the new browser game power matrix (2013)
100	Power Play	2006	Harteveld & Drachen (2015, 477); Ruth et al. (2007)
101	Power Producer	unknown	Play power producer (n. d.)
102	Power Up: Solar and Wind Power Game	unknown	Play power up! (n. d.)
103	Power Up!	unknown	Power up! A game about power choices (n. d.)
104	Residence Energy Saving (RES) - Battle	2014	Dorji, Panjaburee, & Srisawasdi (2015); Johnson et al. (2017, 254, 262)
105	Save the World	unknown	Save the world (n. d.)
106	Social Mpower: a Serious Game for Self-Organization in Socio-technical Systems	2014	Bourazeri, Pitt, & Arnab (2017); Bourazeri & Pitt (2014)
107	Social Power	2014	Wemyss et al. (2018); DeLuca & Castri (2014)

No.	Name	Year (if known)	Published Reference(s) or Game Links
108	Solar Energy Defenders	unknown	Solar energy defenders (n. d.)
109	Spot the Slip-Ups	unknown	Spot the slip-ups (n. d.)
110	Super Delivery	2012	Tsai, Yu, & Hsiao (2012); Johnson et al. (2017, 258, 261-262)
111	Super Eddie Enviro Games	unknown	Super Eddie enviro games (n. d.)
112	The Big Switch (ex Energy Superstar: Bid, Save, Win!	2016	Yang, Lin, & Liu (2017, 886)
113	The Day Amy Saved the World	2011	Amy's energy saving website (2011)
114	The Great Green Web	2008	Katsaliaki & Mustafee (2012); Smith & Currier (2005)
115	The Green Hipster Hotel	2015	The green hipster hotel (n. d.)
116	The Manhattan Project: Energy Empire	2016	The Manhattan project: Energy empire (n. d.)
117	The Nuclear Energy Game	1982	The nuclear energy game (n. d.)
118	The Power House	2006	Bang, Torstensson, & Katzeff (2006); Katzeff & Torstensson (2006)
119	Turn It All Off	2006	Turn it all off (n. d.)
120	Turn Off the Lights!	unknown	Turn off the lights! (n. d.)
121	[Untitled, non-mobile computer game]	2013	Mesquita et al. (2013); Johnson et al. (2017, 256, 262)
122	Wattever	2012	Vaijayanthi & Marur (2012)
123	Watts of Trouble	unknown	Watts of trouble (n. d.)
124	Watts the Answer	2004	Grossberg et al. (2015, 72)
125	WE-Energy Game	2018 (?)	Ouariachi, Elving, & Pierie (2018); We energy game (n. d.)
126	What the Frack?	2013	What the frack? (2016); What the frack (n. d.)
127	Windfall	unknown	Windfall (2016)

2.2.2 A short history of Serious Energy Games and salient features

> "Many, if not most, of the world's problems involve competition for scarce resources. The lowest common denominator of most wars, civil-rights problems, and internal political difficulties is the competition for something in limited supply. This competition has in common with games a partial conflict among actors and objectives, the identities of several distinct actors or groups of actors, and the use by these actors of their scarce resources to achieve their objectives." (Abt 1970, 103)

The 127 games were next studied through published descriptions or reviews, and through actual gameplay where possible to understand game types, salient design structures and relevant outcomes and impacts.

Of the 127 SEGs studied, 5 originated in the 1970s, 7 in the 1980s, 1 in the 1990s, 27 in the 2000s and 49 in the 2010s (Figure 2.6). The 38 remaining games lacked sufficient information to determine their year of origin.

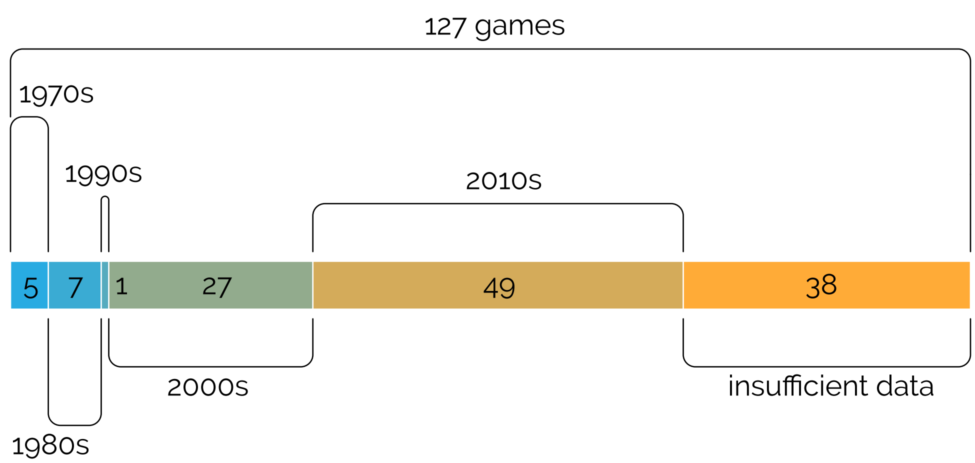


Figure 2.6. Year of Origin.

The subject matter, modality, and purpose of the SEGs that had information available, both reflects and reacts to the state of contemporary society in terms of energy issues. Games created in the 1970s are mainly aimed at education or at creating awareness. Of the five SEGs identified from the 1970s, all five clearly reflect the context of the then-current energy crisis. The earliest game from the 1970s, Energy Crisis (Priddy, 2013, 44-45; Der Kaloustian, 2007), addresses potential behavior change. This stems from its specific subject matter (energy conservation in homes and the use of renewable energy sources) at the building scale. A total of four of the 1970s games, including Energy Crisis, are concerned with the management of energy sources, systems of energy production, and methods of energy distribution and management. These four games are board games requiring an hour or more to play; they are multi-player games targeting 2-6 gamers. The fifth game, Energy Activities with Energy Ant, is aimed at children, in the form of a booklet with games and activities designed to improve awareness and energy-related behavior. (Energy activities with energy ant, n. d.).

Most of the games created in the 1980s have education as their main goal. One of the games, Future Voltage, can also be categorized as a training game for students for electric power planning based on energy systems modeling. Consistent with the idea that Energy Games reflect contemporary issues, the energy crisis remains a common theme in the 1980s games. In response to the 1979 nuclear power plant accident at Three Mile Island, two of the seven games are nuclear power plant Simulation Games. Four of the 1980s games were at the supra-city or city scale. One of them (Energie-Spar-Spiel) had building scale purpose or implementation. Digital games also began to make an appearance in the 1980s. Of the seven games found, two are digital games, one of which (Energy Czar) uses Atari as its platform. Of the remaining games, four are multi-player board games targeting 2-8 gamers, and the last game (the National Energy Policy Simulator) is a multi-player interactive simulation.

Only one energy game was found from the 1990s: Energy Mover. Given the then-current context of public perception of energy issues this paucity is remarkable. While it is true that falling oil prices had caused energy issues to fade to the background of public perception in the 1980s, by 1990, collective American concern about critical energy shortages had returned to the high levels of the mid-1970s (Bolsen & Cook, 2008, 366-367).

Energy Games made a resurgence in the 21st century. In the first decade of the 2000s, 27 games are targeted towards energy issues. Of these, 21 games are either fully or partially designed to be played at the building scale. The first decade of the 2000s also saw a significant shift in game modality from physical to digital. Of the 27 games, 23 are on digital platforms including interactive websites, online games, computer games and mobile apps. The four non-digital games from the 2000s are physical board games. Similar to games from the 1970s, 80s and 90s, board games in the 2000s are multi-player games. However, the digital games vary in format from single-player games to two-player games to multi-player games. According to the search results, Energy Games as mobile applications first made an appearance in this decade and three mobile apps were developed in 2009.

Since 2010, of the 49 games in this period, 6 games are non-digital and 5 games have digital and non-digital components. Most of the non-digital games are board games and some of them have online resources in addition to the physical games. As in previous years, most of the non-digital games are multi-player games. The digital games employ various modalities. Search results include online games and puzzles, video games, interactive websites, mobile apps, computer games, virtual board games and simulations, and tablet apps. While education remained the primary focus of Energy Games in this decade, other categories of game goals such as research, commerce and behavior change started making an appearance.

As long ago as the 1970s, the subject matter of energy games reflects a zeitgeist, i. e., a collective consciousness of the criticality of energy issues. Even as games may be understood as cultural reflections, it is also evident that the games are purposeful and are designed and implemented for the purpose of research, education and creating behavior nudges and some also serve commercial purposes. In addition, as the game media changes, it also impacts structure. The trend has been away from group or cooperative play and a greater number of recent games are designed for the individual gamer on a digital platform, focusing mainly on competitive play or information transfer. To further understand the typology, medium and design of the games that were achieving the desired outcomes as serious games, a study of the games' data collection was conducted.

2.3 Games with outcomes

Each of the 127 Serious Energy Games was examined to identify which of them conducted data collection in support of measuring outcomes. Of the 127 Serious Games, 28 were found to satisfy these criteria (Figure 2.7).

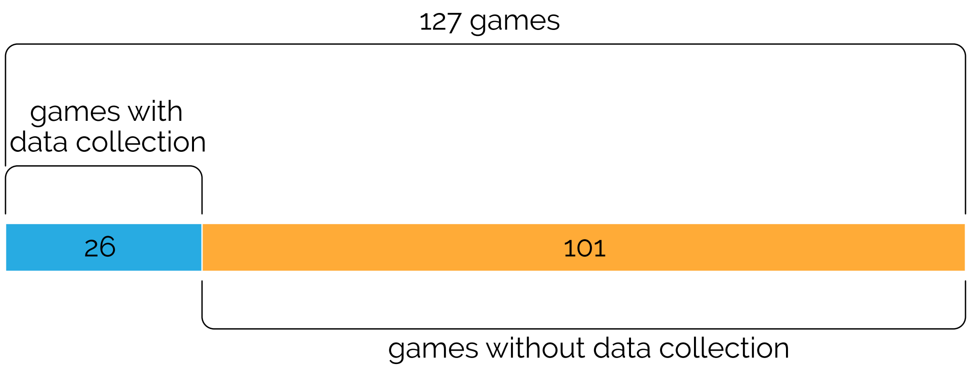


Figure 2.7. Data collection.

The 28 games were further examined to identify (a) whether data concerning learning or knowledge acquisition about energy waste, energy efficiency, or energy use reduction was measured through the game, and if it was accomplished; (b) whether there were any behavior shifts measured and accomplished, both for individual gamers and for groups; (c) whether investments were made in in energy use reduction, energy efficiency, or energy waste prevention; and (d) whether energy savings were measured and accomplished. Other game goals that the game designers measured, collected data for and analyzed, were also noted. Table 2.5 summarizes this examination.

Table 2.5. Data collection status for SPEGs.

tested; statistically significant findings are reported
tested; findings not evaluated for statistical significance
tested; inconclusive or unreported
not tested

			learning	behavior	investment	energy savings
1	SPEG	Age of Energy	n/a	n/a	n/a	unreported
2	SPEG	Agents Against Power Waste	n/a	improved attitude 6% - 8%; p<.001	n/a	n/a
3	SPEG	CityOPT	n/a	20% changed habits	n/a	22% - 28% savings
4	SPEG	Dropoly	n/a	n/a	n/a	unreported
5	SPEG	Energy Chickens	54% of participants	69% of participants	n/a	13% savings
6	SPEG	EnergyLife	M=5; p=0.02	"most participants" changed habits	n/a	38% savings p<0.01
7	SPEG	Green Play / Apolis Planeta	inconclusive	"improvement in most areas"	"increased proportion of [energy-efficient] appliances"	unreported
8	SPEG	IdleWars	"raised awareness ... generally"	varies by question	n/a	n/a
9	SPEG	Makahiki (Kukui Cup Project)	95% of participants	n/a	n/a	n/a
10	SPEG	Mindergie	participants "enhanced their environmental consciousness"	participants "changed their energy consumption behavior"	n/a	n/a
11	SPEG	Power Agent	"situational knowledge" improved	four out of five households "got involved in saving energy"	inconclusive	12.1% - 35.3% savings
12	SPEG	Power Explorer	varies by question	formation of new strategies	n/a	14% savings p=0.16
13	SPEG	Social Power	participants reported learning	varies by question p<.001	n/a	~8% - 9% savings p=.03

Table 2.6. Data collection status for SEGs (non-SPEGs).

			learning	behavior	investment	energy savings
1	non-SPEG	EnerCities	improved awareness p<.001	n/a	n/a	n/a
2	non-SPEG	EnerGAware / Energy Cat	n/a	n/a	n/a	3% - 10% savings
3	non-SPEG	go2Zero	varies by question	inconclusive	n/a	n/a
4	non-SPEG	Green My Place	56% of participants	varies by question	n/a	7% - 30% savings
5	non-SPEG	iChoose (Cool Choices)	n/a	M=0.68 p<.001	n/a	4% savings p=0.02
6	non-SPEG	Ludwig	"leads to ... knowledge transfer" p<.01	n/a	n/a	n/a
7	non-SPEG	Mysusthouse	M=6.71; p=.000	n/a	n/a	n/a
8	non-SPEG	Power House	n/a	increase in # of appliances turned off p<.001	n/a	2% savings; p=.020
9	non-SPEG	Power Matrix	inconclusive	n/a	n/a	n/a
10	non-SPEG	PowerPlay	n/a	varies by question	n/a	n/a
11	non-SPEG	RES Battle	varies by question p<.05	n/a	n/a	n/a
12	non-SPEG	Social Mpower	varies by question	n/a	n/a	n/a
13	non-SPEG	Super Delivery	inconclusive	n/a	n/a	n/a
14	non-SPEG	The Power House	inconclusive	inconclusive	n/a	n/a
15	non-SPEG	WE-Energy Game	"game [is] ... successful in achieving cognitive ... engagement"	n/a	n/a	n/a

Of the 28 Serious Energy Games that conducted some form of data collection, five games (Age of Energy, Dropoly, Power Matrix, Super Delivery, and The Power House) have not published results as of the date of this dissertation (2020). These five games are excluded from the following discussion, leaving a total of 23 Serious Energy Games (a collection of 11 SPEGs and 12 non-SPEGs) for which published results are available.

In examining these games, and in particular asking whether Serious Energy Games may be able to effectively address informational and financial barriers, four broad themes emerged. These themes were knowledge gain and learning (i. e., the extent to which gameplay was shown to improve knowledge), behavior (i. e., the extent to which gameplay was shown to improve energy-efficient behavior), investment (i. e., the extent to which gameplay was shown to result in investment in energy-efficient or energy-saving tools or technologies), and energy savings (i. e., the extent to which gameplay was shown to measurably reduce energy consumption). A range of quantitative and qualitative results were published for the 23 games, and these results were analyzed with respect to the four themes to determine whether any appreciable differences exist between the results associated with SPEGs and the results associated with non-SPEGs.

With respect to knowledge gain and learning, the published results show no obvious distinction between SPEGs and non-SPEGs. however, the analysis necessarily reflects a variety of reporting methods among the different games (e. g., surveys with statistically significant results as well as anecdotal observations). At the most general level, of the 11 SPEGs that conducted some form of data collection, 8 reported that participants demonstrated knowledge gain, learning, or awareness of energy issues. Similarly, of the 12 non-SPEGs, 8 reported knowledge gain, learning or awareness of energy issues.

Next, the published results for all 23 games were considered with respect to behavior. All but one of the SPEGs tested for changes in behavior, while only four of the 12 non-SPEGs did likewise. Of the 11 SPEGs, 10 reported behavior outcomes such as "improved attitude", "most participants changed habits", "improvement in most areas", "participants changed their energy consumption behavior", "four out of five households got involved in saving energy", and "formation of new strategies." The four non-SPEGs that tested for behavior-related results (Green My Place, iChoose, Power House, and PowerPlay) reported results of comparable strength to the best-reporting SPEGs, with reported behavior outcomes such as "increase in # of appliances turned off."

The question of investment was only tested for two games (Green Play and PowerAgent), both of which are SPEGs. For Green Play, Csoknyai et al. (2019) noted that gamers purchased an increased proportion of energy-efficient appliances. Published results were not found for

PowerAgent.

Finally, 10 of the games (6 SPEGs and 4 non-SPEGs) tested for energy savings. Judging by reported results, the six SPEGs performed better in this respect, reporting average savings of 23%, as compared to an average energy savings of 11.5% reported by the four non-SPEGs. Of the 6 SPEGs, 5 reported energy savings in the range of 12-38%, while one had energy savings in the 8-9% range. Of the 4 non-SPEGs, 3 reported energy savings in the 2-10% range and one in the 7-30% range (Figure 2.12). Although the results for energy savings are (among the four broad themes) the only ones that are consistently quantitative and thus susceptible to direct comparison, the reported results are subject to varying degrees of statistical significance.

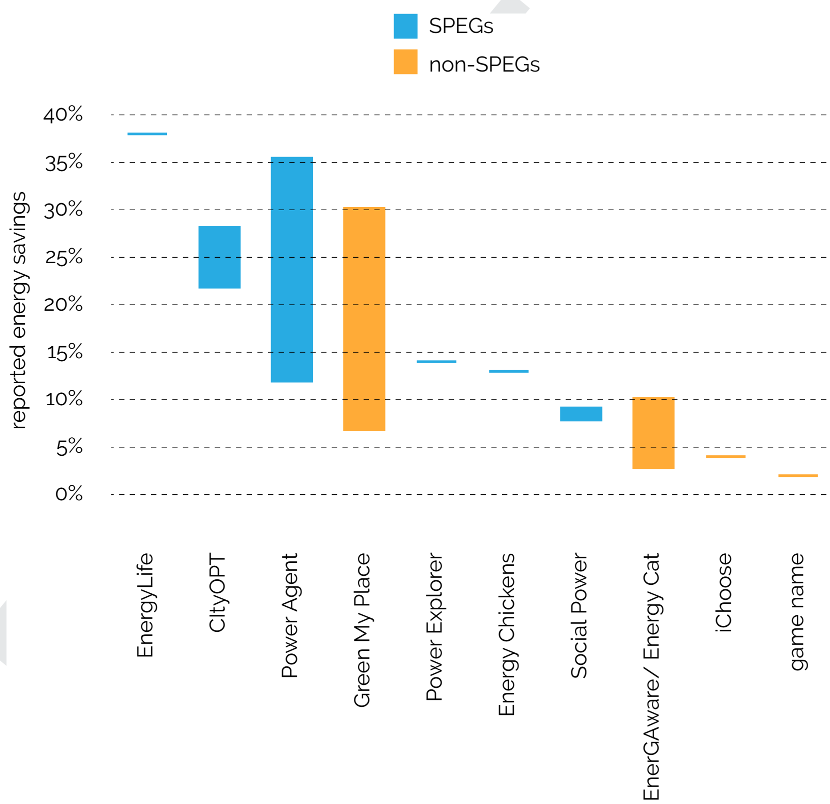


Figure 2.12. Games with energy reduction results (if reported)

In summary, for the 23 Serious Energy Games for which published results are available, SPEGs show better results for energy savings and investment. Among the sample of 23 Serious Energy Games, there is no obvious difference between SPEGs and non-SPEGs with respect to learning or behavior.

2.4 Pervasive Games

Pervasive games exist at the intersection of game life and ordinary life. If the "magic circle" (Montola, Stenros, & Waern, 2009) of a game is the boundary separating the game from ordinary life, pervasive games expand the space, time and social circle of game life into ordinary life and vice versa. Pervasive games include well known examples such as Pac Manhattan (Poplin, 2012; Pac Manhattan, 2004), Killer (Jackson, 1998) and the reality-television show Amazing Race (Mathews, 2009). The pervasive Big Urban Game is a serious urban game (Ferri & Coppock, 2013) in which the built environment is the background for game play, the subject of gamers' actions, and the objective of game play.

Due to the quality of existing simultaneously in game space and ordinary life and space, pervasive games have the potential for purposeful play, i. e., using the pleasure motivations of gaming to achieve goals that may benefit communities in actual life.

In games, the gap exists between transferring abstract concepts learned in games to ordinary life. According to Gustafsson, Bang, & Svahn (2009), "Whilst traditional learning games typically struggle with achieving transfer [11] between game simulation and real world tasks, pervasive games have the potential to directly incorporate reality, providing a situated learning experience. In classic learning theory, transfers to the situation where the learner must generalize and use abstract knowledge (i.e., learnt from a book) and applies this knowledge to real world problems and requirements. An inclusion of reality will obviously minimize this contextual gap." Per Transfer of Learning theory (Perkins & Saloman, 1992), transfer of learning (abstract) from the game to real world application in ordinary life is a key factor for games. Transferring learning from within the magic circle of the game to the real world is a challenge (Gustafsson, Katseff, & Bang, 2009). In Pervasive games, the expansion of the magic circle into the social, temporal and spatial constructs within ordinary life may allow that transfer to occur simultaneously in game space and real life.

2.4.1 The potential of Serious Pervasive Energy Games

In the database of 127 energy games, there were 14 SPEGs (Table 2.4) of which 11 were reporting results (Table 2.5, Figure 2.8) in some category and 3 were not reporting results. Within the short history of Serious Energy Games, Pervasive games made a late appearance starting in 2007 with the Power Agent game, implemented by Anton Gustafsson and Magnus Bang, to encourage teenagers and their families to reduce energy consumption in Sweden (Table 2.4). Versions of this game were implemented in subsequent years. Power Explorer in 2009 (Gustafsson, Bang, & Svahn, 2009) and Agents Against Power Waste in 2010 (Svahn & Waern, 2014). Energy Chickens (Orland et al., 2014) nudge office workers to reduce home and office energy use. Like the Big Urban Game (BUG), these SPEGs have the buildings that make up the built environment (homes, schools, offices etc) as the background for game play, the subject of gamers' actions (occupants acting to save energy use), and the objective of game play (lowering the operational energy needs by acting on the buildings design, use or infrastructure).

The games were further examined for categorization (see Table 2.4) such as, Year of implementation; Scale (where were the games being implemented such as residential, office etc); Mode (what was the media of game play such as mobile devices, websites in addition to ordinary life); Sample size (how many people had played the game); Location (where were the games deployed) and Implementation (were they open or targeted?). Some games were targeted to a specific sample demographic or group like a laboratory-implemented controlled and planned experiment would be, other games were open to voluntary participation like a field experiment might be. Open games are publicly available for gamers to join voluntarily.

Table 2.4. Serious Pervasive Energy Games

Name	Year	Scale	Implementation	Mode	Sample Size
M= mobile digital device; O = ordinary life actions; W = web; S = Ubiquitous sensor systems provide ambient (embedded) interfaces; P = Physical game box and online dashboard; T= tablet Scale: R = Residential; S = Schools; D = Dormitories; W = workplace/office; N = residential neighborhood Implementation: T = Targeted (Laboratory, controlled) ; T(V) = Targeted (volunteer); O= open (field type) Mode:					

1. Power Agent	2007-2008	R	T	M	6 teenagers + family
Story: Role play; Secret Agent to whom various missions are assigned Type: Action/Consequence, Race (save energy over 10 days) Data Collection: Energy measurements + interviews Demographics: Teenager & family Location: Sweden					

2. Power Explorer	2009	R	T	M; O	15 teenagers, 12-14 years of age; 20 control households
Story: Avatar (roleplay) ; Monster blob Duel Type: Space/Displace, Race/Chase Data Collection: Connected to electricity use in home Demographics: Teenagers, Household Location: Sweden					

3. Agents Against Power Waste (different implementation of #1)	2010	R	T	M; O	200-300' four classes of students aged 13-15 years; 127 households
Story: Role play; Secret Agent to whom various missions are assigned Type: Action/Consequence, Race (save energy in a set time period), Adventure Data Collection: Questionnaires, game log data, smart meter system for electricity use Demographics: Teenager & family Location: Eskilstuna, Sweden					

4. The Day Amy Saved the World	2011	R; S	O	W	varies based on classroom and family size
Story: Help game mascot save the world with energy savings Type: Informational / Situated activity based learning Data Collection: None found Demographics: K-6 / Homes Location: Online game with activities on site (Australia?)					

5. Makahiki (Kukui Cup Project)	2011	D	T	W	xxx unknown sample size?
Story: Energy-related educational workshops, field trips, activities (400+) Type: Action / Consequence Data Collection: gamer activity, energy consumption Demographics: First-year college students in university dormitories Location: United States (Hawaii)					

<table>
<tr><th>Name</th><th>Year</th><th>Scale</th><th>Implementation</th><th>Mode</th><th>Sample Size</th></tr>
<tr><td>6. EnergyLife</td><td>2011</td><td>R</td><td>T</td><td>M; S</td><td>First trial: 5 research team households, 8 lay-user; Second Trial: 10 households</td></tr>
<tr><td colspan="6">Story: Reduce energy use, read advice, correctly answer quiz questions
Type: Action/Consequences, Social interactivity as a reward
Data Collection: BeAware sensor system, connected to the base station that collects and analyzes the data, ambient interface to provide cues
Demographics: Household
Location: Europe (Finland, Italy, Sweden)</td></tr>
<tr><td>7. Dropoly</td><td>2012</td><td>R</td><td>O</td><td>W</td><td>not tracked</td></tr>
<tr><td colspan="6">Story: Online game with students, encourage family involvement
Type: Activity, Action / Consequences
Data Collection: Energy usage (utility bills data)
Demographics: Not tracked
Location: United States (Dayton, OH, Missouri)</td></tr>
<tr><td>8. Energy Chickens</td><td>2013</td><td>W</td><td>T</td><td>W</td><td>61</td></tr>
<tr><td colspan="6">Story: Chickens are healthy and lay eggs (rewards) if energy use is low
Type: Action / Consequences
Data Collection: Electricity usage (devices monitored per gamer) (61 workers, 288 devices)
Demographics: Office workers
Location: United States (Pennsylvania, Pittsburgh)</td></tr>
<tr><td>9. CityOPT</td><td>2014</td><td>R</td><td>O</td><td>T</td><td>n= 84 (online survey); n=140 households (application analytics and load curve analysis)</td></tr>
<tr><td colspan="6">Story: “Peak Simulator,” an application designed and developed as a game, made available on tablets distributed to participants.
Type: xxx
Data Collection: online survey, application analytics and load curve analysis
Demographics: Residential utility customers
Location: France (Nice)</td></tr>
<tr><td>10. Mindergie</td><td>2014</td><td>S</td><td>T</td><td>M, O</td><td>12</td></tr>
<tr><td colspan="6">Story: Game with action elements, asking participants to “find something out, save some energy, or propose a solution.”
Type: xxx
Data Collection: questionnaire
Demographics: participants recruited via university intranet
Location: Netherlands</td></tr>
<tr><td>11. Social Power</td><td>2014</td><td>R</td><td>O</td><td>M, O</td><td>two tests (n = 54; n = 54)</td></tr>
</table>

<table>
<tr><td>Name</td><td>Year</td><td>Scale</td><td>Implementation</td><td>Mode</td><td>Sample Size</td></tr>
<tr><td colspan="6">Story: Each of two teams has the goal to save as much electricity as possible compared to the other
Type: xxx
Data Collection: Surveys; energy consumption tracking
Demographics: voluntary household participants recruited using advertising flyers sent by the local utility, public events, school visits, and telephone campaigns.
Location: Two cities in Switzerland, Massagno (city 1) and Winterthur (city 2).</td></tr>
</table>

<table>
<tr><td>12. Age of Energy</td><td>2015</td><td>N</td><td>O</td><td>M</td><td>xxx unknown sample size?</td></tr>
<tr><td colspan="6">Story: Post-apocalyptic scenario, rebuild society, uses real life energy use performance
Type: Action/Consequence, Space/Displace (strategy, luck, skill, teamwork)
Data Collection: Energy use (Linky smart meter data through app)
Demographics: 16-25 year olds to perform energy saving actions to cause behavior change
Location: Europe (Amsterdam, Grenoble)</td></tr>
</table>

<table>
<tr><td>13. IdleWars</td><td>2015</td><td>W</td><td>T(V)</td><td>W</td><td>20</td></tr>
<tr><td colspan="6">Story: People leaving computers idling were “caught” by other people
Type: Action/Consequence, Chase (Detection?)
Data Collection: Interaction logs, comments from participants, computer idle time
Demographics: Office employees
Location: UK</td></tr>
</table>

<table>
<tr><td>14. Green Play / Apolis Planeta</td><td>2015, 2016, 2017</td><td>R</td><td>T; O[1]</td><td>W</td><td>154 homes: 3 cities</td></tr>
<tr><td colspan="6">"Story: Post-apocalyptic scenario of contaminated earth; globe divided into hexagons; gamers can earn “greenies” by saving energy in their home
Type: Action/Consequence, Earn points for Activity, Contest, Wagers
Data Collection: For testing phase, energy audits and on-site surveys in 200 homes in 3 cities.
Demographics: Homes
Location: Europe (Hungary, France, Spain)"</td></tr>
</table>

Of the 14 SPEGs found, 9 were implemented in various parts of Europe, 1 in the UK, 3 in the United States and 1 is an online game with an open implementation. 8 of the games were implemented in households, 1 in schools, 1 in both schools and households, 2 in offices, 1 in University dormitories and 1 is a neighborhood game.

11 of the 14 SPEGs reported results (Table 2.6). Of these, 9 targeted games had sophisticated data collection methods ranging from game logs, interaction logs, temperature logs, smart meters, appliance and device smart sensor systems, interviews and surveys. Gamers reported positive results in interviews, questionnaires and surveys in terms of behavior shifts in individual gamers and as groups of gamers. Of the three games in the United States, one did not report

1 Targeted (Laboratory type) in initial experiment; open (field) implementation for final design

results, but the other two, Energy Chickens and Makahiki (Kukui Cup) reported substantive success. All the targeted games showed positive results in data that has been collected and analyzed. 2 of the 5 open or field-implemented games collected data.

Table 2.6. Results of SPEGs (11 of 14 reporting results) (Srivastava, 2019b).

1. Power Agent	2007-2008	6 teenagers + family
"Source: Gustafsson, Katzeff, & Bang (2009) Learning: Learning in the game, situational learning, information needs for missions, learning from discussions, learning from feedback in game (Gustafsson, Katzeff, & Bang, 2009, 54:14) Behavior: Individual: Yes - highly motivated even with non-normative levels of comfort. (Gustafsson, Katzeff, & Bang, 2009, 54:16). Group: Yes, all but one of the families got involved in saving energy and helping the agent (Gustafsson, Katzeff, & Bang, 2009, 54:11) Investment: Inconclusive. “Some households made permanent changes in lightning [sic] and heating.” (Gustafsson, Katzeff, & Bang, 2009, 54:17). Energy Savings: Both teams reported reduced electricity consumption. Normalized data after all six missions: Team Smedjebacken: –34.3% electricity, –12.1% heat; Team Växjö: –34.0% electricity, –35.3% heat (Gustafsson, Katzeff, & Bang, 2009, 54:9) Game Feedback (Fun/Play): Generally positive, need more variety for older participants Engagement causes: Competition, social demand, peer pressure Behavior retention: No, energy consumption returned to prior levels in few weeks (-0.2%)"		

2. Power Explorer	2009	15 teenagers, 12-14 years of age; 20 control households
"Source: Gustafsson, Bang, & Svahn (2009) Learning: Questions specifically measuring pre- and post-knowledge, varying in statistical significance (Gustafsson, Bang, & Svahn, 2009, 187). Gamers found out what time of day energy was consumed most (Gustafsson, Bang, & Svahn, 2009, 187); they developed knowledge regarding energy use for devices that they personally used (Gustafsson, Bang, & Svahn, 2009, 187); “players were … worse at determining the amount energy used for different tasks after the game” (Gustafsson, Bang, & Svahn, 2009, 187) Behavior: Individual: Yes - formation of new habits, lower degree of extreme measures (Gustafsson, Bang, & Svahn, 2009, 188). Group: Yes, long term energy strategies developed (Gustafsson, Bang, & Svahn, 2009, 186-187). Investment: not tested Energy Savings: Average reduction in consumption during 10 weeks following gameplay:, -14%; 12 of 15 participants lowered energy use, 3 increased or showed no change (Gustafsson, Bang, & Svahn, 2009, 185) Game Feedback (Fun/Play): “Fun and rewarding experience” per the gamers’ interviews. Engagement causes: Immediate feedback, classical conditioning, interest in “how much you used.” Behavior retention: Yes, tentative indications for persistent post-game effect on consumption"		

3. Agents Against Power Waste	2010	four classes of students aged 13-15 years; 127 households
"Source: Svahn & Waern (2014) Learning: not tested Behavior: Individual: 6% positive effects on the attitudes of the children (primary); 6% positive effect in the direction of conserving electricity when compared to control group children; 8% positive effects on the attitudes of the parents (secondary); 7% positive effect in the direction of conserving electricity when compared to control group parents (Svahn & Waern, 2014, 209) Investment: not tested Energy Savings: not tested, although a reduction in energy use during game is noted (Svahn & Waern, 2014, 211)"		

<table>
<tr><td>4. Makahiki (Kukui Cup Project)</td><td>2011</td><td>Almost 40% of 1,035 eligible dormitory residents</td></tr>
<tr><td colspan="3">"Source: Lee, Xu, Brewer, & Johnson (2012)

Learning: 95% of the gamers rated the game as Educational (Lee, Xu, Brewer, & Johnson, 2012, [6])
Behavior: not tested
Investment: not tested
Energy Savings: not tested (anecdotal data is reported but not adequately sourced)

Game Feedback (Fun/Play): 83% of the gamers rated the game as fun; 7% said it was difficult and 2.3% said it was difficult.
Engagement causes: 40% of eligible people played the game (Lee, Xu, Brewer, & Johnson, 2012, [6])
Behavior retention: Not known"</td></tr>
</table>

<table>
<tr><td>5. EnergyLife</td><td>2011</td><td>First trial: 5 research team households, 8 lay-user; Second Trial: 4 households</td></tr>
<tr><td colspan="3">"Source: Gamberini et al. (2012); Spagnolli et al. (2011)

Learning: In the first trial, anecdotally reported: "... individual actions influence environmental health" (Spagnolli et al., 2011, 44). In the second trial, "Participants' interest in smart advice was measured on a scale ranging from 1 to 6, where 6 was the highest positive evaluation; the [mean] score received was ... 5.00" (Gamberini et al., 2012, 107)
Behavior: In the first trial, anecdotally reported: "... most participants agreed that they had changed their energy-consumption habits." (Spagnolli et al., 2011, 44)
Investment: not tested
Energy Savings: In the first trial, "Consumption during the trial's last month with the same period in the previous year ... shows a 5 percent decrease in overall household consumption" (Spagnolli et al., 2011, 44). In the second trial, "[o]n average the day after reading of one or more smart advice tips the consumption of the specific devices dropped ... 38%." (Gamberini et al., 2012, 109)

Engagement causes: Pervasive sensing (individual sources (appliances)"</td></tr>
</table>

<table>
<tr><td>6. Energy Chickens</td><td>2013</td><td>61</td></tr>
<tr><td colspan="3">"Source: Orland et al. (2014)

Learning: 54% of respondents (n=36) "indicated that the game provided accurate information about their energy usage" (Orland et al., 2014, 49).
Behavior: 69% of respondents (n=36) "indicated that the game helped them be more energy conscious" (Orland et al., 2014, 49).
Investment: not tested
Energy Savings: "Energy Chickens game participants decreased their plug load energy consumption by 13% from baseline (23% on non-work days and 7% on work days)" (Orland et al., 2014, 51).

Behavior retention: During the 8-week follow-up after the game play, energy savings did not continue (Orland et al., 2014, 46); "[G]roup-level data do not show statistical evidence of persistence [in energy savings] through the follow-up ... [although some individuals' behavior saw lasting effects]" (Orland et al., 2014, 49)"</td></tr>
</table>

7. CityOPT	2014	140 households

"Source: Santinelli et al. (2016)

Learning: not tested
Behavior: 71% of participants felt that participation did not cause discomfort; 7% felt that participation generated considerable discomfort (Santinelli et al., 2016, 7). 20% of respondents reported changing habits (e. g. postponing dinner, cooking in advance, eating cold meals, etc.) in order to get higher scores (Santinelli et al., 2016, 8).
Investment: not tested
Energy Savings: During peak load, 28% decrease in electricity usage, approximately 28% less than average in the same time interval (Santinelli et al., 2016, 6); "77% of residential customers reduced their electricity consumption between 6 and 8 PM by 22%" (Santinelli et al., 2016, 6)"

8. Mindergie	2014	questionnaire completed by 12 participants

"Source: Kalz et al. (2015)

Learning: "[P]articipants stated that the game enhanced their environmental consciousness." (Kalz et al., 2015, 412)
Behavior: "[P]articipants stated that the game in general changed their energy consumption behaviour." (Kalz et al., 2015, 411)
Investment: not tested
Energy Savings: not tested"

9. Social Power	2014	108 household participants in two cities (competitive vs collaborative models); statistical collection for n=46

"Source: Wemyss et al. (2018)

Learning: Participants reported learning about "electricity reduction ... energy efficiency ... [and] electricity load shifting" (Wemyss et al., 2018, 2068)
Behavior: Significant effects on behavior as measured pre- and post-intervention; no significant differences between competitive and collaborative models (Wemyss et al., 2018, 2067).
Investment: not tested
Energy Savings: "[N]either of the household teams reached the 10% goal [in electricity savings] altogether; however, they all had substantial savings" (Wemyss et al., 2018, 2066); "[C]ompared to the control group, ... competitive [households] ... saved significantly more electricity ... [C]ollaborative [households] ... saved electricity compared to the control group, although this difference is only marginally significant" (Wemyss et al., 2018, 2067)

Behavior retention: not explicitly measured, but participants reported a "future intention to save electricity" (Wemyss et al., 2018, 2068)."

10. IdleWars	2015	20 participants; two-week trial in an office environment

"Source: Tolias et al. (2015) (a), Tolias et al. (2015) (b)

Learning: Anecdotally reported: "[T]he IdleWars game ... raised awareness around energy waste more generally in the workplace"" (Tolias et al., 2015 (a), [233])
Behavior: Anecdotally reported: Commentary, discussions and technical questions debating the benefits of power-off, hibernation and sleep were generated; Two participants who had initially used photos of themselves, returned to change their profile picture to a more humorous image including message, "I busted you" (Tolias et al., 2015 (b), 6). "[T] he IdleWars game stimulated participants to forego proenvironmental behaviours such as setting computers to automatically hibernate or sleep or turning off monitors when not in use" (Tolias et al., 2015 (1), [233])
Investment: not tested
Energy Savings: not tested

Game Feedback (Fun/Play): Participants actively engaged in game play, commenting, emailing with the game designers.
Engagement causes: 14 out of 20 busted another idling computer at least once which is almost a 75%engagement."

11. Green Play / Apolis Planeta	201520162017	157 homes in France and Spain ... consumption habits of approximately 50 homes were "deeply analyzed."
"Source: Csoknyai et al. (2019) Learning: Not conclusive. Behavior: "[E]nergy awareness surveys show certain improvement in most areas even if analysis of monitored data could not always justify all impact of behavioral changes" (Csoknyai et al., 2019, 15). Investment: "[We observed an] increased proportion of appliances with energy class A or better. In 2017 it was 41% only, in 2018 it increased to 64% ... In 2017 only 60% of the homes had efficient lighting, and from that 30% was LED. In 2018 the numbers increased to 81% and 36%. ... [These results] can only partly be explained by the use of Apolis Planeta" (Csoknyai et al., 2019, 15). Energy Savings: "[W]e can conclude that saving energy with a serious game initiating behavioral change could not be achieved and justified, but some positive elements could be found" (Csoknyai et al., 2019, 15)."		

In the Energy Chickens game 69% of game participants indicated that the game helped them be more energy conscious and participants reduced their plug load by 13% from baseline (table 2.6). 95% of the participants rated the Makahiki game educational.

It is evident that SPEGs with outcomes are achieving desired results but only a very few have been designed, implemented and tested and only two in United States. A lot more work remains in iterative design to fully understand the potential of SPEGs.

Serious Pervasive games are being able to achieve surprising results. For example, in Power Agent, gamers reported being highly motivated even with non-normative levels of comfort. The game was also able to engage the family beyond just the primary gamer. Power Explorer gamers reported formation of long-lasting habits towards energy conservation. In Agents against power Waste, 6% positive effects were found in the attitudes of children (primary) in the direction of conserving electricity when compared to control group children. SImilarly, 8% positive effects were found in the attitudes of the parents in the direction of conserving electricity when compared to control group parents. In EnergyLife, gamers agreed that behavior shifts had occurred, while in Energy Chickens, 69% of the gamers reported becoming more energy aware. In Idle Wars a game to catch each other with an idling computer, commentary, discussions and technical questions debating the benefits of power-off, hibernation and sleep were generated. Similarly positive feedback was received for the targeted games for learning or knowledge acquisition. Gamers reported that they were motivated to research more information for game missions, situated or contextual learning addressed the transfer gap often experienced in games. In-game discussions, feedback in the game created learning communities. Specific issues were reported by gamers such as, "found out what time of day energy was consumed most." Others reported gaining specific knowledge regarding device energy use that they personally used. Yet others noted that 95% of the gamers rated the game as educational and helped them understand that individual actions influence environmental health. There were several realizations about inefficient energy use through-out the game; and the discoveries of inefficient appliances.

2.5 Pursuing research in Serious Pervasive Energy Games

Pervasive Games have a large-scale presence, capable of prompting behavior change (McGonigal, 2006). A pervasive game can "minimize this ... [transfer] gap, also referred to as the context gap, because the game can be situated in the real world with real hands-on tasks that require player engagement" (Gustafsson, Katzeff, & Bang, 2009, 54:2). In other words, pervasive games allow occupant actions to achieve game goals, incorporating real life in gameplay; they can also enable knowledge from within the magic circle to transfer to real-world problems. And thus, Serious Pervasive Energy Games (SPEGs) may be deployed in the built environment to address energy issues such as achieving energy savings. They may use physical space as gameboards (background and structure) and they may hybridize digital and physical components to varying degrees. Pervasive Energy Games inculcate understanding on three levels. Spatially, they identify buildings as energy users. Temporally, they highlight time's impact on energy use (e. g., seasonal or diurnal energy use). Socially, they place building occupants as primary determinants for energy use (i. e., energy as related to people's comfort and well-being).

Through the data collection, it is clear that the games are helping gamers learn or acquire knowledge about energy conservation, are causing behavior change towards more efficiency, and are resulting in energy savings. In other words, the games are overcoming the energy efficiency gap.

Valuable research paths forward exist and are needed. Since 2007, SPEGs have been designed and implemented in only four building typologies. Games are being able to achieve substantive energy savings in both targeted and open implementation. Of the games that are showing substantive, measured outcomes in learning, behavior shifts and energy savings are being achieved mostly by Serious Pervasive Energy Games. However, of all the 127 Serious Energy Games that exist, only 14 are Serious Pervasive Energy games and only 5 are open implementations. Of those open implementations only 3 had data collections. Open implementations of games have the potential for large scale impact. Iterative open implementations of Serious Pervasive Energy games need to be studied for larger scale implementations with in-game data collection strategies.

3.0 Research Opportunity and Design: The Georgetown Prize & efargo

Summary

The nationwide Georgetown University Energy Prize (GUEP) competition (2014-2016) provided the opportunity for this dissertation's author to research, plan, design, and implement two Serious Pervasive Energy Games (SPEGs). This effort, which included participation from the City of Fargo, local utilities, and North Dakota State University, was organized under the identity of efargo.

This chapter discusses the research design, including the timeline of interventions and a description of research methodologies for testing the effectiveness of the two Serious Pervasive Energy Games.

3.1 Background

The nationwide Georgetown University Energy Prize (GUEP) competition, which was aimed at improving energy efficiency and reducing the energy use of cities with populations ranging from 5,000-250,000 people, presented an opportunity to examine whether playing Serious Pervasive Energy Games (SPEGs) can impact energy use and bridge the energy efficiency gap ($5 million Georgetown energy prize to reward community sustainability, 2014; About the prize, 2018).
In response to the competition, this dissertation's author established a team at North Dakota State University under the identity of "efargo" (Srivastava, 2019a; Srivastava & Raisanen, 2015). In partnership with municipal government and utility providers, the efargo team entered the GUEP competition, and designed and implemented two SPEGs in the city of Fargo, North Dakota. The competition duration of the semi-finals was January 2015 to December 2016. Data collection of energy use in 2015 and 2016 was compared against a baseline energy use during years 2013 and 2014. In the energy use data collected and published by the GUEP, efargo's work resulted

in Fargo being ranked as the third highest energy saver and overall winner of the Georgetown Prize.

The first SPEG, titled the efargo game, focused mainly on residences but also made gamers aware of energy waste in their workplaces and cities and their ability to have a voice in these arenas. This game was launched in late February 2016, and ended with a community Earth Day celebration in April 2016. The second SPEG, titled the K-12 Energy Challenge, was focused on reducing energy use in K-12 schools while also educating students about energy waste, energy use reduction and energy efficiency. This game was designed, iterated and implemented four times. The first three implementations were in the Spring of 2016, 2017 and 2018. The last iteration included in this study was implemented in Fall 2018. Most of these iterations were implemented in elementary schools, twice in middle school and none in high school.

Participation in both these games was voluntary and open to participation from community members and area schools. The limitation to participation was by building typology. The efargo game was targeted to homeowners and renters in Fargo, while the K-12 Energy Challenge was open to faculty, staff, students or administrators who wanted to participate in the K-12 Challenge. Energy-use data, surveys and interviews conducted and collected before and after the games when possible provide the data to study the impact of these games on knowledge gain about energy use, impacts on energy-use behavior, impact on willingness to make energy-saving investments and lastly, on energy savings.

3.2 Can SPEGs make a difference? Hypotheses & Variables

The four broad themes that emerged from the review of existing Serious Pervasive Energy Games[1] led to the formulation of four major hypotheses and sub-hypotheses (Table 3.2). Collectively, the hypotheses are aimed at understanding the potential of Serious Energy Games to effectively address informational and financial barriers, i. e., the energy efficiency gap.

Table 3.2. Hypotheses.

#	statement of hypothesis

1 See Chapter 2.

Hypothesis 1.	Playing a serious pervasive energy game can lead to awareness and learning about energy savings.
Hypothesis 2.	Playing a serious pervasive energy game can engender a willingness to engage in energy-saving behavior.
Hypothesis 3.	Playing a serious pervasive energy game can engender a willingness to make energy-saving investments.
Hypothesis 4.	Playing a serious pervasive energy game can lead to energy-savings.
Sub-hypothesis 1.	Higher outcomes in the variables for Fun in targeted and open pervasive energy games will have a positive impact on some of the dependent variables.
Sub-hypothesis 2.	Higher outcomes in the variables for Meaning in targeted and open pervasive energy games will have a positive impact on some of the dependent variables.

The design and implementation of the efargo game and the K-12 Challenge provided an opportunity to test these hypotheses. Data collection completed prior to, during and post-game implementation was analyzed to examine whether the hypotheses described in Table 3.2 are supported. The variables outlined in Figure 3.1 were tested.

Dependent Variables	
1	awareness and learning about energy savings
2	willingness to engage in energy-saving behavior
3	willingness to make energy-saving investments
4	lead to energy savings

Moderating Variables	
1	higher levels of engagement
2	higher outcomes in fun
3	higher outcomes in meaning

Figure 3.1. Variables.

3.3 Opportunity: Georgetown University Energy Prize

The GUEP competition began in January 2015 and ended in December 2016. Data analysis was conducted by the GUEP team in 2017 and final results were announced in late 2017. In partnership with local utilities, the competition measured the baseline energy use established during 2013 and 2014 and compared the in-competition performance against the baseline energy use. Partnerships in this two-year effort, titled efargo, included North Dakota State University, the City of Fargo, and the two local utilities (Cass County Electric Coop and Xcel Energy).

In addition to the opportunity to participate in the GUEP and design and implement SPEGs, there were at least four additional cities that were GUEP semi-finalists who also played games in their communities as a way of creating a community awareness and results about energy waste, use and energy efficiency. This performance data and rankings provided by the GUEP also resulted in a set of relevant data in terms of rankings, energy performance, and participation of cities that implemented games in the GUEP compared to the control group of participating cities that did not implement games. The successes of the cities that implemented games are discussed elsewhere in this dissertation.[1]

3.4 The games: efargo and K-12 Challenge

Two SPEGs were designed, implemented, and analyzed in order to examine the proposed hypotheses. The efargo game had a digital game interface, game board, and dashboard incorporating weekly tokens (Figure 3.2). Challenges in each token asked gamers to take action on their homes in order to earn points and achieve energy savings. This game was implemented once in 2016. It was organized based on the census blocks in the city, and a weekly winner was randomly selected from the block with the highest participation points.

1 See Chapter 8.

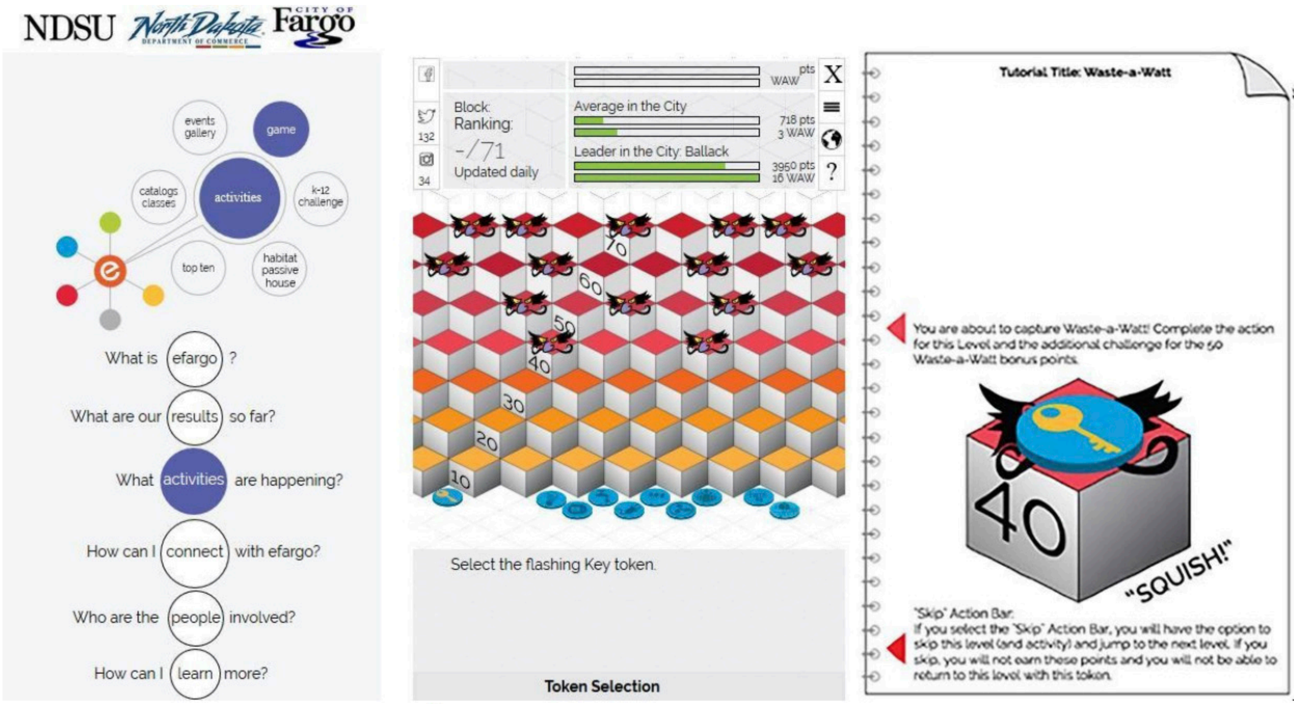


Figure 3.2. Image of efargo game.

The K-12 Challenge (Figure 3.3) asked participating schools to complete various learning (tagging) and energy-saving (fixing) activities over a 3-6 week period. The game design, game tools, reporting structures, and timeline were modified over successive implementations in response to experience and feedback from teachers and students. In each of the four implementations, efargo leaders and stars were awarded to students who participated in the game.

Figure 3.3 Images of K-12 Challenge 2.0 (2017).

3.5 When game life and ordinary life overlap: Spatial, temporal and social expansions

On the basis of prior literature suggesting that targeted implementations of SPEGs have been very successful in creating energy savings, learning and some behavior shifts, in other locations, the efargo game and K-12 Challenge were made open and available for voluntary participation. For the efargo game the gamer community was anybody who rented or owned a home in the City of Fargo. The K-12 Challenge was open to any school in the Fargo Public Schools district. Any school or classroom that participated volunteered to do so. Lacking funding for marketing, the efargo game was introduced to the Fargo community through the efargo website and with the help of a press event in early 2016. Talks at local events about the game prior to and during the game release helped to spread the word. Anyone in the community was welcome to participate. Although, gamers outside City of Fargo did not have complete access (such as access to prizes), some still chose to participate. The K-12 Energy Challenge was made available to the Fargo Public Schools through the Principals' annual meeting in a 5-minute introduction, who in turn were asked to communicate to the teachers and staff in their schools. Outreach to the curricular coordinators and Science instructors was also done through phone calls and informational literature, sent via hard copy and email. Teachers who were interested in participating reached out the the efargo team. Both games were released for a short durations of time, with an end of game celebration meant to coincide with Earth Day celebrations in the schools. The 4th iteration of the K-12 Challenge had a Fall cycle and thus had its ending celebration in the Fall.

To consider the efargo energy game and the K-12 Energy Challenge energy game as Pervasive Games is to encourage expansions of game life into ordinary life and vice versa, specifically with respect to space, time, and social circle. Spatial expansion worked in two ways with the efargo energy game. First, although the efargo energy game used an online interface to structure play, the act of playing the game required gamers to make changes within their physical environment, i. e., their everyday home environment, and subsequently to report or verify that the changes were made. Thus, the game space and everyday space were brought into a mutual relationship, each expanding into the other.

Secondly, by virtue of its online presence, the efargo energy game existed in a spatially dispersed environment typified by the ubiquitous smartphones and laptops. It thus existed alongside, and possibly competed for attention with, gamers' suite of online tools and digital spaces including social media, instant messaging, photo-sharing, etc. In this way, i. e., due to its digital modality, which required action in the physical space, the game space pervaded the space of everyday life.

Spatial expansion occurred in a different though related way with the K-12 Energy Challenge. In this case, there was no digital interface, however, there were opportunities for learning about energy waste through digital means. All the game instructions provided links to websites about energy waste, energy use and energy efficiency. The play was mainly structured by means of physical materials and written and verbal instructions. The rules of the game required gamers to observe, interact with, and make changes to their physical environment in order to "fix" energy waste. Two of the K-12 Energy Challenge games required gamers to "tag" the built environment for energy waste, before fixing it. One of them included tagging as a learning activity. Tagging the waste was the learning process that also earned points in the game. The last two versions of the game, a website link, a VR file link and goggles and energy cards were included in the games. All three duplicated the same information which essentially showed the Waste-a-Watt tags on images of typical school spaces such as hallways, classrooms, gyms, lunch rooms etc. The students could use the VR goggles and file, the website or the physical energy cards to tag their school's energy waste. The tags in the game space then could be "fixed" or "learned about" to earn points. Thus the tagged space became the pervasive game interface.

In the efargo energy game, gamers were obligated to report their energy-saving activities. They could volunteer their energy use meter readings to the game team but this was not required. For the K-12 Challenge, the game research and design staff performed a "behind-the-scenes" verification by means of reading energy meters in the schools that gave permission. These reports and readings were reported to the teachers and students, in part as a means of inspiring student-gamers to improve their performance. Thus, game space (points being earned) and ordinary space (energy use performance) were mutually implicated.

Temporal expansion related to subject matter and when the game was played in the efargo energy game and the K-12 Challenge.

In both games, activities were included that could help gamers understand the implications of diurnal and seasonal cycles in energy waste and energy efficiency. In addition both games included activities that needed to be performed at different time intervals and frequencies for short term or long term impact. For example students could conduct Energy Patrols that would not only check lights and devices but also close and open shades in the morning or afternoon to allow solar gain and keep those gains contained in the space during winter and vice versa during summer. Orientation of the classroom towards cardinal directions was also included. In the efargo game, patterns of thermostat setbacks for different seasons were part of the game activity and the game included other daily (daytime, nighttime), weekly, actions. The release of a weekly token or challenges, announcing of weekly block and individual winner, also set up a rhythm in the game that pervaded ordinary life space. Therefore time expansions were both content related and activity related.

The efargo game, due to its online presence, while it was live for a 9-week period, explicitly enabled asynchronous play: during the competition stage of the game, there was no forced limit on when gamers could engage the game. Stated differently, whether the gameplay took the form of using the digital interface or making changes to the physical environment, it could take place irrespective of the time of day or the concurrent engagement of other gamers. Of course the GUEP competition enforced a large-scale, two-year time limit to gameplay, but on the level of daily experience, game time and everyday time were blurred.

In contrast, in the K-12 Challenge, game time was limited and structured by school time, although these limits were developed differently in different schools, e. g., some schools participated only during certain days of the week while other classrooms played on all school days during while the Challenge was ongoing. In this way, game time was selectively expanded into everyday time, but not without limit.

Expanding the social circle was explicit in the structure of the efargo game. The participation in the game was tracked through the online game. Groups were defined by blocks in the City that were areas grouped together by the Census. A weekly token or Challenge was issued in the game. The Block with the greatest participation and points was declared the weekly winner. However, the weekly prize was given to a random person selected from the gamers in the winning block. As a result, it was in the interest of the gamers to cooperate with the neighbors in their census block to try to maximize their chances of winning. The random selection of the winning gamer added an element of chance to the game. The extent to which the efargo energy game expanded the social circle(s) of ordinary life into that of game space, and vice versa, is suggested by the presence of efargo-related hashtags, comments, and likes in social media applications (e. g., Facebook and Twitter). Gameplay explicitly encouraged these kinds of online social interaction, and the proliferation of likes and hashtags undoubtedly provided access points to the game for persons otherwise unaware of its existence. For the K-12 Challenge, the expansion of the everyday social circle into and out of that of the game was in part a function of the individual schools' curricular and classroom structures: groups of schoolchildren who organized specifically to play the game may or may not have had prior social connections, depending on the structure within which gameplay was made available to them (e. g., as part of a class or of an after-school activity).

The efargo game and K-12 Challenge were designed such that every community member or student who became a gamer would expand their understanding of space (i. e., places, homes and schools), time (diurnal, seasonal impacts and strategies) and social circles (people whose actions determine the amount of energy used) as units of energy use and therefore actionable in terms of game goals such as the prevention of energy waste, increase in energy efficiency and promotion of energy conservation. McGonigal (2006) describes pervasive games as those that "explore urban identity, critique habitual behaviors, and seek to construct experimental social structures" (McGonigal, 2006, 174).

3.6 The Triadic Game Design Model

Guiding principles of the game designs emerged from a study of the Triadic Game Design model (Harteveld, 2011), where the balance between the three major game worlds or principles of Meaning (motivation of the gamers), Reality (ability/agency of the gamers by referencing and reflecting their reality, flexibility) and Play (entertainment/fun, competition, skill development for the gamers) is critical, albeit not a guarantee, for game success (Figure 3.4).

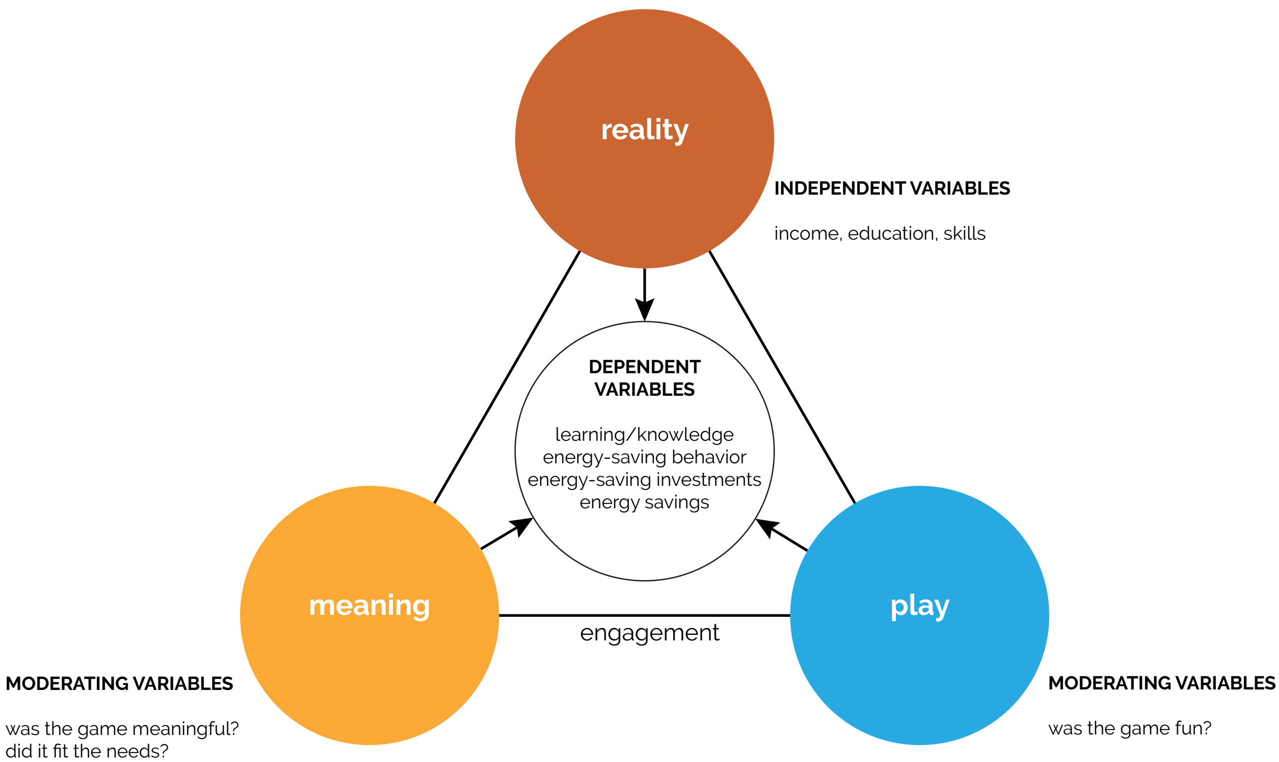


Figure 3.4. Triadic Game Design. After Harteveld (2011).

Although Harteveld suggests that to act on these issues concurrently during the entire design process would be impossible, the efargo game and the K-12 Challenge were designed, developed, and critiqued in order to balance the three worlds of Reality, Meaning and Play.[1]

3.7 Timeline: When did we play?

The efargo game was implemented once in 2016. The K-12 Challenge was implemented four times with design changes incorporated each time based on the feedback from teachers,

1 See Chapters 4 and 6 for further articulation of these principles within the specific games.

administrators and students. Based on gamer feedback different design iterations and durations were tested for the K-12 Challenge. The games are summarized in Table 3.3.

Table 3.3. Game timelines.

game	time	kick-off week	start	end	duration
efargo game	Spring 2016	Feb 23	Feb 28	Apr 29	1-week kick-off + game play; 7-week game play + 1-week game play + closing celebration
K-12 Challenge 1.0	Spring 2016	Feb 29	Mar 7	Apr 10	"1-week kick-off; 6-week game"
K-12 Challenge 2.0	Spring 2017	Feb 14	Feb 21	Apr 3	"1-week (tag the waste); 6-week game (fix the waste)"
K-12 Challenge 3.0	Spring 2018	Apr 7	Apr 14	May 4	"1- week kick-off (learning, tagging, preparing); 3-week (fix the waste /playing)"
K-12 Challenge 4.0	Fall 2018	Sep 29	Oct 6	Nov 2	"1-week kick-off (learning/ preparing/ tagging); 4-week (fix the waste / playing)"

3.8 Data collection

Three primary types of data were collected prior to, during and after game implementation: (a) energy-use data, (b) surveys and interviews, and (c) game activity. The energy-use data was collected prior to the games, during the games, and when possible after the games (efargo game) (Table 3.4). There were two types of energy-use data collection. First, the energy data was collected from the utilities, when permissions were granted by building owners. This data was typically available in the format of monthly energy use. The second type of energy-use data collection was from direct meter readings, if permissions were available, from school principals and facility staff.

Table 3.4.Energy-use data collection (boldface check marks indicate year game was played)

intervention	utility data or utility bills				weekly meter readings from game site for duration of game and baseline		
	2013	2014	2015	2016	2016	2017	2018
Efargo game: energy data for individual gamers	✓	✓	✓	☑			
GUEP Participating CIties	✓	✓	☑	☑			
GUEP City of Fargo	✓	✓	☑	☑			
K-12 Challenge 1.0					☑		
K-12 Challenge 2.0						☑	
K-12 Challenge 3.0							☑
K-12 Challenge 4.0							☑

3.8.1 Georgetown Prize energy-use data collection

Citywide municipal and residential energy data collection was collected from 2015 January to December 2017 with permission from the City of Fargo and the local utilities, Xcel Energy and Cass County Electric Cooperative. This initiative was part of the GUEP data collection, of which the efargo game was a primary activity. This data was submitted to the GUEP management, quarterly for normalization and comparison.

3.8.2 efargo game energy-use data collection

The gamers were asked to give a privacy release in order for individual energy use data to be collected from the utility. A few gamers gave permission to access their energy use data. Of the few gamers who gave permission, the utility wasn't able to access some of their records due to address or names not matching utility records exactly or owner had moved from the home or apartment. Finally the number of available individual records was 19. Out of these 13 individual records were complete for electrical energy use. 3 people had incomplete records. There were only 6 gamers whose partial or complete gas use records were found.

3.8.3 K-12 Challenge energy-use data collection

Energy use data collection before and during the K-12 Challenge game iterations related to energy use in participating Fargo area schools was completed in two parts. First, weekly meter readings were collected starting with one or two baseline weeks when the game had not been implemented. The normalized average of these weeks created the baseline of energy use for comparison to the game period. Weekly readings were continued while the game was being implemented. These energy results were aggregated and reported to the schools weekly during the game. The efargo team was not able to collect meter readings after the game was completed, consistently, making the analysis of persistence difficult.

3.9 Surveys and Interviews

The second type of data collection were the pre-game and post-game surveys of the gamers. These surveys collected information about gamer demographics, game experience, and post-game impact on gamers, in terms of learning and behavior change.

3.9.1 efargo game surveys and interviews

The gamers completed a four-part survey before and during the game and then a single post-game survey. The four-part pre-game survey was deployed in the game interface itself and served the purpose of making the gamers familiar with the game interface and at the same time collecting information. A link in the game directed gamers to a qualtrics survey portal. The four parts of the survey coincided with game levels and were numbered Go 40, Go 50, Go 60, and Go 70. Go 40 contained six questions and asked the gamers details about their families and homes. Go 50 had 9 questions and asked gamers questions about their heating and cooling systems, devices and lighting. The Go 60 survey had 5 questions and asked the gamers about area in which they are willing to conserve energy, their needs in order to conserve energy, and their willingness to spend time and money on energy conservation. The Go 70 survey had 3 main questions related to willingness to take specific energy-saving actions in no-cost, low-cost and high-cost categories. Low-cost categories usually indicated a behavior shift in other words investment of time and high cost category usually indicated investment of money. The low-cost strategies usually included some level of investment of time and money. The four Qualtrics surveys had links to enter back into the game to the next level. Increasing number of points were awarded for each level that was completed. The post-game survey was deployed via Qualtrics link sent by email and collected information regarding the game experience. The post-game survey had 31 main questions, some of which had supporting questions. Lastly, gamers were given prompts throughout the game play to express their thoughts on energy issues at the individual scale (their thoughts, ideas, actions and behaviors) and at larger scales (such as the city's actions, ideas) about energy policy. These questions were called the Waste-a-Watt bonus questions and they earned gamers bonus points. There were 32 Waste-a-Watt bonus questions. Table 3.5 summarizes the data collection.

Table 3.5. efargo game survey and interview data collection.

efargo game	Pre-game surveys		WAW In-game conversation		Post-game survey	
2016	Go 40 (Pre-game survey part 1) See Appendix Table 3.a	122	WAW Bonus question responses See Appendix Table 3.e	701	Post-game survey responses in qualtrics See Appendix Table 3.f	64
	Go 50 (Pre-game survey part 2) See Appendix Table 3.b	107				
	Go 60 (Pre-game survey part 3) See Appendix Table 3.c	90				
	Go 70 (Pre-game survey part 4) See Appendix Table 3.d	85				

3.9.2 K-12 Challenge game surveys and interviews

In addition to the weekly energy use data collection by the efargo team of participating schools, interviews and surveys were conducted of the participating students and teachers. Pre-game and post-game surveys of teachers were completed in 2016 and 2018. Pre-game and post-game surveys of the participating students were completed in 2017 and 2018. Table 3.6 and Table 3.7 summarize the data collection.

Table 3.6. Sample sizes for K-12 Challenge data collection (See Appendix Tables 3.g- 3.n).

	Teacher pre-game survey	Teacher post-game survey	Student pre-game survey	Student post-game survey	Teacher Interview
K-12 Challenge 1.0: Spring 2016	n/a	14	n/a	n/a	5
K-12 Challenge 2.0: Spring 2017	n/a	n/a	135	125	4
K-12 Challenge 3.0: Spring 2018	0	0	134	134	n/a
K-12 Challenge 4.0: Fall 2018	5	5	93	93	n/a

Table 3.7. Details of K-12 Challenge surveys and interviews.

period	SCHOOLS PARTICIPATING[1]	STUDENTS Pre-game	STUDENTS Post-game	TEACHERS Pre-game	TEACHERS Post-game
Spring 2016	7-week energy challenge - Spring 2016				
	R. Elementary School	n/a	n/a	n/a	Qualtrics Survey (n=2) + interviews (n=1)
	L. Middle School	n/a	n/a	n/a	Qualtrics Survey (n=3) + interviews (n=2)
	L. C. Elementary School (partial)	n/a	n/a	n/a	Qualtrics Survey (n=4) + interviews (n=2)
	J. Elementary School	n/a	n/a	n/a	Qualtrics Survey (n=5)
Spring 2017	6-week energy challenge - Spring 2017				
	R. Elementary School	3-option survey (n=28)	3-option survey (n=27)	n/a	Interviews (n=1)
	W. Elementary School	3-option survey (n=40)	3-option survey (n=57)	n/a	Interviews (n=1)
	L. C. Elementary School	n/a	n/a	n/a	n/a
	L. Middle School	5-scale survey (n=135)	5-scale survey (n=125)	n/a	Interviews (n=1)
	H. M. Elementary School	n/a	n/a	n/a	Interviews (n=1)

1 School names are anonymized.

period	SCHOOLS PARTICIPATING[1]	STUDENTS Pre-game	STUDENTS Post-game	TEACHERS Pre-game	TEACHERS Post-game
Spring 2018	3-week energy challenge - Spring 2018				
	W. Elementary School	5-scale survey (n=57)	5-scale survey (n=60)	n/a	Google form Survey (n=0)
	L. F. Elementary School	5-scale survey (n=78)	"5-scale survey (n=74)"	n/a	Google form Survey (n=0)
Fall 2018	4-week energy challenge - Fall 2018				
	W. Elementary School	5-scale survey (n=56)	5-scale survey (n=58)	5-scale survey (n=3)	5-scale survey (n=3)
	C. Elementary School	5-scale survey (n=22)	5-scale survey (n=23)	5-scale survey (n=1)	"5-scale survey (n=1)"
	M. Elementary School	5-scale survey (n=15)	5-scale survey (n=12)	5-scale survey (n=1)	5-scale survey (n=1)

3.10 Game activity descriptives

The third type of data collection was related to the game play itself, specifically game points earned and activities engaged in. This data was collected and visualized through the digital dashboard and mapping interface for the efargo game (Figure 3.5). As the gamers completed games tokens and challenges, their progress was recorded in the game database (shown in the left panel of Figure 3.5). In addition the overall comparative game activity in each census block of the city was recorded (shown on the right side of Figure 3.5).

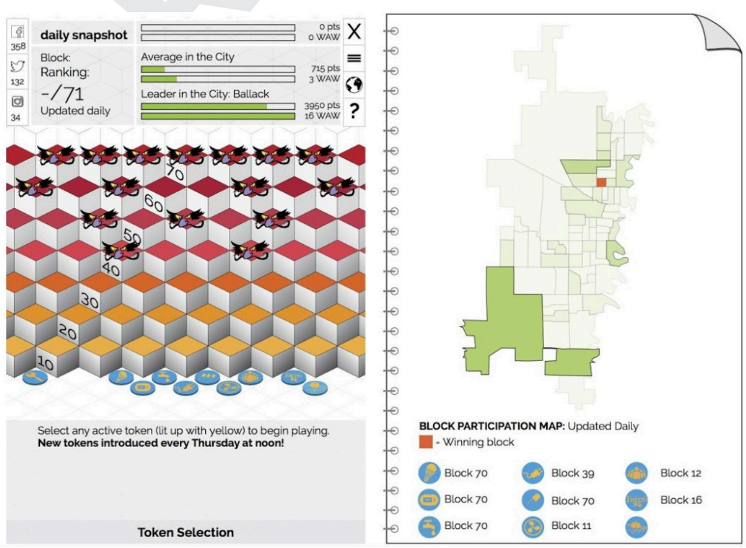


Figure 3.5: efargo dashboard and map.

As part of the entry sequence in the game, each gamer identified the census block they lived in by selecting the appropriate block using an interactive map. Online gamers would see a weekly update of the number of points each block had scored. This was displayed by assigning a fill gradient, green, to each census block boundary. The more saturated the color fill, the more points that block had scored in the previous week. This update also included a display of the weekly winning block, highlighted using 'efargo orange'. This was the winning block. No gamer identities were revealed through the dashboard or through the mapping.

In the K-12 Challenge, in order to track activities and student participation, teacher and staff interviews were completed in 2016 and 2017. In 2018 (Challenges 3 and 4), the tracking of activities, engagement and participation was accomplished by using a physical score-board or game tile (Figure 3.6) that was completed by the students or teacher, photographed and shared with efargo team, every week. This dashboard recorded activities every day based on the categories such as kick-off activities (green), lighting (yellow), heating and cooling (red), devices (purple) and dissemination/activist friday (blue). The students and teachers recorded which activities were completed in their classroom multiplied by the number of people who completed the activity to get a classroom score for that particular activity. The classroom would total all the activity points at the end of the week and send a photograph of the scorecard to the efargo team. The efargo team would then aggregate all the weekly results from various classrooms in a weekly report that was distributed to all the classrooms at the beginning of the next week.[1]

1 See Chapters 4 and 5 for a detailed discussion on game objects related to the two games.

Figure 3.6: Fall 2018 K-12 Energy Challenge 4.0, Game tiles and dashboard.

3.11 Analysis Methods

Various methods were utilized to test the collected data. Weather normalizations were completed for the energy use data, and various descriptive and inferential methods were used for the quantitative data. In addition, descriptive summaries and visualizations of information gathered before, during and after the games were completed.

3.11.1 Normalizing Energy-use data

For the energy-use data, normalizing for variable weather patterns was conducted in three different ways. First, the GUEP quarterly energy use data for residential and municipal buildings was normalized for weather, any growth in population, and carbon intensity of source energy. This normalization was carried out by the GUEP team at Georgetown University. The GUEP team used Energy Star's Portfolio Manager to complete weather normalizations. An online tool, Portfolio Manager is used to measure energy and water consumption as well as greenhouse gas emissions. It is capable of benchmarking the performance of a single building or a portfolio of buildings (Energy star portfolio manager, n. d.; Palma, 2018). To normalize each community for its relative size, the GUEP team divided the total normalized energy consumption by the number of residential bills issued each month. Residential energy bills were used as a standardized way of comparing energy use of two different-sized communities by calculating the average energy consumption per residential customer. In order to enable energy cost estimation in the Performance Dashboard, the first quarterly report from the communities also included the average gas and electricity costs (per energy unit) during 2014 (i.e., averaged over the entire year). This baseline cost information was used throughout the competition and did not reflect any rate changes in the intervening time. Performance in the competition, and the energy performance rankings, were based on the 24-month average of the normalized energy performance per residential energy customer. The Overall Energy Score (OES) was calculated using the formula in Table 3.xxx.[1]

1 See Appendix 8.A for a discussion of the GUEP methods for performance calculation.

Table 3.xxx. Calculation of Overall Energy Score (OES).

Overall Energy Score (OES)
$$OES = 100 \times \frac{\text{(Competition Average - Baseline Average)}}{\text{Baseline Average}}$$

Baseline Average

Secondly, the individual gamers' annual and monthly energy use data for the efargo game was normalized using ETracker (Kissock, 2003), a tool developed with support from the United States EPA for the Energy Star Buildings Program. Unlike Portfolio Manager, which can only produce annual results, ETracker can visualize normalized results by month. ETracker "uses ambient-temperature regression models to reduce the influence of changing weather so that retrofit savings can be more accurately measured" (Kissock, 2003, 3). ETracker requires two kinds of data: first, files containing energy use data from utility bills, and second, files containing average daily temperatures such as weather data files from EPA or the National Weather Service. Files available from the University of Dayton contain average daily temperature data for selected cities from 1995 to the present. Additional daily temperature data files specific to Fargo were available from the University of Dayton. This data can also be accessed from the National Oceanic and Atmospheric Administration, whose National Weather Service office is located in Grand Forks, North Dakota,[1] from the Applied Climate Information System (ACIS),[2] which is a joint project of the Regional Climate Centers,[3] the National Centers for Environmental Information (NCEI),[4] and the National Weather Service.[5] Once the two data sources are prepared for input, the software:

> "... merges the energy use and temperature data, and develops a best-fit regression model of energy use and temperature from before the retrofit. To measure energy savings, energy use from after the retrofit is compared to the model's prediction of

1 https://w2.weather.gov/climate/xmacis.php?wfo=fgf

2 http://www.rcc-acis.org/

3 https://www.ncdc.noaa.gov/customer-support/partnerships/regional-climate-centers

4 https://www.ncdc.noaa.gov/

5 https://www.weather.gov/climateservices/

how much energy the building would have consumed if it were not retrofitted. ETracker displays numerical results, and creates easily understood graphs of pre and post-retrofit energy consumption for easy comparison. This method of measuring savings is recommended by the International Performance, Measurements and Verification Protocols (IPMVP), the Federal Energy Management Program (FEMP) Measurement and Verification Guidelines and ASHRAE Guideline 14" (Kissock, 2003, 3).

In the K-12 Challenge, weekly energy-use data was collected from meter readings at the participating schools (and control schools when permission was available). Before the weekly data could be properly compared for analysis, it required normalization for weather. The data was normalized using Woodcock's method (Woodcock, 2015; Palma. 2018). While Woodcock's method does not normalize the consumed energy value, it provides the performance efficiency of two or more properties and normalizes that use for weather conditions. Table 3.xxxx summarizes Woodcock's method.

Table 3.xxx. Step-by-step description of Woodcock's method for energy use comparison between buildings.

Step	description	
1	Determine the Total Degree Days by adding heating degree days (HDD) and cooling degree days (CDD) for one building for a period of time	$\text{Total Degree Days} = \text{HDD} + \text{CDD}$
2	Determine the Average Energy for the building by dividing the total kWh used at that building during the same period of time by the Total Degree Days	$\text{Average Energy}_{\text{building1}} = \dfrac{\text{(Total Energy in kWh)}}{\text{Total Degree Days}}$
3	Repeat the same calculation for a second building	$\text{Average Energy}_{\text{building2}} = \dfrac{\text{(Total Energy in kWh)}}{\text{Total Degree Days}}$
4	Compare results from Steps 2 and 3	$\text{Average Energy}_{\text{building1}} <?> \text{Average Energy}_{\text{building2}}$

The meter readings were first multiplied with the meter multiplier supplied by Fargo Public Schools or the utility providers. The electricity reading from the electrical meter, or the sum of all electrical meters for each school, formed the weekly electricity reading in kWh. For a given current week, the previous week's meter reading was subtracted from the current week's meter reading to calculate the electrical energy use for the current week. This was the energy use for the school for that week in kWh. Heating Degree Days (HDD) and Cooling Degree Days (CDD) for the given time period were accessed from the North Dakota Agriculture Weather Network (NDAWN).[1] Following Woodcock's method, the week's energy use in kWh was divided by the sum of HDD and CDD for the week. The resulting value provided the normalized energy use (NEU) for that week. To calculate the percentage change in the NEU for the schools, the weekly game NEU was compared to the NEU for the baseline week prior to the start of the game play, consistent with the normalization process outlined by the GUEP.

3.11.2 Quantitative analysis (efargo community game and K-12 Energy Challenge).

Where the sample sizes and response scales allowed it, descriptive and inferential methods, including the following listed below, were used to test hypotheses 1-4.

Frequency tables with corresponding percentages for nominal or ordinal variables (Nicol, 2007).

Two-way tables and contingency tables for relationships between variables (Rayner & Best, 2006).

Calculation of means and standard deviations for analyzing relationships and describing interval/ratio data (Salkind, 2007).

Pearson's correlations for describing interval/ratio variables (Chung, 2007).

Cronbach's alpha to test the reliability of composite variables (Barchard, 2007).

Chi-square tests of independence to test null hypotheses (Lane, 2007).

Student's t-tests to test combinations of independent and moderator variables (Prescott, 2006), including Likert scale responses (Likert, 1932), modeled as if interval/ratio data.

F-tests to test for statistical significance among any of the independent variables in a multiple linear regression model (Daniel, Onwuegbuzie, & Leech, 2007).

One-way analysis of variance (ANOVA) to test combinations of independent and moderator variables, if there were more than two levels to the independent variable (Field, 2007).

Graphics and diagrams corresponding with statistical analysis and numeric summaries.

[report what was done ... we counted all of the engagement data ... the fact that it was done]

1 https://ndawn.ndsu.nodak.edu/

Lastly, although inferential methods yield reliable results, there are caveats to be considered. Both the efargo game and K-12 challenge provide the information for this study and the participants are self-selected to some degree introducing a relevant bias. By definition, participation in games is voluntary. The ability of people and groups of people to voluntarily participate was important on the "open" definition of the Pervasive Serious Energy games. To summarize, a number of inferential tests were applied to variables from this study.[1]

Summary

The pervasive nature of the efargo game and the K-12 Challenge has the potential for purposeful play, i. e. using the pleasure motivation of gaming to achieve goals that may create reduction in energy use. In addition, the efargo game and K-12 Challenge may be categorized as Serious Games (games which have more than an entertainment purpose) as they educate and train people about energy efficiency in homes (Michael & Chen, 2006) and schools. Further, they are categorized as Serious Pervasive Energy Games (SPEGs), because they are designed to create spatial, temporal, and social expansions. This chapter outlines the research design implemented in aid of hypotheses to be tested, data collected, and tests conducted to understand the outcomes of SPEGs in an open structure in the City of Fargo.[2]

1 A combination of reliable descriptive statistics and selective use of inferential methods created the analysis for this dissertation as outlined in Chapters 6, 7 and 8.

2 The results of these analyses are described in Chapters 6, 7, and 8. The limitations found in the implementation, testing, data collection and analysis in Pervasive games are further discussed in Chapter 9.

4.0 Game Design: The efargo game for Homes

Summary

This chapter discusses the design model, design process, structure, and implementation timeline of a public pervasive game called the efargo game targeted to homeowners in the city of Fargo, North Dakota.[1] The game was designed to enable gamers to act on energy-saving behaviors in their homes through game play.

The efargo game was a pervasive energy game open to public participation, implemented once in Spring 2016 over a nine-week period (a one-week kick-off and an eight-week game period).

4.1 Introduction

This chapter presents a public pervasive game called the efargo game. The game's design model, design process, structure and mechanisms, implementation timeline, and telemetry are discussed in detail. The efargo game aimed at enabling participants to overcome the informational and behavioral challenges of the energy efficiency gap (Hirst & Brown, 1990) and thereby adopt environmentally beneficial behavior with proven outcomes (Head & Hunt, 2014).

By bringing the fun of a game to the space of ordinary life, and combining it with the purposefulness of energy games implemented at the city scale, the efargo game harnessed game characteristics to achieve a positive shift in the energy-use behavior of people who were simultaneously city dwellers and gamers. The game was designed to create playful engagement through game components (such as competition based on game prizes, goals

1 This chapter is based in part on Srivastava (2016).

and incentives to educate about energy use in homes) and consequently to cause energy-use reduction through game play activities. Gamers assumed various roles during game play, such as learner, teacher, story-teller, advocate, handy person, and activist. These play characteristics of role-play, territory-based competition, game narrative, uncertainty, and unpredictability are essentially fun elements that differentiate the game from Froelich's eco-feedback, or information-based strategies to persuade and motivate community members towards energy conservation behavior (Froehlich, 2014).[1]

4.2 Game structure

The structure of the efargo game is described with reference to Poplin's game elements, i. e., environment, objects, goals, rules and player (Poplin, 2011, Poplin, 2012, 199). The game environment, which for Poplin (2012, 199) means a geographical location, was the City of Fargo for the efargo game. Game objects, for Poplin (2012, 199) are physical objects such as buildings, and also stakeholders (their moods, satisfaction) and events. The efargo game was specifically meant for homes in the city of Fargo, so the game objects includes these buildings but also the occupants in the homes. This dissertation extends Poplin's definition of game objects to any activity that has a material representation (physical or digital) in the game, or on which there is a material impact of the game. In Poplin's framework, game goals include finding satisfactory real-life solutions and educating players (Poplin, 2012, 199), and thus can be understood to refer to both the purposes behind creating games as well as players' objectives. The goals of the efargo game include enabling gamers to gain knowledge and awareness about energy efficiency and energy waste, to effect a behavior change towards more energy-efficient behavior, to increase their willingness to make energy-saving investments, and lastly to achieve energy-savings. Poplin's game rules define how the games are played and how activity is rewarded (Poplin, 2012, 199). and game players are the people who played the game (Poplin, 2012, 199), which in the efargo game meant homeowners and renters.

In this dissertation, Poplin's framework of categories is extended to include the game narrative

1 Game design, development, and implementation was supported in part by a seed grant from the City of Fargo, ND, and a grant from the State Energy Program of the North Dakota Department of Commerce (supported by the U. S. Department of Energy), on which this dissertation's author was the Principal Investigator. Refer to acknowledgements for a full list of team members involved in the implementation of the efargo game.

and game tools (Srivastava, 2016). The game narrative, which in the efargo game was based on a character called Waste-a-Watt, provides a story linking the environment, objects, goals, rules, and players. Game tools are the objects or interfaces required to play the game, including the rules governing gamers' actions and determining game incentives and rewards. All of these elements come together to create a game's magic circle, i. e., the boundary separating the game from ordinary life (Montola, Stenros, & Waern, 2009).

4.2.1 Game narrative

In the efargo game, the game narrative was centered around the typical good-versus-evil story, incorporating an evil character called Waste-a-Watt who thrived on wasted energy, with community members as heroes or champions defeating the character. The more energy wasted by the community, the stronger he grew. The Waste-a-Watt character was originally developed for the K-12 Energy Challenge to provide that game with a narrative.[1] Initial caricatures produced were presented to elementary and middle school children at an Earth Day 2014 event at the Fargo zoo called Party for the Planet.[2] The children generated several versions of the Waste-a-Watt character (Figure 4.1, Figure 4.2).

1 See Chapter 6.

2 Initial Waste-a-Watt sketches were completed by Mackenzie Lyseng and Mike Christenson

Figure 4.1. Children at Party for the Planet generating their own versions of Waste-a-Watt

Figure 4.2. Waste-a-Watt versions generated by elementary school students at the Party for the Planet (initial drawings by Mike Christenson and Mackenzie Lyseng, final compilation by Troy Raisanen)

Some of these drawings were combined and developed into the final Waste-a-Watt character (Figure 4.3). Although there were no studies conducted to test game implementation with or without the narrative and character, it was evident that Waste-a-Watt caught people's attention in the K-12 Challenge (people would take photos with the Waste-a-Watt character statue at the library; children wanted the Waste-a-Watt cards at community events). Waste-a-Watt was therefore incorporated into the efargo game both to provide an easy-to-communicate central thematic concept and to build upon the design and the name within the K-12 Energy Challenge (Figure 4.9).

Figure 4.3. The Waste-A-Watt character within the efargo game web interface.

4.2.2 Game environment

The efargo game was primarily played in the city of Fargo. The city of Fargo is divided into seventy-one community blocks based on U. S. Census block boundaries. During sign-up, each gamer identified their census block based on their geographic location in the city; gamers who were not residents of Fargo were allowed a game path that engaged approximately 80% of the game play but excluded crucial aspects of the game environment such as presence on the game dashboard, eligibility to win weekly prizes, receipt of local news announcements, and participation in local community events related to the game play.

Individual homes were the focus of the game in the first six of nine weeks, This focus recognized that the home was the most immediately actionable and therefore educational and meaningful unit of game play. Later, the play later expanded to spaces outside the home. This expansion recognized that game-based learning could create awareness capable of translation into more social and complex spaces such as other building typologies in the city. Ultimately, this concept of expanded awareness was utilized by the final token in the game (the Community Celebration token) which required individual community members or groups to become active in issues of energy policy. This was achieved by engaging gamers directly with the city-provided Sidewalk app for community engagement, including conversations and polling. By connecting the efargo game to the Sidewalk app, it became possible for gamers to provide feedback on municipality-related questions about energy policy. In this way, the game aimed to expand its environment from the home to municipal engagement; the magic circle (Montola, Stenros, & Waern, 2009) expanded outward and the game became increasingly pervasive.

4.2.3 Game objects

Game objects included homes in the city of Fargo, i. e., single-family homes as well as apartments. Additionally, occupants in the homes were considered game objects, as were the energy-saving actions (events and activities) and the families of the gamers (stakeholders). Finally, because the game incorporated the census block as a unit of play, the neighborhood and the city as a whole became game objects.

Per the game design, the census blocks competed with each other for weekly recognition. The game scores of all gamers in a census block were aggregated to create the block participation score. The census block with the highest block participation score for the week was declared the block winner. The game also included a weekly reward (a $50 gift certificate to a local hardware store) given to a randomly selected gamer from the winning block (not necessarily the gamer with the highest individual score). The identification of weekly champions was designed to encourage neighbors to build community around the idea of energy conservation, and to ask their neighbors to participate, thus increasing their own chances of winning, and increasing the opportunities to disseminate information and influence community behavior beyond their own home. Anticipation of the final grand prize (a NEST thermostat) awarded to the person(s) with the highest score in the city was meant to incentivize higher levels of engagement from individual gamers, to provide rewards aligning with game goals about energy conservation, and to create spatial, social and temporal expansions. The awards for the weekly block winner and the weekly champion gamer were announced via social media with public gamer IDs (Figure 4.14), within the game and emails to all gamers who chose to receive emails.

Figure 4.14: Weekly block and individual winners announced weekly via social media, email and events.

4.2.4 Game goals

Pervasive games like the efargo game exist at the intersection of game life and ordinary life. Designers of pervasive games like efargo must seek to expand the space, time and social circle of game life into ordinary life and vice versa. This involves interpreting and implementing ordinary life actions, spaces, and social circles as game elements.

Working from the assumption that games in general and pervasive games in particular have the potential to create community, action and participation, the efargo game was designed and implemented with the goal of reducing energy use in Fargo homes. As such, homeowners and renters of all residential typologies such as single family homes, duplexes, townhomes, and apartments were able to learn about energy waste in their homes (learning and awareness), take action to reduce energy use (behavior) and invest time and financial resources in order to reduce energy use (investment). Acknowledging that renters might be limited in their ability to make longer-term changes such as appliance replacements, the game included several opportunities focused on energy use behavior for renters and owners.

The efargo game was also designed to overcome informational gaps and behavioral inertia among gamers, providing nudges for behavior shifts to address the energy efficiency gap. To earn as many points as possible, gamers had to complete energy-saving actions. To be successful in their actions, gamers needed to become better informed about energy waste and energy efficiency through information and quizzes in the game, and they had to share ideas with the game community in order to make progress.

As a Serious Pervasive Energy Game (SPEG), the efargo game was designed such that every community member who became a gamer could expand their understanding of space (i. e., places, or more particularly homes), time (seasonal impacts), and social circles (people whose actions determine the amount of energy used) as units of energy use. As such, these units became actionable in terms of game goals such as the prevention of energy waste, increase in energy efficiency, and promotion of energy conservation.

Lastly, the game's research purpose was to study whether serious energy games can cause learning awareness about energy use and behavior change towards energy-efficiency, increase the willingness of gamers to make investments towards energy reduction, and whether the game can cause a reduction in energy use. In order to do this, pre- and post-game surveys were conducted, and limited energy use data was collected from those gamers who gave permission for access. As part of the GUEP participation requirements, in partnership with local utilities, energy use improvements were measured against baseline energy use established during 2013-14).

4.2.5 Game tools

Game tools enable people to play the game. The version of the efargo game that was implemented in 2016 included a web-based digital game board (Figure 4.10) that allowed people to engage the game,and which could be accessed on desktops, laptops, tablets or smartphones. The game board educated and instructed gamers to complete activities in their homes, thereby earning points (an example of spatial expansion). The game board included a dashboard allowing gamers to see their scores in comparison to other gamers, how much they had advanced in the game, and visualizations that allowed them to see how their block was faring in the game in comparison to other blocks in the city. The game board also included a tutorial area that taught people how to play the game, a communications box that guided gamers through game sequences and interactions, a Help area that allowed gamers to ask the efargo team for help, and a map area (replacing the tutorial depending on context) showing the performance of the city as a whole, based on census blocks.

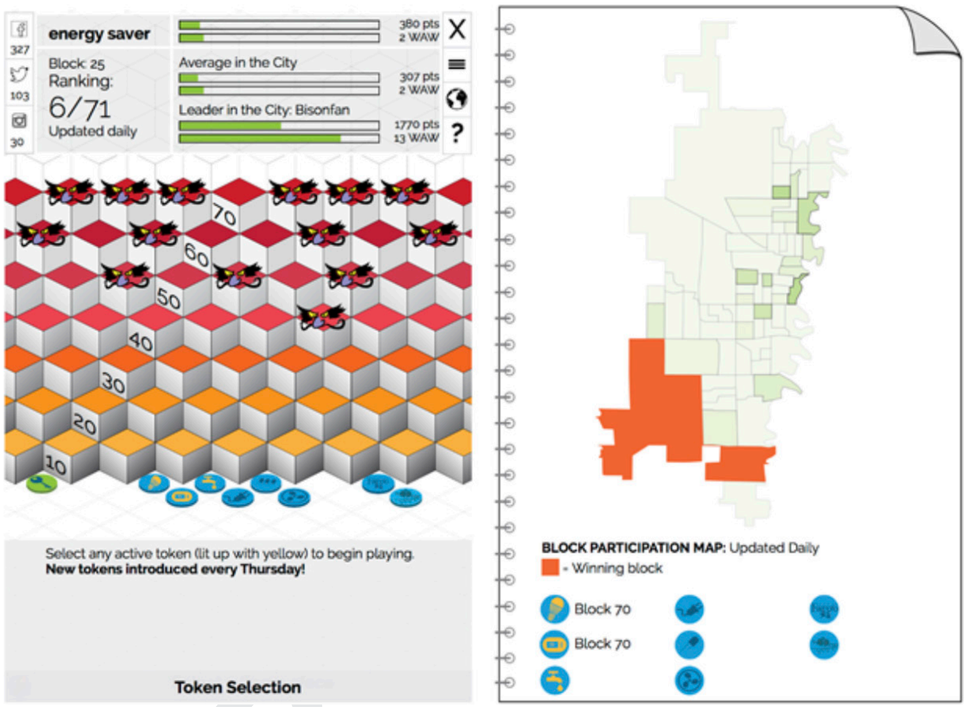


Figure 4.10. The efargo game board, dashboard, communications box, tokens, challenge block levels and mapping (this would be replaced by the tutorial page if the gamer was in token play mode).[1]

The efargo game was designed to be open to anyone in the community who wished to join. Yet, not all community members necessarily had access to the computer-based gameboard. To counteract this issue, game kiosks were set up at the public libraries to allow people access to the game and to receive help if they needed it. At these kiosks, a dedicated computer terminal was available to allow community members easy access to the game. In addition, efargo team members were present at the library for two hours every week to help community members sign up for the game and learn how to navigate the interface. The game did not track the location of the gamers.

1 See Figure 4.10.a for examples of tutorial pages, Appendix 4.d includes a selection of tutorial pages from the game

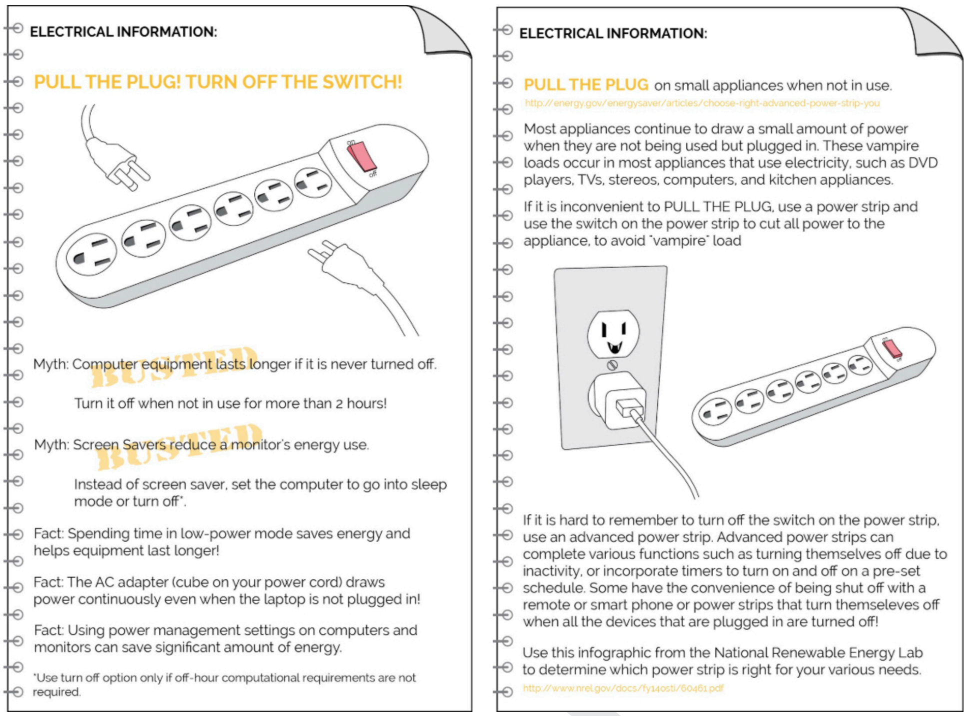


Figure 4.10.a An example of tutorial pages from the game.[1]

Action tokens and challenge level blocks in the gameboard enabled gamers to make progress within the game. Members of the efargo team released weekly tokens containing action items for gamers to complete in their homes and thereby meeting game goals or advancing their own positions in the game. These action items allowed gamers to engage in energy-saving practices in their homes, racing to complete as many as possible to maximize their scores and savings. Each token had seven challenge levels and addressed a particular area of energy-savings in the home such as lighting, devices, space-heating, space-cooling, etc. (See Table 4.1, Figure 4.11, Figure 4.12). Two of the game tokens contained city-based awareness and commentary and community events as a game component, expanding the game beyond the home to a larger scale.

1 Appendix 4.d includes a selection of tutorial pages from the game.

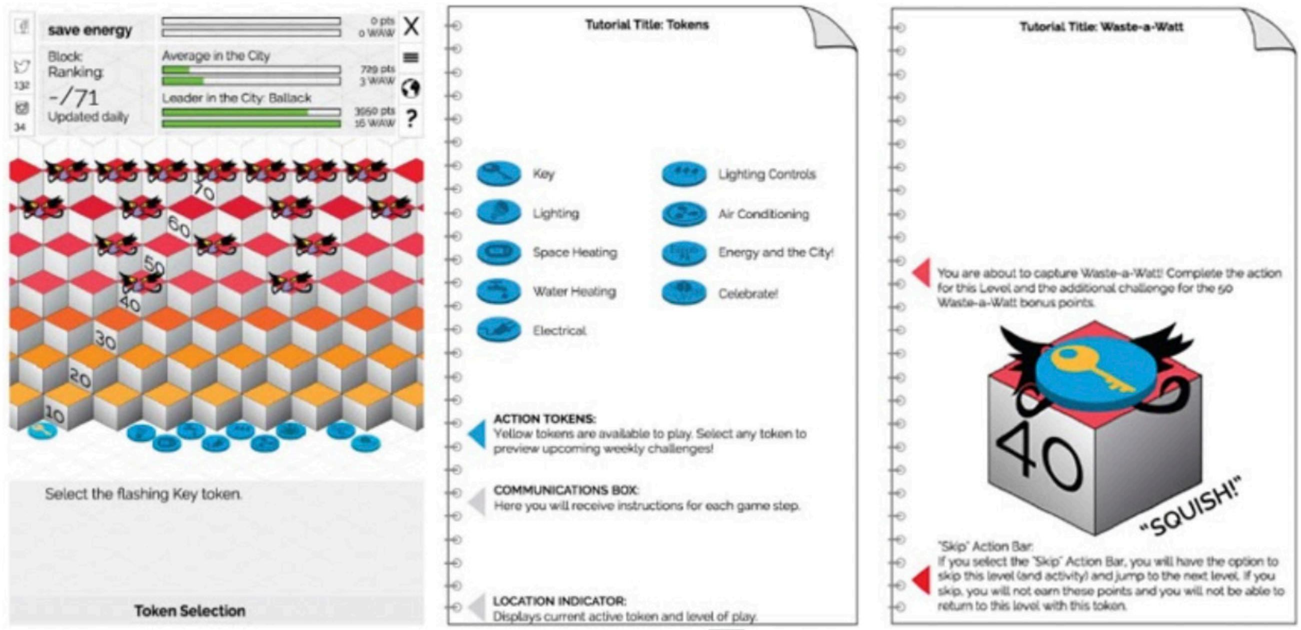


Figure 4.11. Game tokens moving across the board, capturing Waste-a-Watt as part of bonus game play

Table 4.1. Summary of game "action tokens" point system.

	TYPE	ACTION	ROLE	POINTS
CHALLENGE 1: INDIVIDUAL				
WEEK 1: KEY 2/23/2016	*required*	Provide gamer identify, location, utility.	*gamer*	10
	required	Review gamer energy bill.	*gamer*	20
	required	Post on social media and invite friends to join.	*advocate*	30
	optional	Answer a survey.	*research*	40
	optional	Answer a survey.	*research*	50
	optional	Answer a survey.	*research*	60
	optional	Answer a survey.	*research*	70
			weekly point subtotal:	*280*
CHALLENGE 2: INDIVIDUAL / NEIGHBORHOOD				
WEEK 1: LIGHTING 2/28/2016	*required*	Read paragraph + take quiz (color temp, energy use and life of LED lights).	*learner*	10
	required	Replace (5) bulbs @ most used interior lights w/LED.	*gamer*	20
	required	Use the links to share your promise to save energy with LED bulbs with your friends. Ask them to do the same.	*reporter/teacher*	30
	required	Replace (3) exterior light bulbs with LED.	*gamer*	40
	optional	Replace (5) more interior light bulbs with LED.	*gamer*	50
	optional	Replace holiday and landscaping lights with solar-powered LED lights.	*gamer*	60
	optional	Replace at least 75% of your bulbs (interior and exterior) with LED.	*gamer*	70
			weekly point subtotal:	*280*
WEEK 2: HEATING 3/3/2016	*required*	Read paragraph + take quiz (Keep shades and curtains open for solar gains and daylight).	*learner*	10
	required	Dial back thermostat 2 degrees in winter, dial back thermostat during nights and when you are away.	*gamer*	20
	optional	Post via hashtag #efargogame.	*reporter/teacher*	30
	optional	Set back your thermostat a minimum of 5 degrees F.	*gamer*	40
	optional	Change your HVAC filter, repeat regularly at least every 3 months.	*gamer*	50
	optional	Install a programmable or interactive learning thermostat with reporting and interactive capability. If you have a programmable thermostat make sure your settings are correct.	*gamer*	60
	optional	Have ducts cleaned, repeat every 3-5 years; fix duct leaks.	*gamer*	70
			weekly point subtotal:	*280*
WEEK 3: WATER **3/10/2016**	*required*	Read paragraph + take quiz (shorten showers, don't leave water running).	*learner*	10
	required	Lower water heater temperature to 120F (install a timer to turn heater off when not home).	*gamer*	20
	optional	Post via hashtag.	*reporter/teacher*	30
	optional	Wash clothes with cold water - detergents can clean equally well in cold and warm water.	*gamer*	40
	optional	Insulate your water heater if it has a storage tank. Consult a professional.	*gamer*	50
	optional	Insulate at least 6 feet of hot and cold water piping. Consult a professional.	*gamer*	60
	optional	Install aerating and low-flow shower heads and faucets. Consult a professional.	*gamer*	70
			weekly point subtotal:	*280*
WEEK 4: ELECTRICAL 3/17/2016	*required*	Read paragraph + take quiz (pull the plug, dishwasher on economy, air dry, cover the pots).	*learner*	10
	required	Powerstrips (electronics, small appliances).	*gamer*	20
	optional	Post via hashtag.	*reporter/teacher*	30
	optional	Set electronics and computers to hibernate or sleep mode when not in use.	*gamer*	40
	optional	Pull the plug on the second refrigerator. (Use if needed for holidays).	*gamer*	50
	optional	Install timers on kitchen exhaust fans.	*gamer*	60
	optional	Energy star appliances (such as induction cooktop).	*gamer*	70
			weekly point subtotal:	*280*

	TYPE	ACTION	ROLE	POINTS
WEEK 5: CONTROLS 3/24/2016	*required*	Read paragraph + take quiz (color temp, energy use and life of LED lights).	*learner*	10
	required	Add dimmers to most used rooms or fixtures.	*reporter/teacher*	20
	optional	Post via hashtag.	*reporter/teacher*	30
	optional	Add timers to bathroom exhausts.	*gamer*	40
	optional	Add motion detectors to least used rooms.	*gamer*	50
	optional	Add motion and daylight sensors to exterior fixtures.	*gamer*	60
	optional	Replace exterior holiday lights with solar-powered LEDS.	*gamer*	70
			weekly point subtotal:	*280*
WEEK 6: COOLING 3/31/2016	*required*	Read paragraph + take quiz (Close shades to prevent solar gain during the day).	*learner*	10
	required	Open windows for ventilation @ swing seasons.	*gamer*	20
	optional	Post via hashtag.	*reporter/teacher*	30
	optional	Increase temperature set point to 78 degrees F or greater when you are in the house. Increase temperature set point to 85 degrees F when you are out of the house.	*gamer*	40
	optional	Install and use ceiling fans or table fans.	*gamer*	50
	optional	Install exterior shades on south side windows; plant deciduous trees.	*gamer*	60
	optional	Invest in a heat pump room air conditioner for swing seasons.	*gamer*	70
			weekly point subtotal:	*280*
WEEK 7: GAMER CHOICE 4/7/2016	*	Lighting.	*designer / gamer*	10
	*	Space Heating.	*designer / gamer*	20
	*	Water Heating.	*designer / gamer*	30
	*	Electrical.	*designer / gamer*	40
	*	Controls.	*designer / gamer*	50
	*	Space Cooling.	*designer / gamer*	60
	*	Renewables.	*designer / gamer*	70
		** (based on responses to WAW questions)*	*weekly point subtotal:*	*280*

CHALLENGE 3: CIVIC

	TYPE	ACTION	ROLE	POINTS
WEEK 8: CITY 4/14/2016	*required*	Read paragraph + take quiz.		10
	required	Identify an energy waste prevention opportunity in the city: Post notice on Fargo One.		20
	optional	Post via hashtag, tag the mayor or commissioners.		30
	optional	Identify an energy idea for the city.		40
	optional	Vote for your favorite energy-saving idea that the city should implement.		50
	optional	Email a City Commissioner about your energy saving idea.		60
	optional	Email the Mayor about your energy saving idea for the City.		70
			weekly point subtotal:	*280*

CHALLENGE 4: CELEBRATE

	TYPE	ACTION	ROLE	POINTS
WEEK 9: CELEBRATION 4/21/2016	*required*	Attend the exhibit at the efargo event.		10
	required	Attend 2 workshops at the efargo event.		20
	optional	Attend free improv comedy! Post via hashtag!		30
	optional	Attend 2 workshops at the efargo event.		40
	optional	Attend 3 workshops at the efargo event.		50
	optional	Attend Mayor's town hall meeting at efargo event.		60
	optional	Attend evening entertainment at efargo event.		70
			weekly point subtotal:	*280*

TOTAL TOKENS	2800
WASTE A WATT QUESTION BONUS POINTS	800
GRAND TOTAL	3600

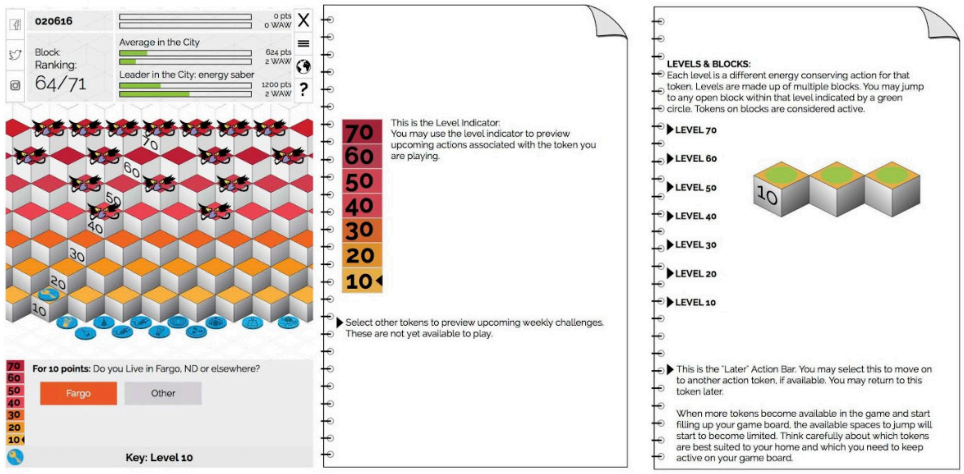


Figure 4.12: Levels and tokens

Each token had to be selected and then moved by a gamer to climb challenge levels represented by blocks. Each level (made up of seven blocks) was associated with a level of difficulty. The hierarchy was arranged such that the first three levels (Levels 10-30) were mandatory and easier to complete, and the next four levels (Levels 40-70) were optional, more difficult, but with greater point rewards. For each token, Level 10 (the first level) presented information in the form of tutorials and diagrams (Figure 4.10.a., Appendix 4.d) and quizzes for the gamer to complete. Level 20 included an easy action item associated with that token that is typically a low-cost or no-cost energy-saving effort in the gamer's home which was neither time- or knowledge-intensive. Level 30 asked people to share their participation in that week's token through social media or traditional media (phone, email, conversation), inviting friends, family, and most importantly neighbors to participate. Levels 40-70 asked gamers to complete energy-conserving action items with increasing levels of difficulty, requiring more time, effort, cost or preparation.

Since the game incentives were organized by block, activities that involved connecting with neighbors in order to engage broader participation from the block and disseminate information about energy efficiency and the ease with which it could be achieved were incentivized in the game. The game emphasized that the behavior of building occupants was material to energy use and waste, and that mitigating it through gamer outreach created social expansion (Figure

4.13). It allowed gamers to disseminate information about energy waste and energy efficiency more broadly in the community.

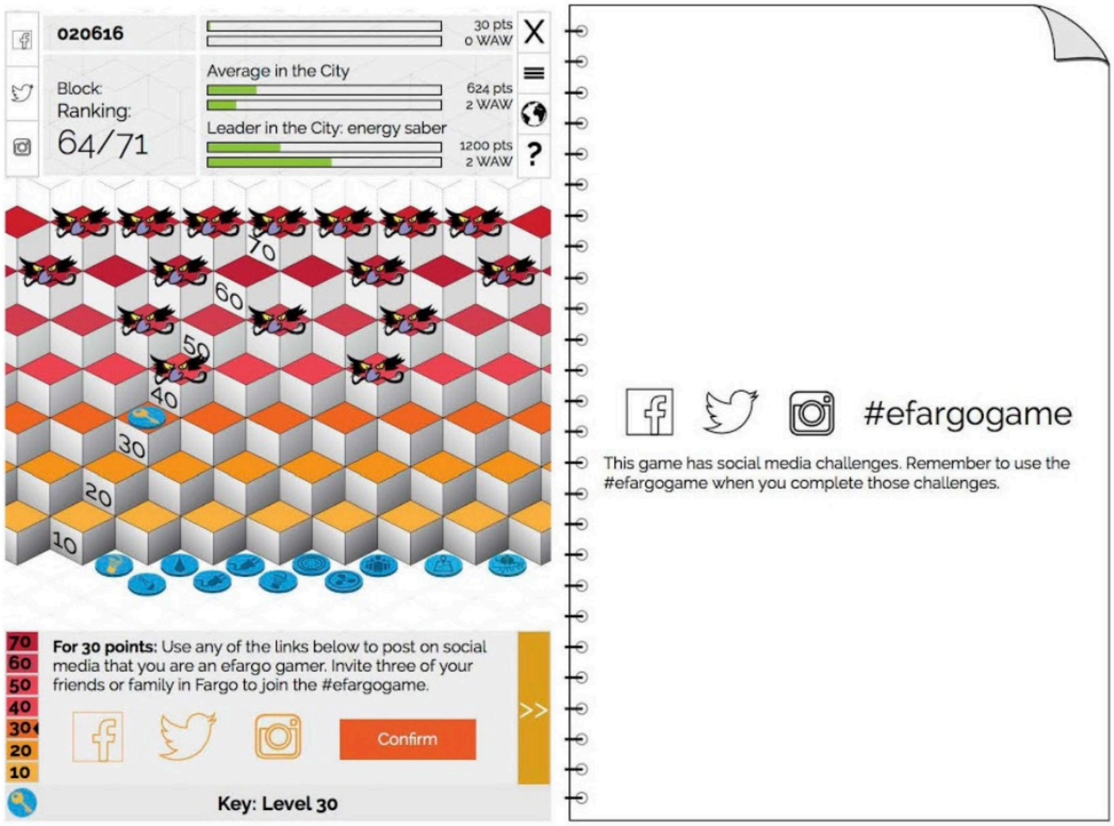


Figure 4.13: Social expansions through gamer outreach

The game also included a concealed Waste-a-Watt in some of the blocks at higher levels, which when discovered by a gamer, became an opportunity to earn bonus points. The action associated with the Waste-a-Watt capture was relatively easy, such as answering a question about energy efficiency ideas that gamers could share with others. This was another method of structured social expansion based on dissemination of information and sharing of ideas and experience in order to create an active and engaged community.

4.2.6 Game rules

Game rules essentially describe game play to the gamer. In the efargo game, the rules of play were communicated through an initial experience enabling gamers to interact with the game board as they signed up. In this way, the sign-up sequence, training, pre-game surveys, and rules-communication were all incorporated into an introductory token ("Go"), allowing gamers to earn game points as they learned the rules.

4.2.7 Game players and game play

Gamers who were renters, owners, or occupants of homes could join the game at any point during the nine-week game period and use the game tools to engage the game environment in pursuit of game goals. In doing so, gamers were asked to assume various roles such as observers, learners, teachers, storytellers, action-agents (handy person), idea generators (designers), information providers, and ultimately activists in the game, with the City token (Week 8) and the Community Celebration token (Week 9).

Energy-saving actions, social expansions, timing, information and strategy were cornerstones of individual or group (household) and voluntary play in the game. Depending on when the community member became a gamer, they had a choice of action tokens to select and play. The strategy involved making a choice of which tokens to play, how many tokens to play simultaneously, and which tokens were most appropriate for their home to be taken to the highest levels of play resulting in greatest points earned. However, the simultaneous play of tokens could clutter the game board path to higher levels; Waste-a-Watt bonus points also potentially diminish the investment of time and effort in each token. Hence, gamers needed to first learn about the various tokens (i. e., become educated in their own home's energy-saving potential) and in the process decide the greatest needs and priorities of their home -- thus creating the best strategy for their own play.

As part of the play, gamers were incentivized with points to answer quick surveys. The surveys asked the gamers about time and financial investment, their level of awareness about energy use, difficulty in game play, engagement with the game, entertainment potential of the game based on their own experience, etc. Gamers were also incentivized with Waste-a-Watt bonus points to answer questions that asked them about their concerns, ideas, reportage about problems they had identified, or issues they would have liked to bring to the attention of the gamer community at large. This was the point where they became reporters and idea generators. Gamers were also asked to engage their social networks through traditional, digital or social media as story-tellers and teachers, describing how they had played the game in their household and shared their successes or asked for help from the community. These stories created the visual and literary narrative of the game play.

In the later part of the game (the final three tokens) the game expanded socially to incentivize group participation and create an activist community around the idea of engaging the municipality to adopt and enforce energy efficiency policy. The last three tokens were the Gamer's Choice token (Week 7), the City token (Week 8), and the community Celebration token (Week 9). The Gamer's Choice token was designed based on the Waste-a-Watt responses of the community, incorporating ideas generated or needs identified by the gamers. The City token allowed gamers to become aware of past efforts on energy or environmental matters made by the state of North Dakota and the city of Fargo. The token enabled gamers to voice their concerns and ideas. (At the time of the game implementation, according to DSIRE,[1] North Dakota ranked last among all U. S. states in the provision of financial support instruments that encourage energy efficiency such as tax incentives or PACE programming. The City of Fargo did not have any such incentives at the local level either, although the local affordable housing program had a weatherization component.) The Celebration token, planned to coincide with Earth Day, was aimed at bringing the community together in active groups while the City token involved these active groups or individual gamers engaging city officials in order to communicate ideas and concerns about energy efficiency at the policy level. At the celebration event, gamers earned points by visiting various booths about the environmental efforts in the city available for their participation, such as a community solar park, composting programs, and a bike share program. The event featured an interview of local politicians seeking election to the city commission, conducted by a group of policy-based improvisational comedians.

4.3 Game design process and limitations

The game's iterative design process relied on Harteveld's Triadic Game Design model as the central form of critique (Harteveld, 2011).[2] The design of Reality within a game allows the game to connect to something familiar in the real world, with game components sharing some of

1 The Database of State Incentives for Renewable Energy, http://www.dsireusa.org/ (Accessed December 10, 2019)

2 See Chapter 3.

those characteristics. As Harteveld clarifies, a game is not a model of reality, although it may rely on a conceptual model that is based in reality (for example a book or a film based in reality). Meaning in a serious game comes from the achievement of value in the game, in terms such as knowledge acquisition, skills development, attitude or behavior shifts, data collection, or other similar means. Games are set apart from other cultural expressions by the inclusion of game structures that simultaneously allow engagement, fun, competition, story-telling, role-play, and rules that create the immersive magic circle of the game, and which form the third world, Play, of Harteveld's three-world model.

In Pervasive games, where life's ordinary spaces, time and society are cast into the magic circle (Montola, Stenros, & Waern, 2009), the idea of reality and its representation take on new meaning. For Baudrillard (1994), the "precession of simulacra" involves four stages, where the first stage is a faithful representation of reality, the second stage is a distorted representation of reality, the third stage is a representation that pretends to be a faithful representation or reality, and the fourth stage involves a representation with no relationship to any reality whatsoever. The pervasive game is a cultural artifact where the reality is a representation for the game. The time, space and society of a community become the representation in the game reality. Boyer's discussion of the contemporary city as a spectacle (Boyer, 1994) captures the implementation of certain pervasive games like Pac Manhattan or the B.U.G (Big Urban Game).

However, per Harteveld's model, if the pervasive game is a serious game, then it must contribute some value. As Harteveld asserts, "Games, like other media, can have a profound effect on society at large and can be seen as cultural expressions in their own right." This dissertation asserts that in Pervasive serious games where reality may be considered representation for the game, the value the game contributes must be meaningful in reality.
In other words, in pervasive play where the serious game exists in the reality of ordinary life, it becomes essential to derive value for the community where the game is played. For example, Meaning could be gleaned from the game's suitability to the circumstances of the constituent gamers in the community. If a home renter playing the game is unable to complete any of the activities, then the game is unsuitable and not meaningful to them. The pervasive serious game

could also derive meaningful value to the community as a whole, for example energy savings could result in lower carbon emissions which could ultimately result in improving air quality.

Connected to the notion of meaning and generated value in Harteveld's model is the feedback to the community for achievement in the game or value from the game. For serious pervasive energy or environmental games, Froelich asserts that there are several persuasive technologies with the purpose of providing monitoring and feedback in order to persuade people to engage in individual or group behaviors that reduce impacts on the environment, termed eco-feedback (Froehlich, 2014). Examples of eco-feedback include easy-to-understand information presented in a memorable way as close as possible to the time and place of environmental choice; comparison between people and groups that motivates action; incentives and disincentives; setting commitments and goals that are challenging yet achievable; and feedback that is both motivational and informational. Froelich further distinguishes between eco-feedback and games with the concept of designed playfulness which includes competition, narrative, uncertainty, unpredictability, and fun, in addition to other persuasive technologies. This connects the notion of eco-feedback to both the meaning and play qualities of the game.

The Play component allows the game to incorporate qualities of immersion and fun, distinct from other cultural media. This is a particularly important aspect in a pervasive game with a serious purpose, because game play that spans between the digital environment and the real world requires gamers to move from one to the other, which can be disruptive to the game's immersive quality. This can create a substantive challenge for serious game design. Fun and immersive qualities can be achieved through actions, adventures, role-play, puzzles and strategies within the game design, per Harteveld. When these are placed in the reality of ordinary life, the transfer gap, which is the struggle to transfer abstract concepts learned in the game to real world tasks (Gustafsson, Bang, & Svahn, 2009), is absent, although persistence beyond game time may not be ensured.

4.3.1 Design process

This section of the chapter reviews a selection of significant elements in the efargo game's design process. Along with Froelich's eco-feedback and designed playfulness, Harteveld's aspects of Play, Meaning, and Reality served as the basis for critique of every game concept during the design and development phase of the efargo game.

The initial game structure diagramming began with an interpretation of the distinguishing attributes of Pervasive games, namely, social, temporal, and spatial expansions (Figure 4.1). Social expansions were realized as the game began primarily from individual actions, expanded to secondary-level social networks such as friends and family, and then further expanded to tertiary relationships such as government and community, such as places of gathering or workplaces. Temporal expansions were envisioned within the game as different frequency cycles of weekly, bi-weekly and monthly activity, even as the game proposed a focus on learning about seasonal and diurnal energy-saving strategies. Spatial expansions were planned to be scale- and typology-based, with game play starting in the home leading to the city or urban concerns. All three expansion attributes served as the basis for initial game design concepts (Figure 4.2).

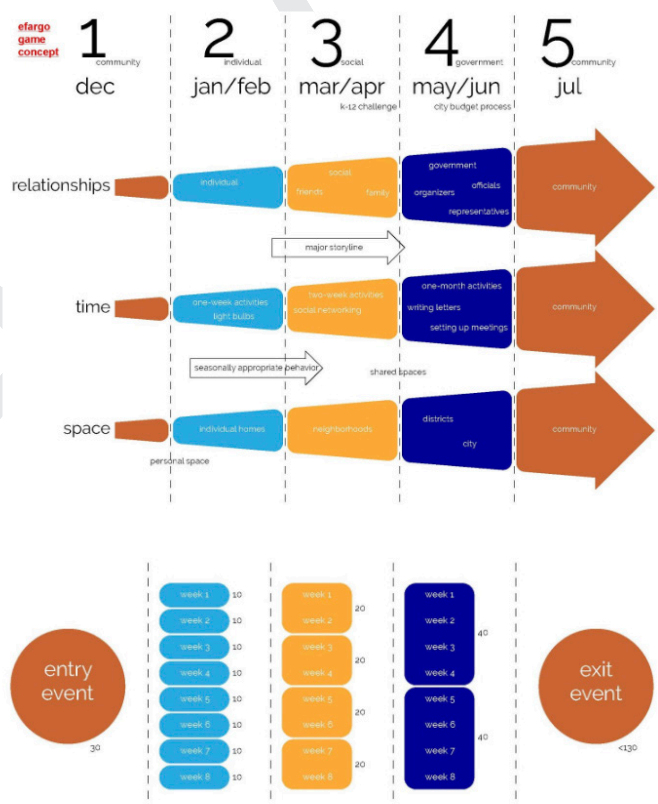
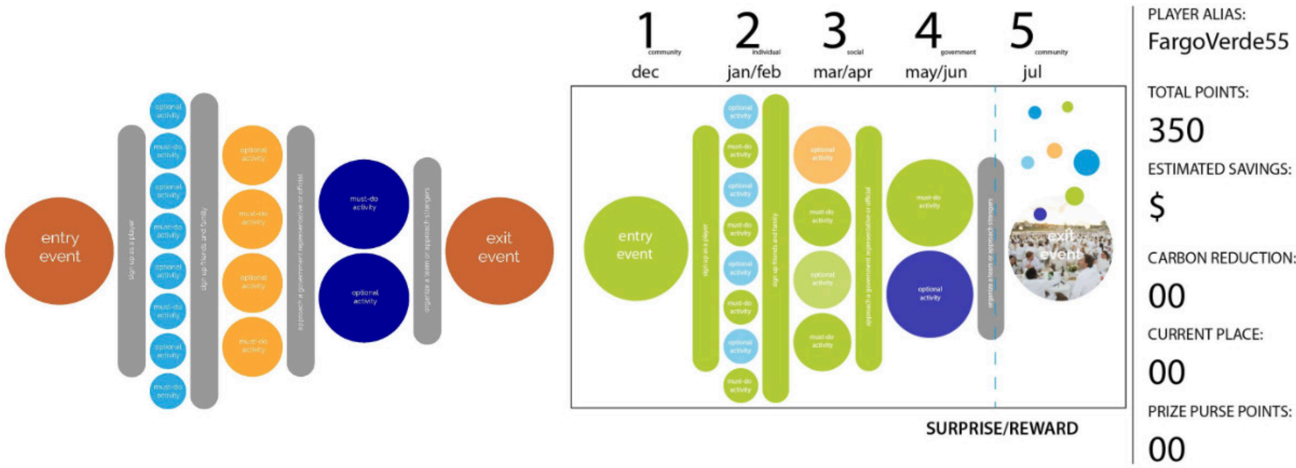


Figure 4.1: Initial diagram of the efargo game based on Pervasive game expansions



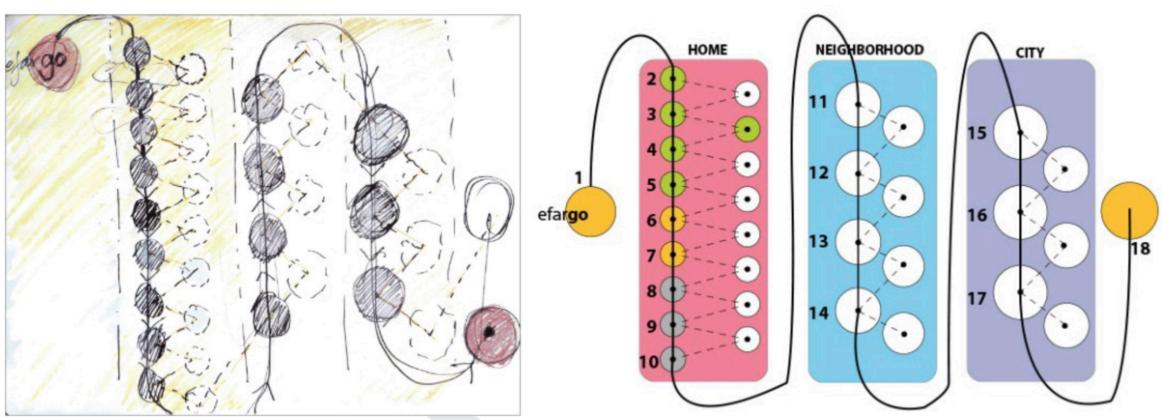


Figure 4.2: Diagrams as game boards, spatial, social and temporal expansions

Early design attempts gamified the initial conceptual diagrams by adding elements such as buttons, community imagery, and dashboards. The first attempts proposed idealized representations of reality (e. g., Fargo as a large metropolitan area) in the digital space, using the diagrams as the game board (Figure 4.3), assuming citizens as game pieces or as action figures completing missions at the scales of home, neighborhood, and city (testing spatial and social expansions). Later ideas for mapping and showing game activity on a map as a competitive play element emerged from these early ideas.

Flexibility became a key attribute in the efargo game design process, The game design accounted for the idea that the traditional one-size-fits-all solution may be a cause for the energy-efficiency gap. Furthermore, gamers can be expected to have varying circumstances in ordinary life, and a game will be meaningful to them only if it provides multiple paths and options to energy-savings that reflects their reality and suits their ability. Moreover, multiple paths enable play elements like strategy, and multiple possibilities may make the game more engaging. Early diagrams in the efargo game design process incorporated a series of "must-do" items on a linear path and the possibility of optional activities or game play and rewards available to the gamer who chooses to veer off the linear path.

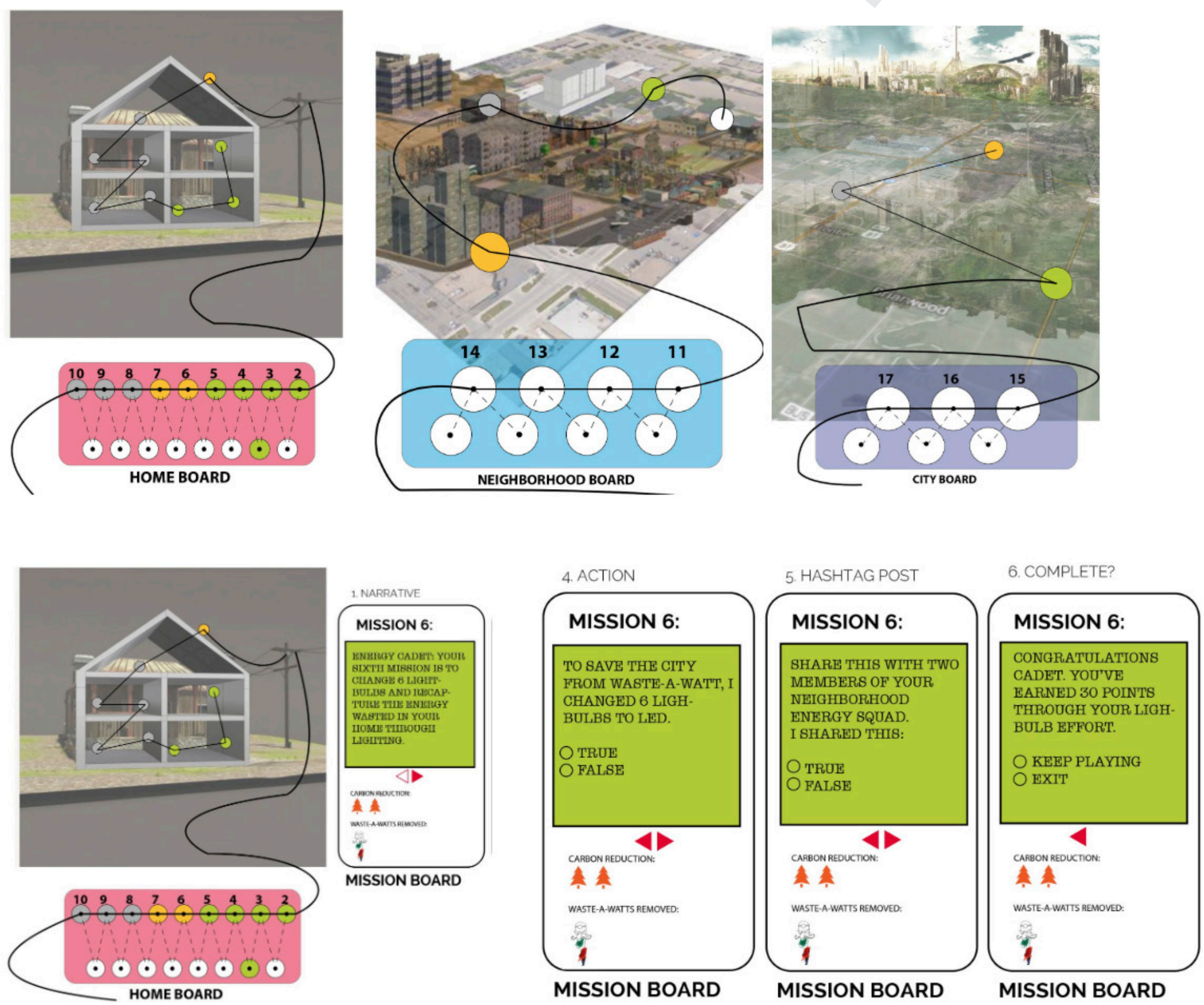


Figure 4.3: Representing an idealized reality in the digital game space

Subsequent versions of the game board were developed, still referencing the initial diagrams but beginning to add new narrative and game-play components to the digital game board. The first set extended the diagram into perspectival space, creating an idealized, triangulated path with missions and an inverted apex. Further versions of the game board incorporated spatial paths that could include multiple paths for gamers or game plays with Waste-a-Watt acting as obstructions to be captured in the game dashboard. Although spatial conceptions began to emerge through the design process, the concept for gameplay remained essentially linear (Figure 4.4). At this point in the process, the diagrams were abstract rather than being meaningfully connected to the reality of the game environment or game objects.

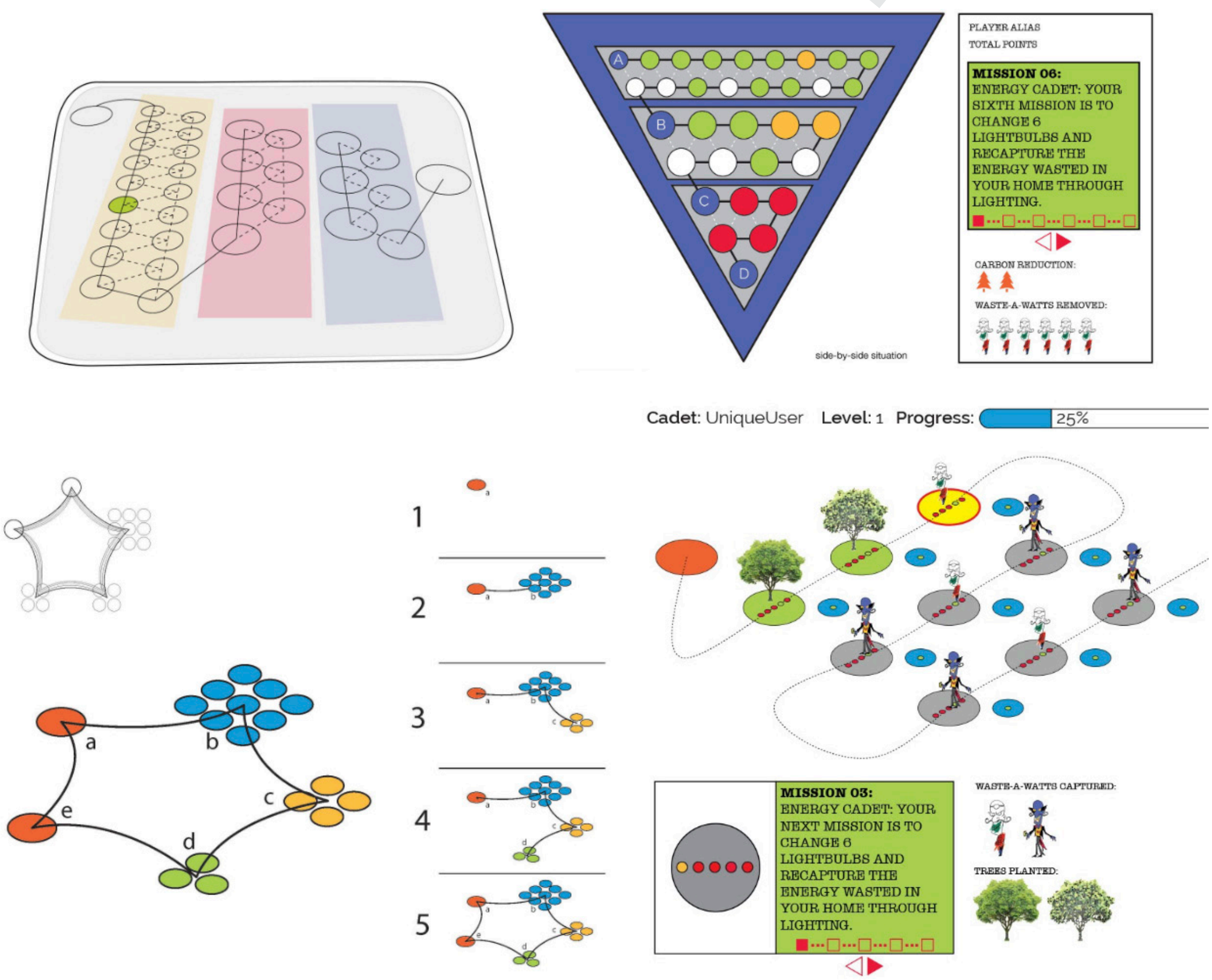


Figure 4.4 Race games, spatializing the linear paths

The first set of non-linear pathway formats included some choices for gamers. What began in the early diagrams as sketched circles depicting action items now became buckets filled with balls depicting action items. This version involved the gamer or community member completing missions, for example emptying a large gray bucket and filling smaller colorful buckets to get to Waste-a-Watt (Figure 4.5). However, this version had the potential for a gamer to follow multiple paths to get to Waste-a-Watt. Another design concept along the same lines allowed gamers to move beads on an abacus-like structure with the potential to have multiple activities in play. In these versions of the game, while there were multiple paths, the path of each activity type was separated from others, in effect resulting in multiple linear paths.

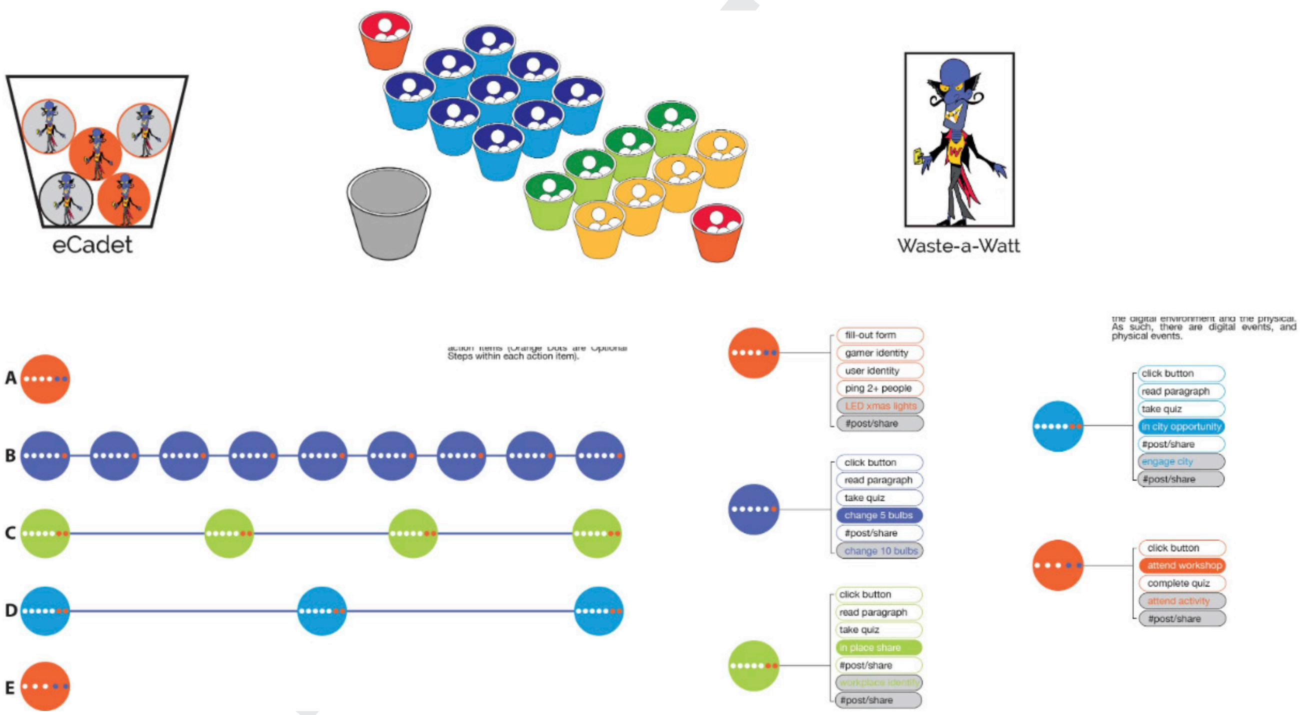


Figure 4.5: Race games - multiple linear paths

The next set of concept diagrams (Figure 4.6, Figure 4.6a) incorporated multiple ideas developed in previous versions to provide a multi-activity, common space diagram that required gamers to implement simple strategic thinking to complete the game. Multiple tokens could reach the top (apex or top challenge level), however, if multiple tokens were in play at the same time, the gamer would need to study the activities for each token that allowed them to reach the top level.

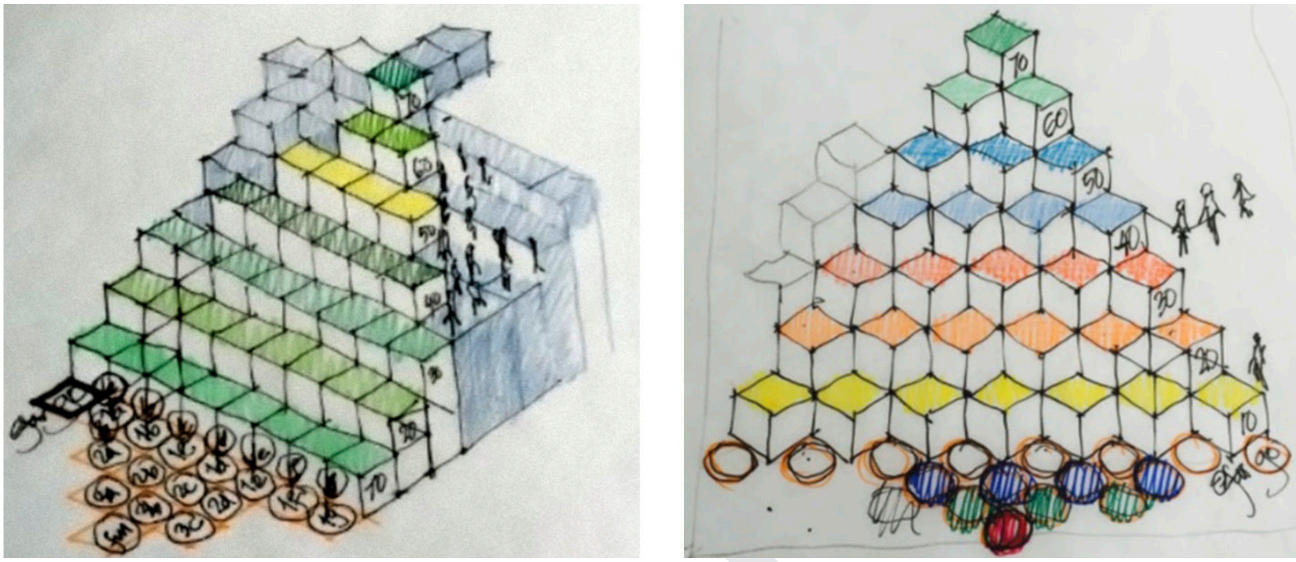


Figure 4.6: Race and list games - non-linear paths, simple strategy

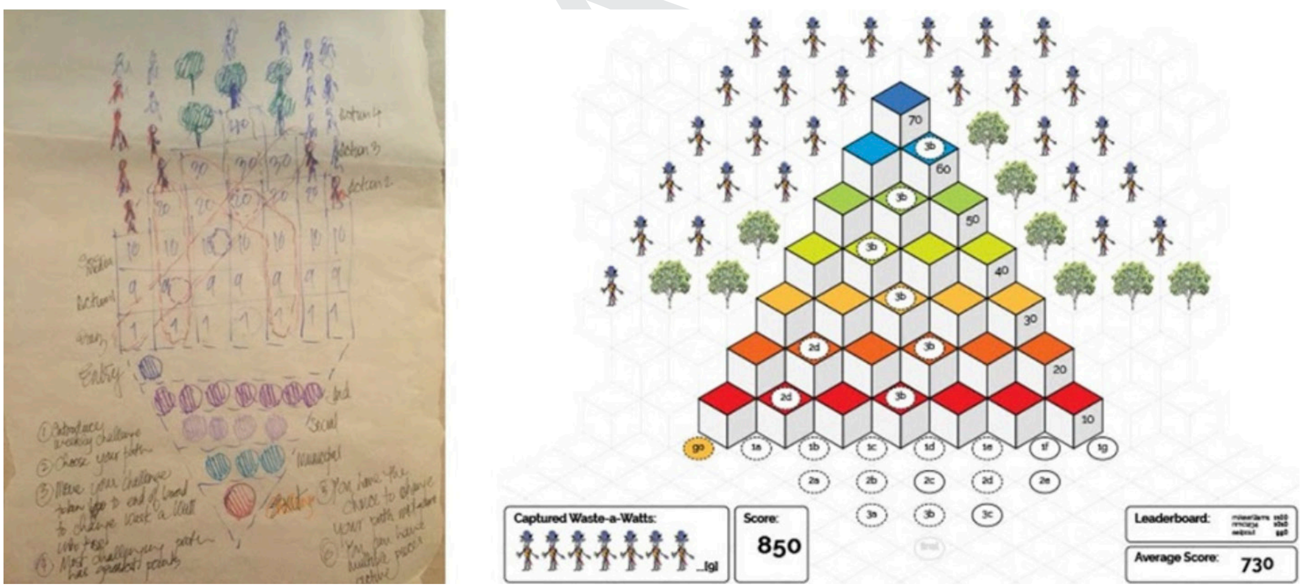


Figure 4.6a: Race and list games - non-linear paths, simple strategy

The final version of the game board, subject to minor modifications made in the course of gameplay, incorporated these ideas (Figure 4.6b). In the final game board, gamers were required to determine the combination of tokens and paths that would earn them maximum points and be the most meaningful in terms of the value they created, in the limited-time game.

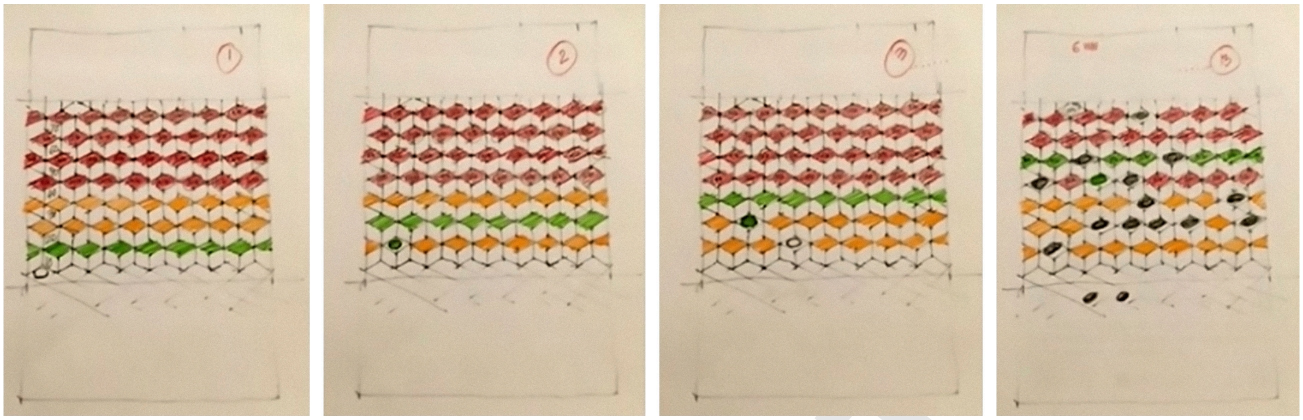


Figure 4.6b. Final version of efargo game board.

Alongside the development of the game board, the design process also considered different configurations of in-game paths and space, and other engagement structures (such as social media connections, competitive dashboards, and mapping) relative to real-life activities, and particularly as a means of connecting with real community geography and locations (Figure 4.7, Figure 4.8).

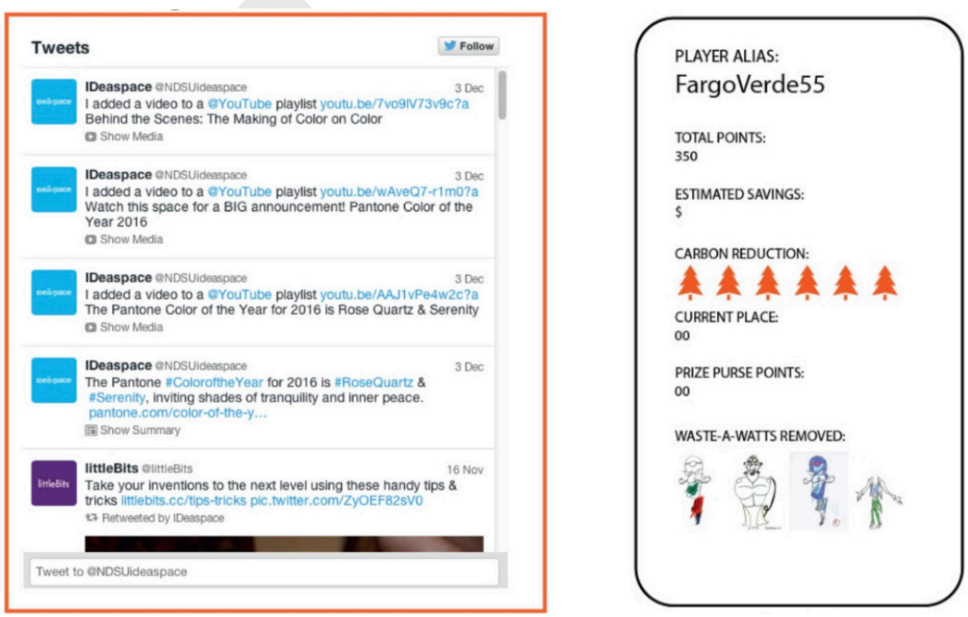


Figure 4.7: Social media and dashboard concept diagrams (LEFT: image credited to Ludvik Harrera's Ideaspace at North Dakota State University)

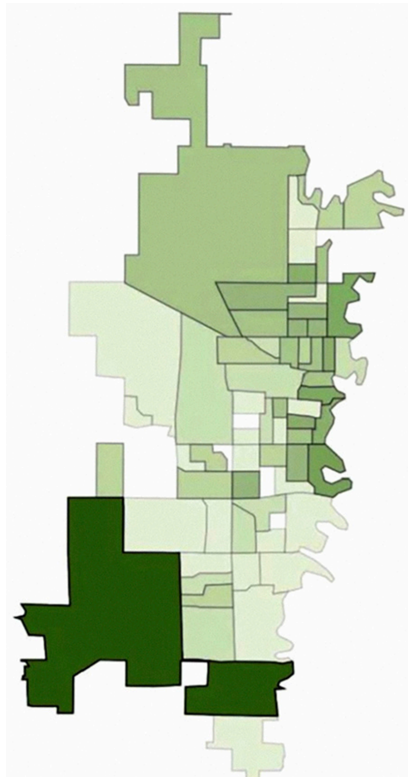


Figure 4.8: Mapping based on specific geography of census blocks which were the basic structure of game incentives

By asking gamers to share energy-saving activities via social media (Figure 4.7), the design proposed to educate gamers beyond the game, and make it possible for them to understand behavior as being intrinsic to energy use, Members of the efargo team, operating in the capacity of designers and implementers, managed the mapping and created visualizations based on the engagement in the game. The organization and incentivization of the game by census block (Figure 4.8) encouraged intra-block identity and inter-block competitiveness.

The efargo game design process involved critique and discussions from the point of view of intrinsic and extrinsic motivations. The discussions addressed the potential ability of the game to convert short-term extrinsic motivations to long-term intrinsic behavior change through repetitive eco-feedback, nudging for the purpose of habit formation (Froelhich, 2014, Fogg, 2009), although this effect was not formally tested as part of this dissertation. Ultimately, the game design did not incorporate rewards in relation to individual gamer performance: rewards were made on a census-block level, at random.

4.3.2 Design of the game rules

Part of the design process was the introduction of the game rules, structure and incentives. During the game design process, three distinct approaches were considered for communicating the rules, structure, and how the game was to be played. The first approach considered was giving the gamers a list of rules prior to game play that they would need to read. The second approach incorporated a gamer registration and tutorial into the game play, allowing gamers to earn points as they registered for and learned how to play the game. However, this approach presented technical difficulties (e. g., how to register game points in the database without first having created a database cell for the gamer through a registration process).

In the end, it was determined that the ideal approach of creating a barrier-free game-play process through immediate immersion was technically difficult to solve within the time and resources available. The combination of a short sign-up sequence with immersion into the game play through the key/unlock token meant that the data collection process through quick surveys could be separate from the sign-up sequence and incorporated into key/unlock game play, thus allowing gamers to earn points as they understood the interface. The potential barrier inherent in this approach was that the gamers were engaged in the digital environment but not completing any action in ordinary life that would directly lead to energy efficiency.

4.4 Weekly game design timeline & Incentives

The efargo game was launched on February 26th, 2016 after a research and iterative design process that began in Fall 2015. The game ended on April 29th, 2016. During the nine weeks of play, the efargo team released energy action tokens at the rate of one token per week, except in the first week of play when the introductory “Go” token was released alongside the Lighting energy-action token. An orchestrated work cycle of content development, design, review, coding, testing, re-review and launch of various game components such as awards announcement, Waste-a-Watt questions, educational materials, new token launches, social media announcements, and game page announcements was executed on a tight weekly timeline (Table 4.2).

Table 4.2: Weekly token production cycle (See Appendix 4.b for the weekly download)

Thursday	Token Launch
	Waste-a-fact
	Winner email for next token
	Next token graphics reviewed
	Social media review for next token
Friday	Block winner announcement
	Map update
	Winner on main page
	Email announcement
	Champion release signed
	Champion on main page review
	Champion cued
	Next token graphics reviewed
	Social media review for next token
	Next token content prep
Saturday	Champion announcement
	Map update
	Champion on main page
	Next token content transferred
	Next token graphics comments transferred
Sunday	Content preparation
	Game token pdf received for coding
	Edu graphics developed
	Game sequence coded
Monday	Community member highlight
	Coding completed for testing
	Graphics completed for review
	Game sequence pdf sent for review

Tuesday	Token review
	Community member interview post
	Coding tested, sequence tested
	Graphics reviewed sent back with notes
	Language reviewed sent back with notes
Wednesday	Token waste-a-watt teaser review and launch
	Final coding test, final sequence test
	Final graphics review
	Final language and links review

4.11 Game descriptives

This and the following sections describe the sample of voluntary gamers. 322 gamers signed up for the game. 301 of these gamers were part of the original 9-week game play. 21 were post-game joiners (via the live link to the game; no data was collected) immediately after the game ended. The game has not been tracked since its first implementation ended in April 2016. A total of 299 people progressed beyond the initial sign-up. Of the 299 gamers who joined the game during its 9-week play, there was a spike of initial sign-ups (33%) and then the weekly sign-ups were an average of 21 new gamers per week (Figure 4.15, Figure 4.16).

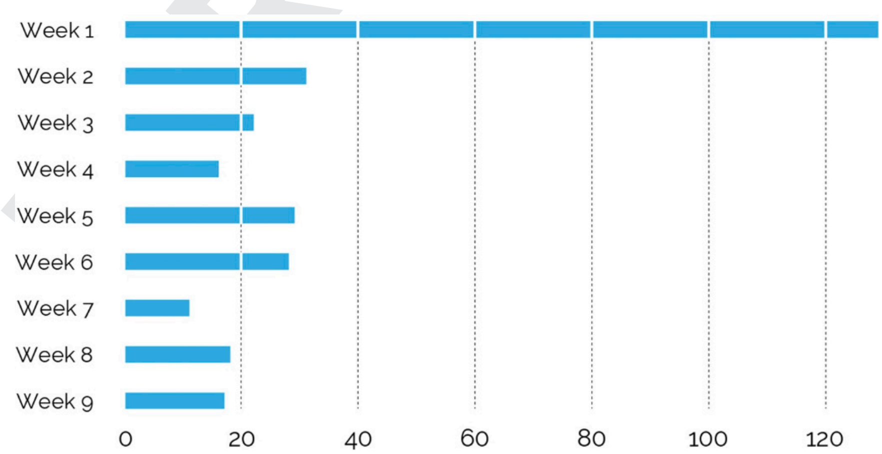


Figure 4.15 Gamer sign-up by week

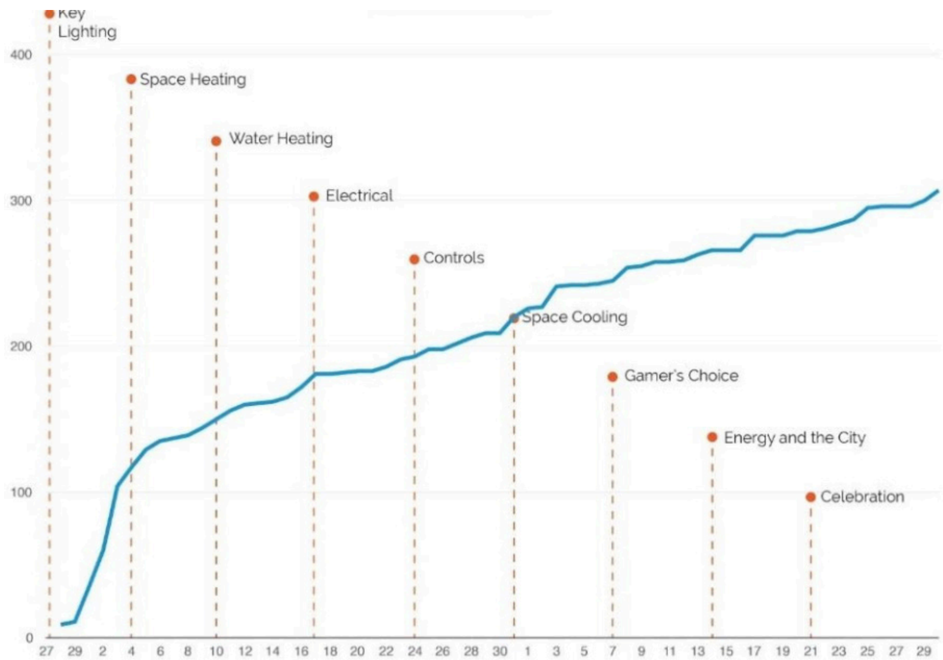


Figure 4.16 Gamer sign-up by day and token

While 70% of the gamers who signed-up were from Fargo, 19% did not report their location and the rest were distributed mostly amongst Moorhead and West Fargo, and a smaller number were from other cities (Figure 4.17).

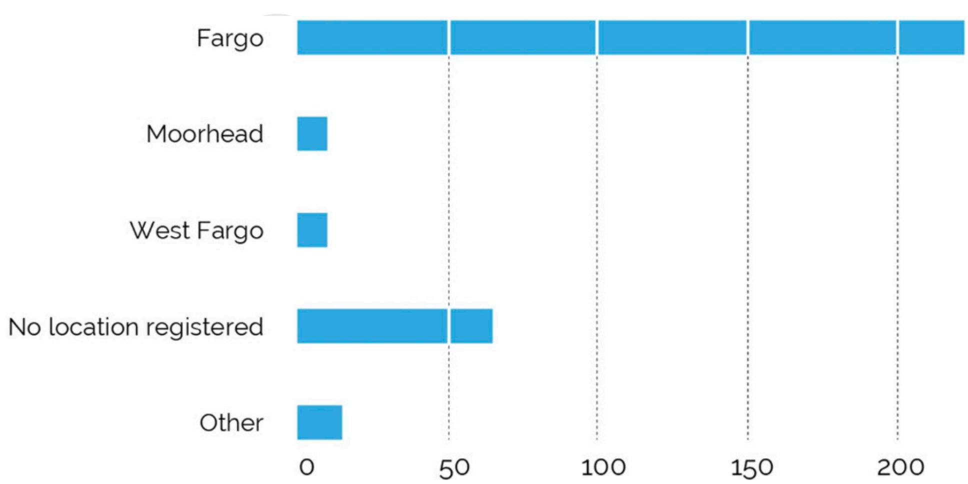


Figure 4.17 Gamer distribution by locations

Of the 299 gamers who signed up, 242 provided their location by city and 198 supplied the census block for the game dashboard (Figure 4.18).

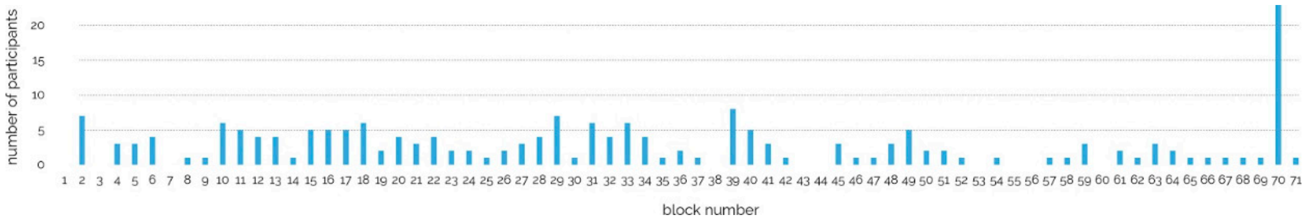


Figure 4.18. Gamer distribution by census block

Since the game dashboard and incentives were structured at the census Block level, the gamers who identified Fargo as their location were then asked to identify their Census Block by clicking their location on a map of Fargo (Figure 4.19).

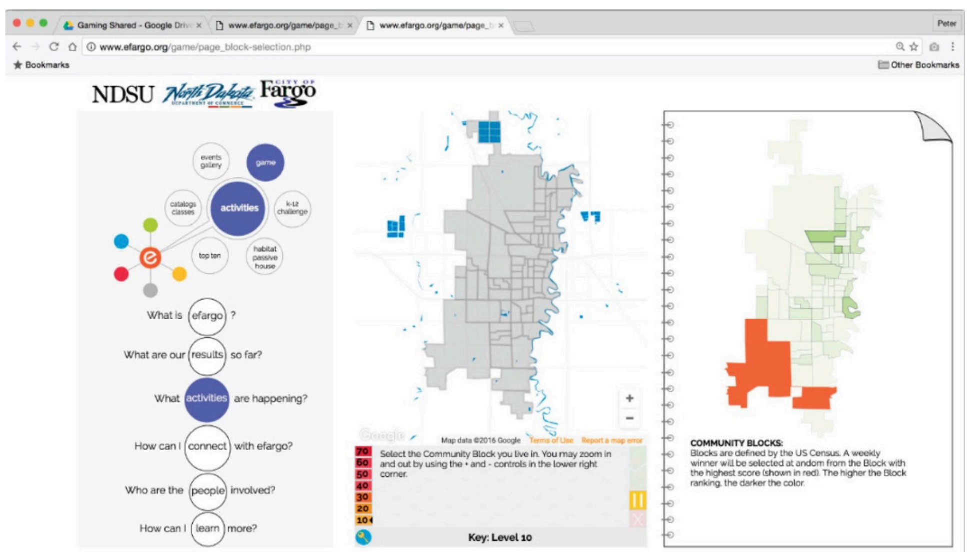


Figure 4.19. Example of map used in the game to identify gamer location by Census block

182 gamers gave the information on utility provider (Figure 4.20) and over 150 gamers established energy saving goals,

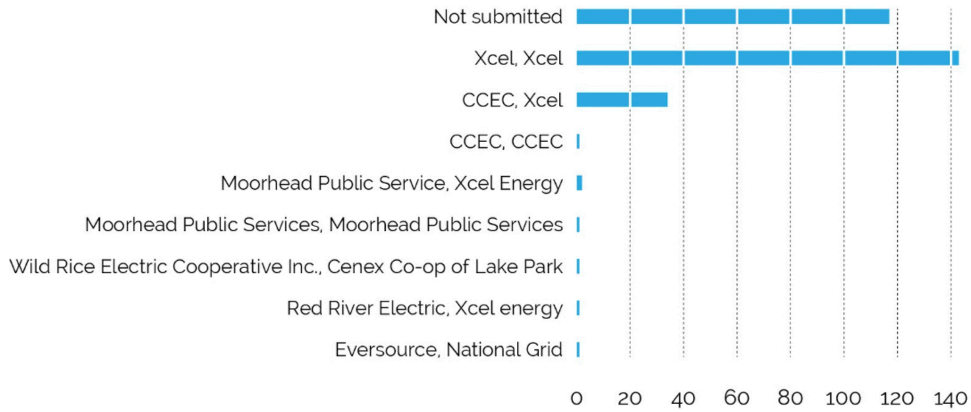


Figure 4.20. Gamer distribution by utility

4.11.1 Data collection and surveys as part of game interface (Go10 - Go70)

Through the web-based game interface, a sign-up form collected information on the distribution of the gamers as described in section 4.11.1. In order to make data collection a part of the game process, a number of data collection activities were part of the initial "Go" token. This was a distribution of gamers in the Go sign-up token that was accessible immediately after the sign-up process (Figure 4.21).

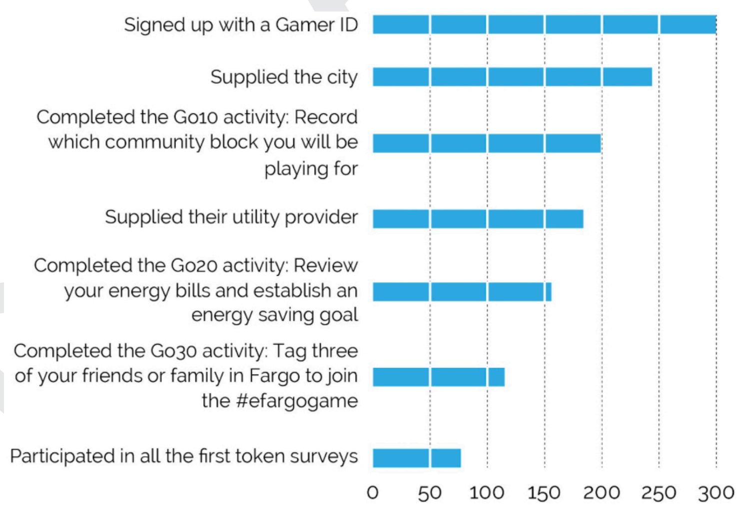


Figure 4.21. Number of gamers completing challenge levels and data collection activity in the "initial sign-up" section

After the data collection, four surveys were part of the "Go" token at different challenge levels (Go40, Go50, Go 60, and Go 70). Participation in the survey was voluntary. It earned the gamers points but they were not required to complete this to progress to the rest of the game. If they did not complete the Go40 through Go 70 survey, the Go token would occupy a position on their game board at Level 30 and not move up to capturing the additional points embedded in the upper levels through action items and Waste-a-Watt questions.

The Go 40 survey was answered by 122 people (Table Chapter 3), of whom 96 were complete responses and nearly 80 had gamer identifiers. The Go 50 survey was answered by 107 gamers of which there were 96 complete responses and over 70 had gamer identifiers. The Go 60 survey was answered by 90 gamers with 84 complete responses of which over 60 gamers had gamer identifiers. The Go 70 survey was answered by 85 gamers with 84 complete responses and 56 of those responses had gamer identifiers. Following was the participation levels in the surveys through the game play (Figure 4.22)

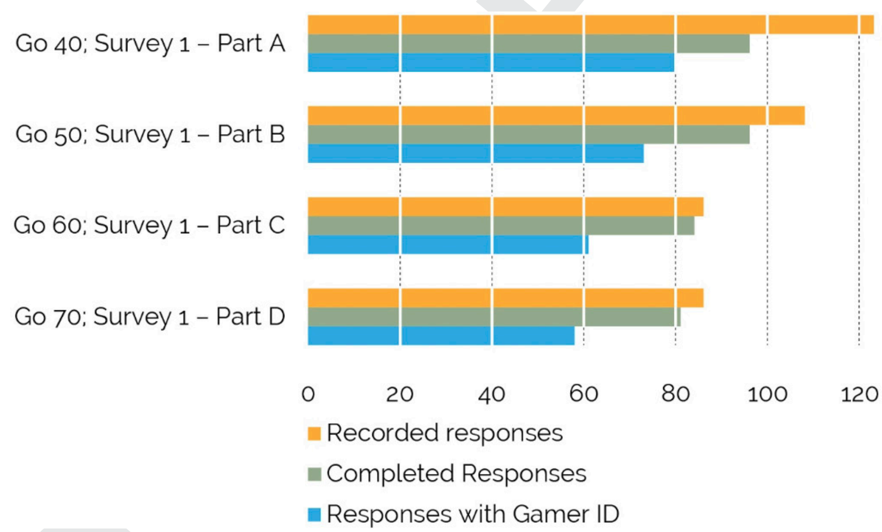


Figure 4.22. Gamer responses to Go token surveys

The following diagrams describe the responses that the gamers who completed the surveys gave in response to the survey questions. For descriptions of gamers (Go 40 and Go 50) who participated please see Appendix 4.c.

4.11.2 Go60 survey:

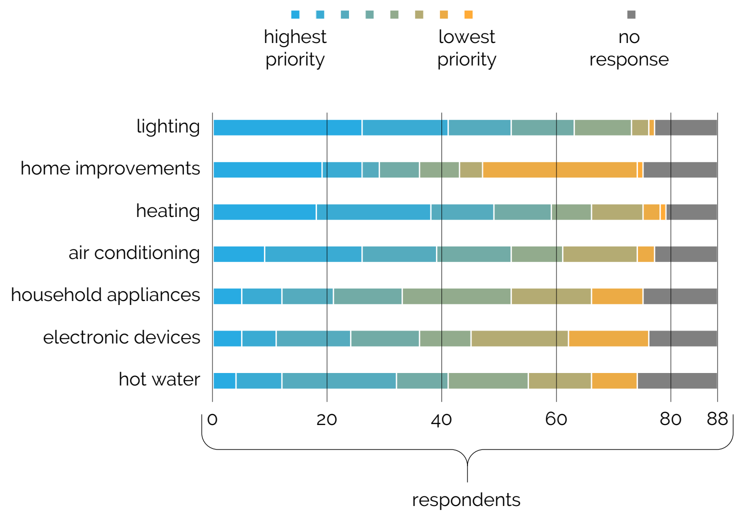


Figure 4.23. Responses to Go60 Question 1, "In which of the following areas would you be willing to reduce your use to lower your energy bills? List in order of priority with 1 being the highest priority."

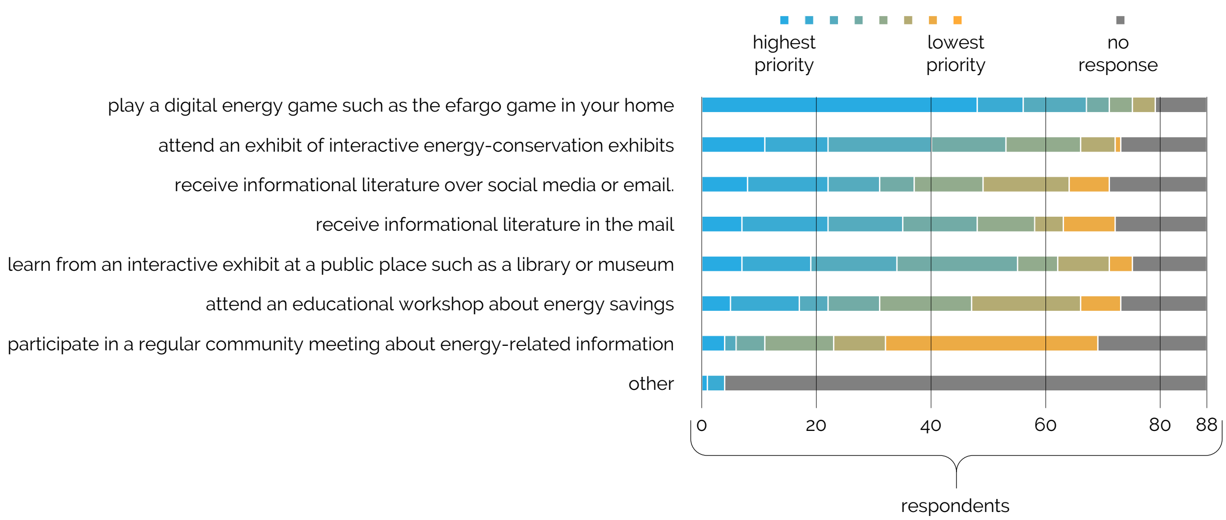


Figure 4.24. Responses to Go60 Question 2, "Which of the following are you more likely to participate in to learn about energy conservation? List in order of priority with 1 being the highest priority."

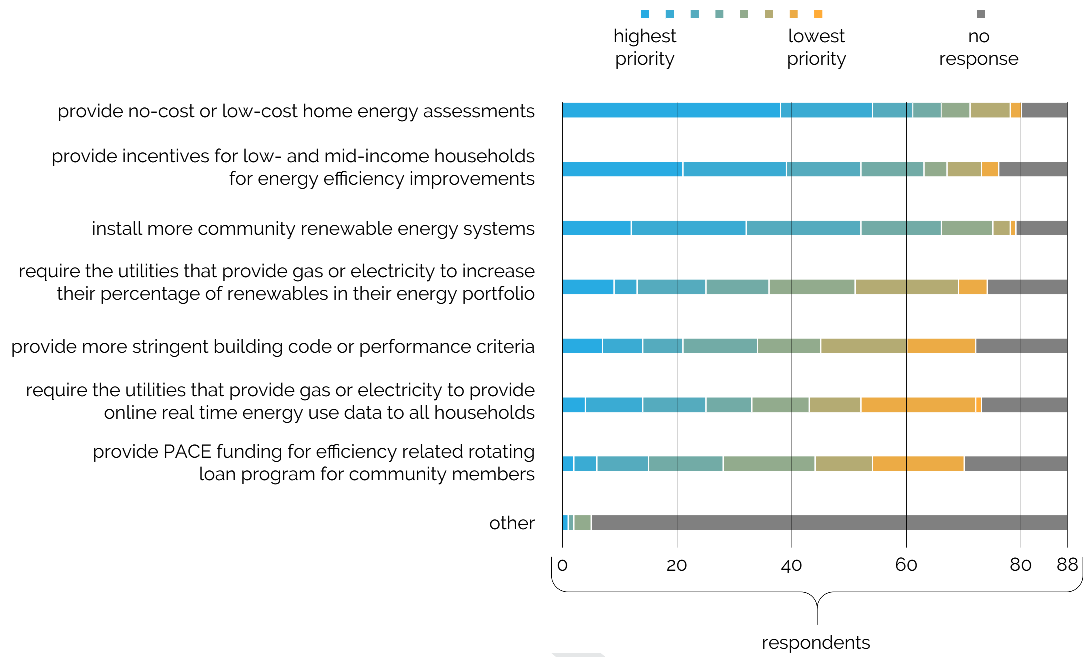


Figure 4.25. Responses to Go60 Question 3, "What would you like the city to do about energy efficiency? List in order of priority with 1 being the highest priority."

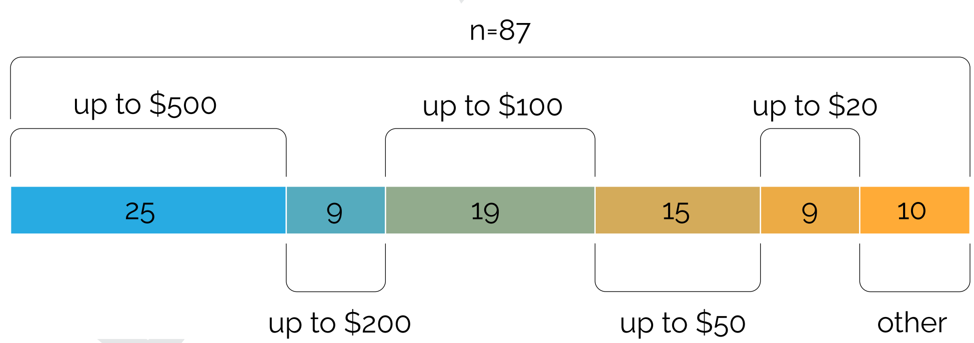


Figure 4.26. Responses to Go60 Question 4, "How much money are you willing to invest in making your primary residence more energy-efficient?"

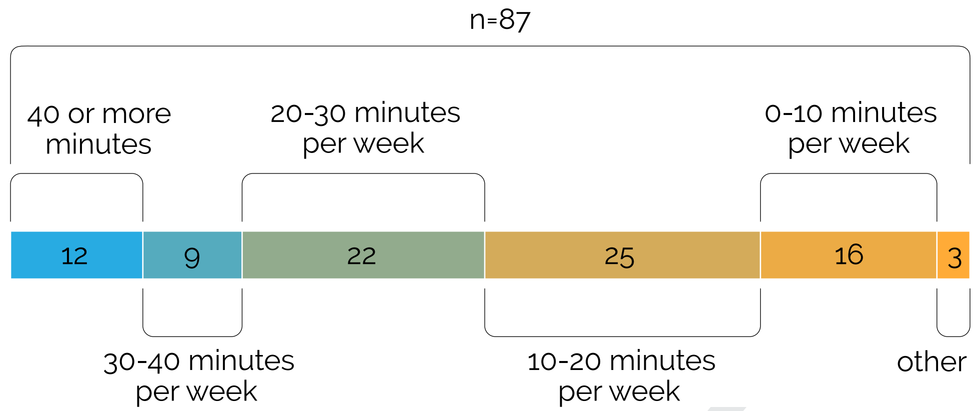


Figure 4.27. Responses to G060 Question 5, "How much time are you willing to invest in making your primary residence more energy-efficient?"

4.11.3 G070 survey:

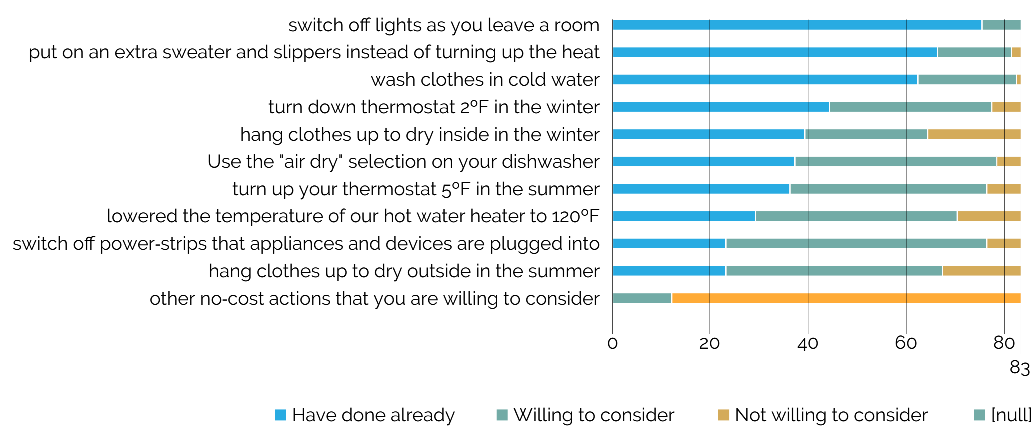


Figure 4.28. Responses to G070 Question 1, "Check if you have 'already implemented' or are 'willing to consider' or not 'willing to consider' the following zero-cost actions to save energy in your primary residence?"

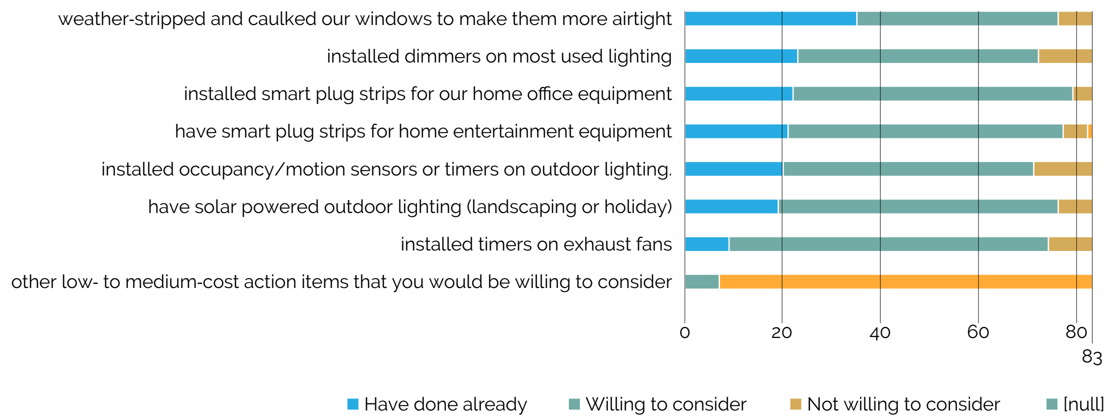


Figure 4.29. Responses to Go70 Question 2, "Check if you have 'already implemented' or are 'willing to consider' or not 'willing to consider' the following low- to medium-cost actions to save energy in your primary residence?"

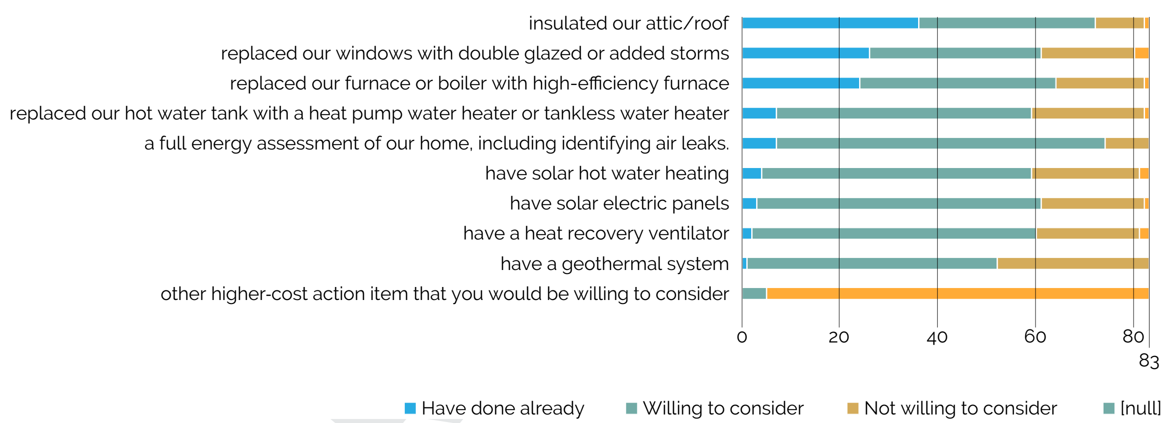


Figure 4.30. Responses to Go70 Question 3, "Check if you have 'already implemented' or are 'willing to consider' or not 'willing to consider' the following higher-cost actions to save energy in your primary residence?"

4.12 Concluding summary of limitations

Community members being aware of the game as a freely available and easy-to-use tool is fundamental to the game's success: awareness that a game exists is a first step in gamers joining the game. Following awareness, knowledge of opportunity to play is also important. For example, if the game interface is digital, having a device that can access the digital game provides an opportunity to play the game. For the efargo game, the funding of the game could only be utilized for game-based outreach: marketing expenses were not allowed. The word about the game was spread through a news conference by the City of Fargo for game announcement and invited presentations around town with audiences ranging from 6 to

80 people. New gamers tended to increase around particular events (figure 4.43), through a detailed study of this phenomenon has not been conducted for this dissertation.

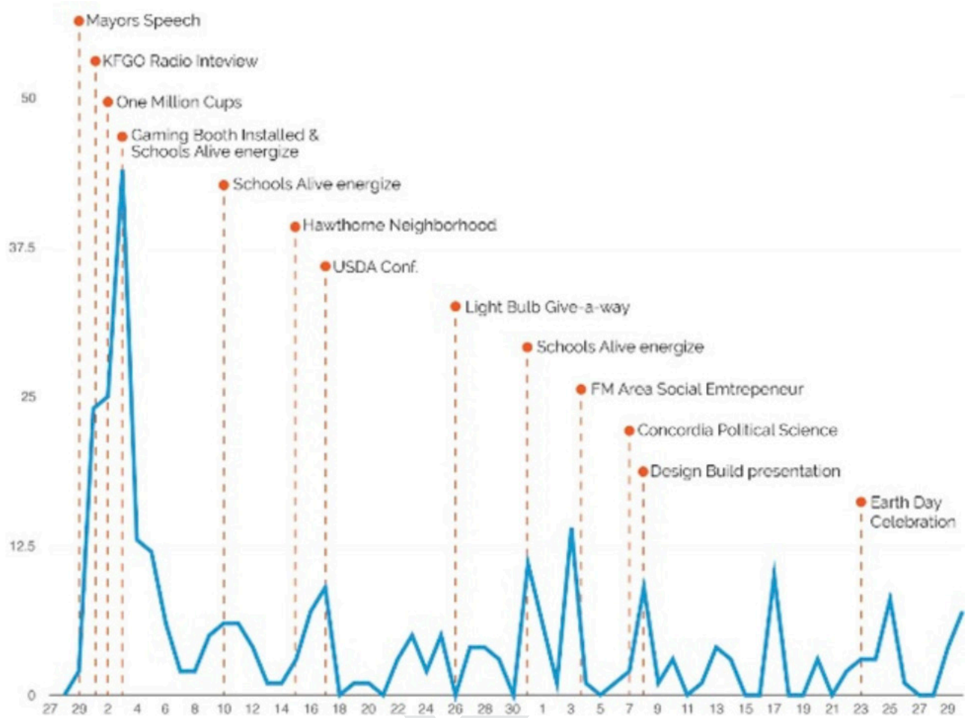


Figure 4.33. Dates gamers signed up for the game and dates of events

The City of Fargo acted as champion and community liaison for efargo. The outcome of these funding limitations was that the efargo game's availability was communicated primarily social media, small local events, emails and word of mouth.

Games where the target audience or demographic is open, i.e. anyone who has the interest and knows about the game, can join the game, can result in wide-ranging demographics. Wide-ranging demographics could require multiple modalities of play that can cater to the various demographics for successful game adoption. For example, people lacking access to a digital platform may have been aware of the game, but unless they also knew that it was possible to play the game at the local library at a dedicated computer station, they could not access the game. It follows that the target audience and aligned modality or modalities of game play should be an important factor of game design. If resources are limited, then there needs to be designed alignment between game modality, target audience, and marketing effort.

Another factor that emerged was that web-based games need to have development, review, and coding and testing efforts for various browsers. The efargo game could only be communicated to community members via an online platform and specific browsers, and the efargo game was coded and tested primarily on Google Chrome due to severe time limitations (following from the GUEP timeline). Gamers reported difficulties with playing the game on Explorer and Mozilla firefox.

Also, due to the data collection being for purposes of game research, NDSU's IRB review resulted in game access being limited to adults (i. e., minors could not access the game). As a result, one of the game's target demographics (ages 13-18) was excluded from the game play. This was a major loss for the efargo effort and the research design.

The purpose of the efargo game was the bridging of the energy-efficiency gap. If the game was successful in this sense, it would result in a reduction in energy use among the gamers. In order to examine this question, first, the data collected for the residential energy-use submittals to the GUEP would show shifts in city-wide performance measures. Secondly, since the object of game play was individual homes, shifts in energy use of individual homes participating in the game would indicate the game's effectiveness. However, there were several privacy concerns with the collection of energy use data from individual homes. In order that there were no privacy violations, the energy use data was collected in two ways. First, the city-wide energy use data was aggregated for submission to the GUEP. The data was normalized by the GUEP team and analysis of this normalized data is presented in Chapter 8. Second, the gamers were asked to volunteer their energy use data by signing a release form in the post-game survey. Of the few people who agreed to provide energy use data release (figure 4.46), there was a distribution of game points earned (Figure 4.47). Most of the agreements were from respondents in the medium to high range of points. There were a handful in the lower range of points. This energy use data is normalized and analyzed in Chapter 5.

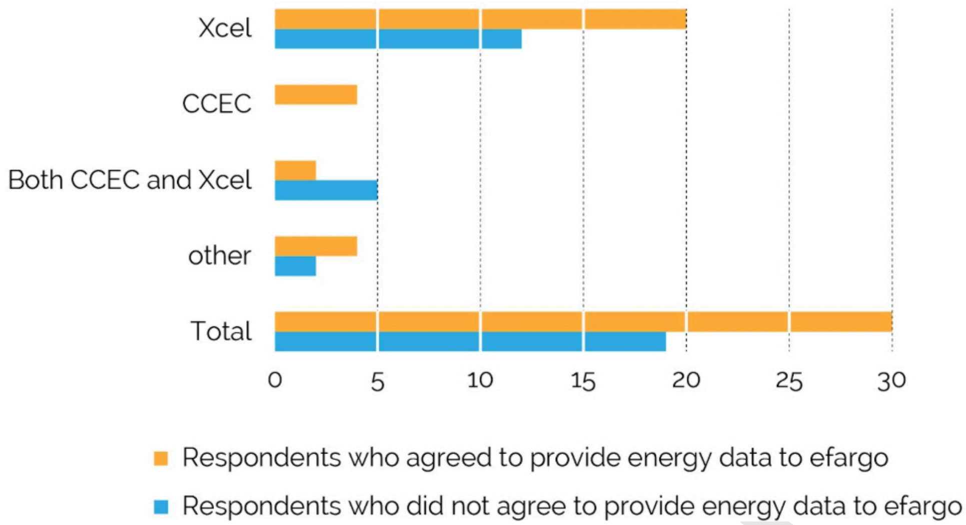


Figure 4.34. Respondents for the collection of energy use data

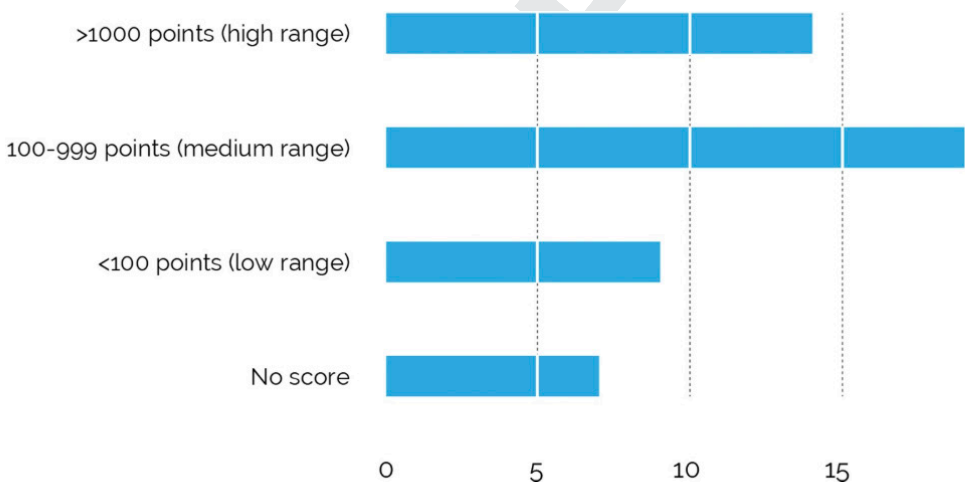


Figure 4.35. Point ranges for those who agreed to provide household energy use data

Through an analysis of the pre- and post-game surveys, energy use data analysis (Chapter 5), this dissertation addresses the hypotheses listed in Chapter 3, i. e. that serious pervasive energy games have the potential to impact learning, behavior, and investments for energy savings, and that they cause energy savings, specifically for the efargo game.

5.0 Outcomes: Savings, knowledge, behavior shifts, and investments in the efargo game

Summary

This chapter examines the efargo game and analyzes Hypotheses 1-4 based on data collection prior to, during, and after game implementation. The hypotheses are that playing a pervasive game can lead to learning and awareness about energy savings; willingness to engage in energy-saving behavior; willingness to invest in energy savings; and result in energy-savings. All four hypotheses were supported by positive findings for the efargo game, with varying degrees of statistical significance.

Through survey responses, efargo gamers reported learning about energy savings ($n = 56$, $p < 0.01$), willingness to engage in energy-saving behavior ($n = 56$, $p < 0.01$), and willingness to invest in energy savings ($n = 56$, $p = 0.00$). Moreover, gamers reported completing energy-saving tasks during the game and a willingness to complete energy-saving tasks after the game.

Data revealed energy-use reductions that began during the game and increased in the 8-month period after the game implementation. A monthly total savings of 1,273 kWh, or 12%, was observed ($n = 13$, $p = 0.25$).

5.1 efargo gamers and game play

301 of the gamers who signed up for the game were part of the 9-week game implementation for which data was collected. Since the 9-week implementation ended in April 2016, the gamer activity has not been tracked. Of the 301 gamers, 299 progressed beyond the initial sign-up during the 9-week play. It was possible for any gamer to earn a maximum of 3,600 possible points in the game.[1] Of the gamers, 5% achieved the maximum number of points, 10% had a high range of points, 27% had a medium range of points, 31% had a low level of points, and 27% did

1 See Chapter 4 for game description.

not progress to earning points (Figure 5.1).

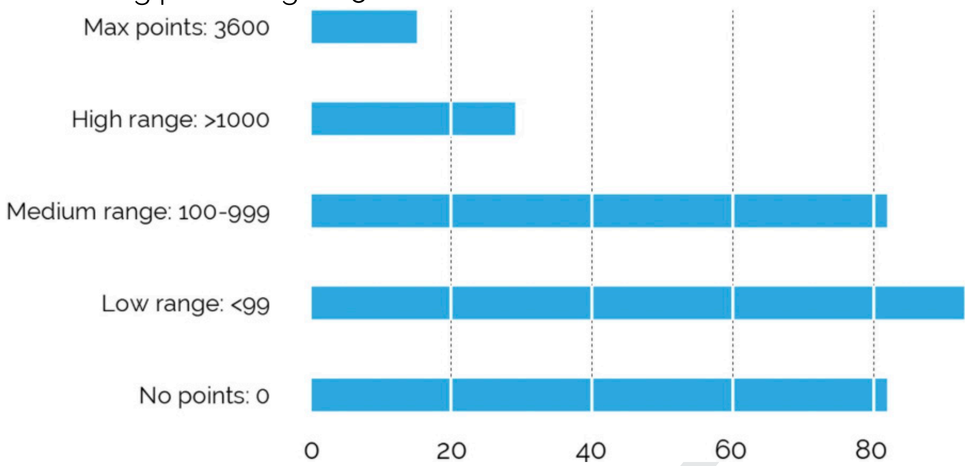


Figure 5.1. Distribution of points earned during the game

During the 9-week game play, a new activity token was released each week. Gamers used the activity tokens to navigate the game board to earn points. Figure 5.2 shows the distribution of gamers who completed activities and earned points diagrammed by weekly tokens during the game. The Key/Go token, the first to be introduced, required gamers to become familiar with the game interface by responding to surveys and educational materials. From the second token onwards, the gamers were asked to complete energy-saving activities in their homes in addition to topic-specific educational and community engagement activities.[1] Of all the tokens or topic areas, Lighting had the most engagement (as measured by the number of gamers who earned points), followed by Space Heating, Water Heating, Devices, Controls, and Cooling & Ventilation. In the City-Community token, gamers were asked to leave the game portal and enter an app called SIdewalk provided by the CIty of Fargo, to respond to questions and suggestions for ways in which the city could address energy waste, energy savings, and climate change. In the last token, efargo organized a celebratory in-person event where gamers could earn points. The attendance at the event (approximately 275 people over the course of 4 hours), was much greater than the number of gamers who used the game to report their points and celebratory activities (29 gamers).

1 See Chapter 4 for detailed description of activities.

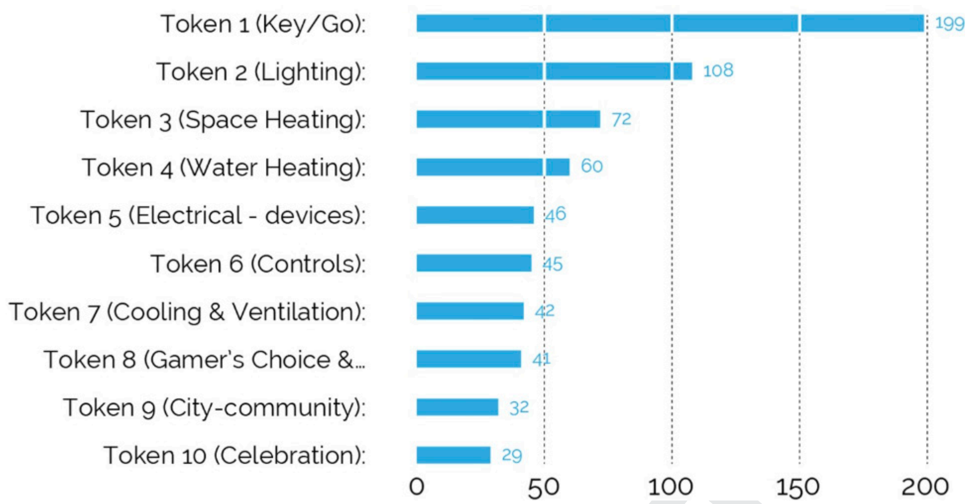


Figure 5.2. Distribution of gamers who completed activities and earned points distributed by weekly tokens during the game

This chapter provides a discussion and further examination of engagement in point-earning activities in the game, and its impact on energy savings, learning about energy waste and energy savings, willingness to engage in energy-saving behavior, and willingness to make investments in energy-savings.

5.2 Efargo game's impact on gamers' energy savings (Hypothesis 4)

To support analysis of the impact of the efargo game and its activities on energy savings, data related to household energy use was collected in two ways before, during, and after the game. First, access to personal energy use data was requested from efargo gamers in a post-game survey. Of the 301 people who joined the efargo game during the 9-week implementation, 64 people completed a post-game survey. Of these, 55 people also completed the pre-game survey, as part of which they identified their utility provider. Of these 55 people, 26 people gave permission to access the energy use data. Of these 26 people, 18 were identified as customers with active accounts in a City of Fargo utility, 13 with Xcel Energy and 5 with CCEC.[1] 13 of the 18

1 Failure to associate individual gamers with active utility accounts was largely due to mismatches in exact names or addresses, or to owners moving from an address. The utility was only able to match customers to their database if the accounts had the exact spelling of names and addresses, including prefixes, suffixes, numbering system, capitalization and punctuation. For example an account that was listed as "Eighth Street" could not be matched with the database if it was spelled by the gamer in the agreement form as "8th Street". The database also could not be searched one variable at a time. Even though gamers were willing to provide scans of their utility bills, it was hard to get matches in the utility database. Other reasons for incomplete data include owners or renters having moved during the 2013-2016 data collection period,

gamers had complete electricity-use records covering the 2013- 2016 period (provided by the utilities). All except 3 gamers had incomplete gas records. Since Cass County Electric Coop does not supply gas, all these were Xcel customers. The gas data was not analyzed. Electricity use data for the 18 individual gamers was collected for the four-year period from 2013-2016. Only the 13 who had complete records were included in the analysis.

Second, aggregated household energy (electricity and gas) data for the City of Fargo was collected from January 2013 to December 2016, with permission from the City of Fargo and the local utilities, Xcel Energy and Cass County Electric Cooperative (CCEC). This initiative was part of the Georgetown University Energy Prize data collection, of which the efargo game was a primary activity.[1]

5.2.1 Comparing predicted and actual energy use data

Two study periods were considered for analysis: during game play and after game play. The efargo game's first "action token" was introduced on February 28, 2016, and the final token was introduced on April 21, 2016. To allow alignment with monthly ETracker data, the first study period (during game play) was defined as March 2016 – April 2016. The second study period (after game play) was defined as May 2016 – December 2016.[2] For both study periods, ETracker was used to predict the individual electricity use for the thirteen gamers. This prediction was made on the basis of electricity bills collected for a four-year period (2013, 2014, 2015 and 2016). Electricity use prior to March 2016 was used to create electricity-use data files for each of the individual gamers. Over each study period, each gamer's actual electricity use (in kWh) was reported from utility records. Individual gamers' predicted electricity use from ETracker was then compared to their actual electricity use data from the utilities, and the difference was calculated for each gamer. Table 5.1 summarizes data for the first study period (during game play).

Table 5.1. Monthly energy-use data for individual efargo gamers during efargo game or Study Period 1 (March 2016 - April 2016).

1 The analysis of this data is included in Chapter 8.

2 See Chapter 3 for a description of ETracker methodology.

gamer ID	Predicted average monthly electricity use during study period 1 (kWh)	Actual average monthly electricity use during study period 1(kWh)	Savings (Predicted - Actual) (kWh)	% savings
hpu7j	1188	827	361	-30
408p8	1298	1060	238	-18
msa7z	523	428	95	-18
dv6kn	1086	997	89	-8
tu7kn	517	454	63	-12
qa1fe	1216	1154	62	-5
ciq8d	1332	1304	28	-2
0aejw	209	224	-15	7
8isl1	101	128	-27	27
yqu8q	841	944	-103	12
qyfj8	600	764	-164	27
sd2a7	1351	1601	-250	19
s1zb0	1292	1642	-350	27
total	11554	11527	27	0.23
mean	889	887	2	0.23

During the first study period, some individual improvements in electricity use were observed: of the 13 individual gamers, 7 showed electricity-use reductions. A monthly total drop of 27 kWh, or 0.23%, was observed. Figure 5.3 summarizes the actual and predicted electricity use data during the first study period.

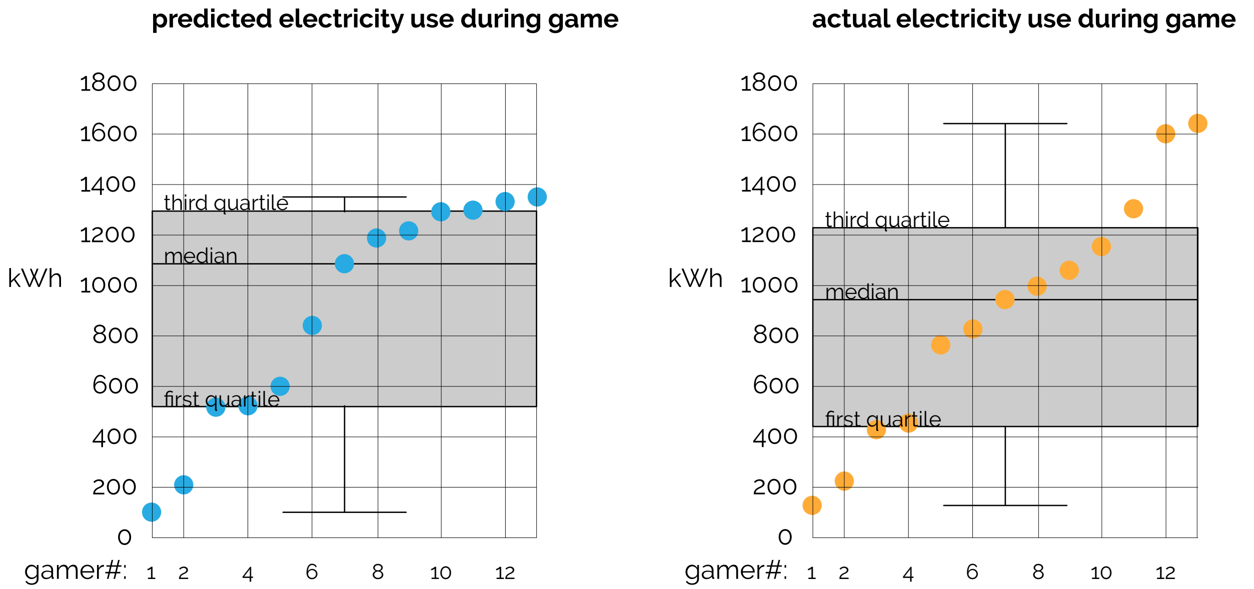


Figure 5.3. LEFT: Predicted average monthly electricity use (kWh) for individual efargo gamers during Study Period 1 (March 2016 - April 2016), based on baseline energy use data for three years prior to study period, normalized using E-Tracker. RIGHT: Actual average monthly electricity use (kWh) for individual efargo gamers during Study Period 1 (March 2016 - April 2016).

To test the statistical significance of the observation concerning mean difference, a two-sample t-test was conducted on the two samples (actual and predicted use), assuming equal variances as suggested by a two-sample f-test. The t-statistic was calculated as 0.011 and the t-critical (one-tail) value as 1.71, with $p = 0.50$ (>0.05). This implies that the observed difference in mean-level electricity use (predicted vs. actual), during the game, is not statistically significant.

Post-game analysis was conducted on the remaining months of electricity use data available, from May 2016 to December 2016. Table 5.2 summarizes data for the second study period (after game play).

Table 5.2. Predicted and actual average monthly electricity use (kWh), and associated savings (kWh and percent), for individual efargo gamers during Study Period 2 (May 2016 - December 2016), based on baseline energy use data for three years prior to study period, normalized using E-Tracker.

gamer ID	Predicted average monthly electricity use during study period 2 (kWh)	Actual average monthly electricity use during study period 2 (kWh)	Savings (Predicted - Actual) (kWh)	% savings
hpu7j	1,264	685	579	-46
s1zb0	950	642	308	-32
ciq8d	1,266	1,000	266	-21
qa1fe	1,034	791	243	-24
408p8	1,275	1,086	189	-15
yqu8q	941	757	184	-20
sd2a7	1,183	1,066	117	-10
dv6kn	1,218	1,163	55	-5
msa7z	578	525	53	-9
0aejw	236	223	13	-6
qyfj8	652	829	-177	27
8isl1	105	336	-231	220
tu7kn	223	549	-326	146
total	10,925	9,652	1,273	12
mean	840	742	98	12

More substantive savings were recorded in the second study period (post-game) from May 2016-December 2016: 10 of the 13 gamers achieved household energy savings. A monthly total drop of 1,273 kWh, or 12%, was observed. Figure 5.4 summarizes the actual and predicted electricity use data during the second study period.

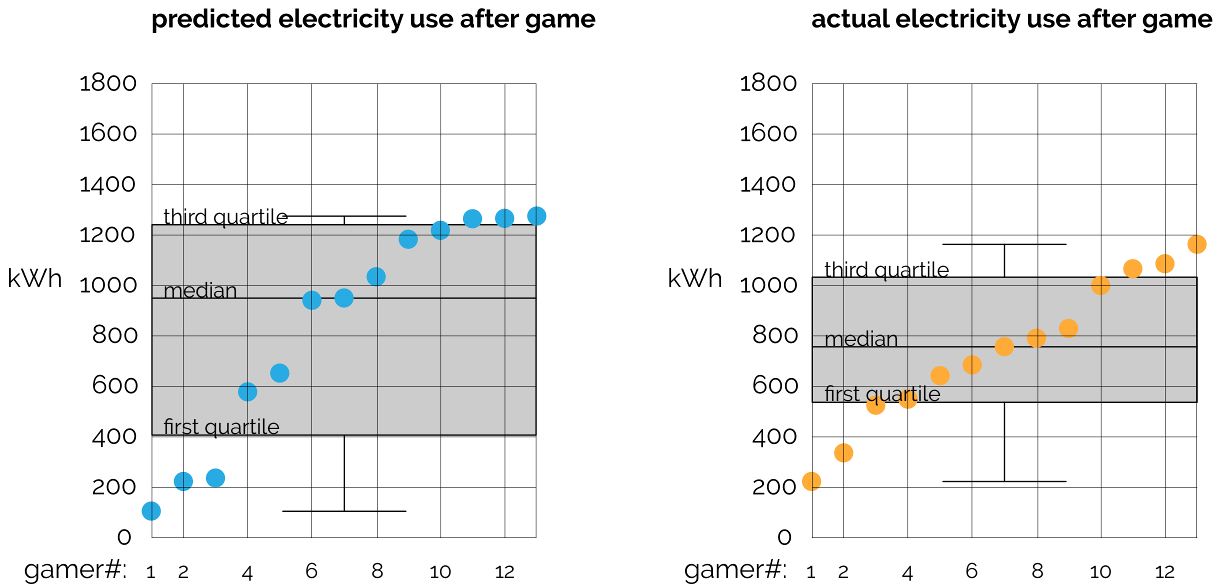


Figure 5.4. LEFT: Predicted average monthly energy use (kWh) for individual efargo gamers during Study Period 2 (May 2016 - December 2016), based on baseline energy use data for three years prior to study period, normalized using E-Tracker. RIGHT: Actual average monthly energy use (kWh) for individual efargo gamers during Study Period 2 (May 2016 - December 2016).

Figure 5.5 and Figure 5.6 summarize the individual gamers' electricity use in the two study periods. An increased number of gamers experienced energy savings in the second study period.

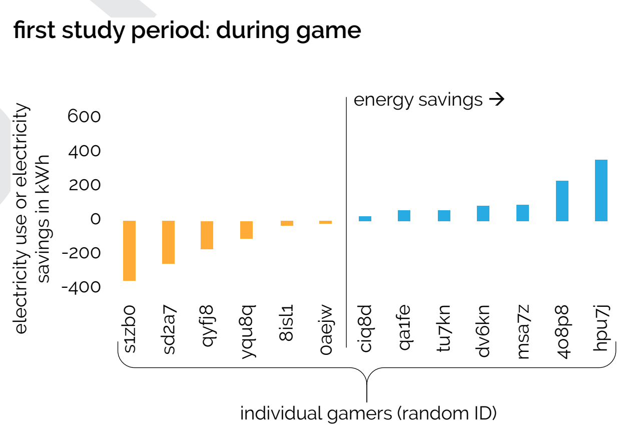


Figure 5.5. Actual energy use (kWh) for individual efargo gamers during Study Period 1 (March 2016 - April 2016).

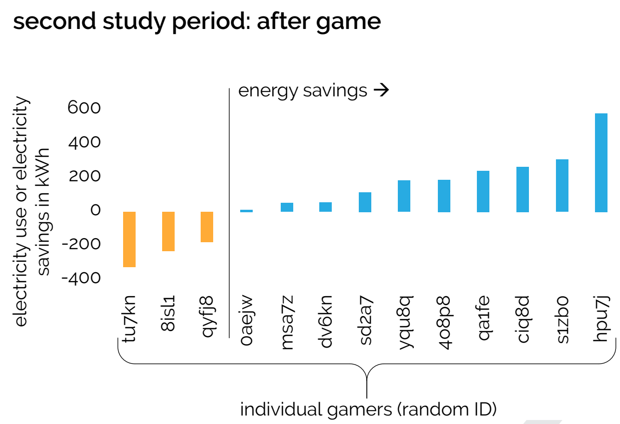


Figure 5.6. Actual energy use (kWh) for individual efargo gamers during Study Period 2 (May 2016 - December 2016).

Thus, with respect to the comparison of (a) predicted energy use with (b) actual energy use, both before and during the efargo game, findings are positive and consistent with Hypothesis 4, that the playing of the efargo game, an open serious pervasive energy game led to energy savings.

To test the statistical significance of the observation concerning mean difference, a two-sample t-test was conducted on the two samples (actual and predicted use), assuming equal variances as suggested by a two-sample f-test. The t-statistic was calculated as 0.676 and the t-critical (one-tail) value as 1.71, with p = 0.25 (>0.05). This implies that the observed difference in means is not statistically significant (p > 0.05). This is most likely due to the small sample size of gamers.

Based on normalized energy saving results from the efargo gamers that allowed access (Table 5.3), this analysis concludes that the average gamer started to have reductions in electricity use during game play and that the greatest reductions in electricity use were evident in the eight months after game play.

Table 5.3. Data Sources and Results, Energy Savings.

data source	Basis for Determination	Changes in Energy Use	Implications for Hypothesis 4
efargo game (2016)	comparison of predicted with actual energy use	In the period following gameplay, tracked user data indicated an average 12% decrease in energy use	positive support, not statistically significant

5.3 Gamers' Learning and Awareness about energy-savings (Hypothesis 1)

The efargo game design addressed the informational barriers associated with the energy-efficiency gap.[1] In order to adopt energy-saving behaviors that result in energy savings, people first need to know where the energy waste is, how to prevent it and take action in ways that align with their available resources. The efargo game incorporated educational components in various tokens and action areas.[2] This aimed at providing gamers with information about where energy was potentially being wasted in homes and how to prevent it. Game levels were arranged in an ascending hierarchy of resources (cost, time, and skill) needed to complete action items. Table 5.4 charts the numbers of activities completed by gamers through the game interface in each Token and Level. Highlighted are the number of didactic educational activities that gamers completed. This does not account for any heuristic learning experience through action items that the gamers reported completing. In the Go/Key starting token, gamers reviewed their own energy bills in order to establish a personal energy-saving target and be aware of their own energy use. Tokens 2 through 6 and 7 incorporated information and a quiz at the starting Level 10 of every token. The Level 10 contained a summary paragraph and supporting tutorials that translated energy use information into easy-to-understand info-graphics.[3] Level 7 was action items based on gamer choice. Token 9 was a celebration event that incorporated various learning activities that gamers could attend in person and earn points for through the game interface. These included workshops, exhibit, a town hall meeting, Improv comedy show and a panel with City of Fargo commissioners.

155 gamers reported completing the activity of reviewing their energy bills related to Go/Key Token. 178 activities completed were reported for in-person attendance at various workshops,

1 See Chapter 2.

2 See Chapter 4; 4.7 Game Tools.

3 See Figure 4.10.a, Appendix 4.d.

exhibit, town Hall with the Mayor, Improv comedy and City panel about energy issues during the final Celebratory event related to Celebration Token in Week 9. 428 information summaries and related quiz reponses were completed throughout the game for various Tokens.

Table 5.4. Number of activities reported completed by gamers (educational activities highlighted)

Week	# of Players / week	Token/Topic	Educational Activities	# of activities completed by gamers								
				Lvl 10	Lvl 20	Lvl 30	Lvl 40	Lvl 50	Lvl 60	Lvl 70	TOTAL (educational only)	TOTAL (action items and community conversation, not including educational items and surveys)
1	129	Go / Key	Level 20: Review Energy Bill	198	155	113	96	96	84	81	155	470
1		Lighting	Level 10: Review + quiz	107	79	62	52	50	51	45	107	339
2	160	Heating	Level 10: Review + quiz	70	61	50	49	43	42	43	70	288
3	182	Water	Level 10: Review + quiz	58	47	42	42	38	35	35	58	239
4	198	Electrical	Level 10: Review + quiz	43	43	37	37	36	37	36	43	226
5	227	Controls	Level 10: Review + quiz	42	36	35	32	31	32	31	42	197
6	256	Cooling	Level 10: Review + quiz	40	39	36	36	36	36	34	40	217
7	266	Gamer Choice	All advanced action items	38	34	32	30	29	29	27	0	181
8	284	City	Level 10: Review + quiz	30	30	30	30	30	30	30	30	180
9	300	Celebrate	Various - see below	26	26	26	25	26	25	24	178	0*
			Educational Activities offered during Celebratory Event	Exhibit	1 workshop	Improv	2 workshops	3 workshops	Mayor's Town Hall	City Panel	723	2337

* Not counting in-person attendance of educational events at the Celebration

Notable is that in most of the tokens, the educational activities (highlighted orange in Table 5.4) have the greatest number of reported completions. This could potentially be explained by the fact that there is an ease with completing the activity within the digital game interface as compared to completing activities that require changes to be made in the home.

A post-game survey was conducted in order to examine the gamers' perception of the learning and awareness about energy savings through the game. Hypothesis 1 for this dissertation states that playing a serious pervasive game (like efargo) can lead to Learning and Awareness about energy-savings. In the efargo game, the perception of learning and awareness was measured and assessed by means of a combination of three questions from a post-game survey given to efargo gamers (Table 5.5). The total number of survey respondents was 64. Eight of these respondents did not answer the majority of survey questions, leaving a subset of respondents (n=56) for analysis.

Table 5.5. Questions relevant to Learning and Awareness from the efargo post-game survey.

#	question text
Q17	As a result of playing the efargo game, I learned where energy might be wasted in my home.
Q18	As a result of playing the efargo game, I learned how I could save energy through more energy conscious behaviors.
Q19	As a result of playing the efargo game, I learned that small investments in energy-saving products can help save energy and lower utility bills in the long term.

Question responses were on a five-point Likert scale ("Strongly agree," "Somewhat agree," "Neither agree nor disagree," "Somewhat disagree," "Strongly disagree"). For purposes of analysis, the responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). Figure 5.7 illustrates the responses to the three questions, graphically sorted by respondent. Inspection of Figure 5.7 suggests that the responses show good cross-question reliability. To test this observation, Cronbach's alpha for the three questions (Q17, Q18, and Q19) was calculated as .919, indicating an excellent level of reliability across the questions, i. e., that the responses to the three questions in Table 5.5 are very well-correlated.

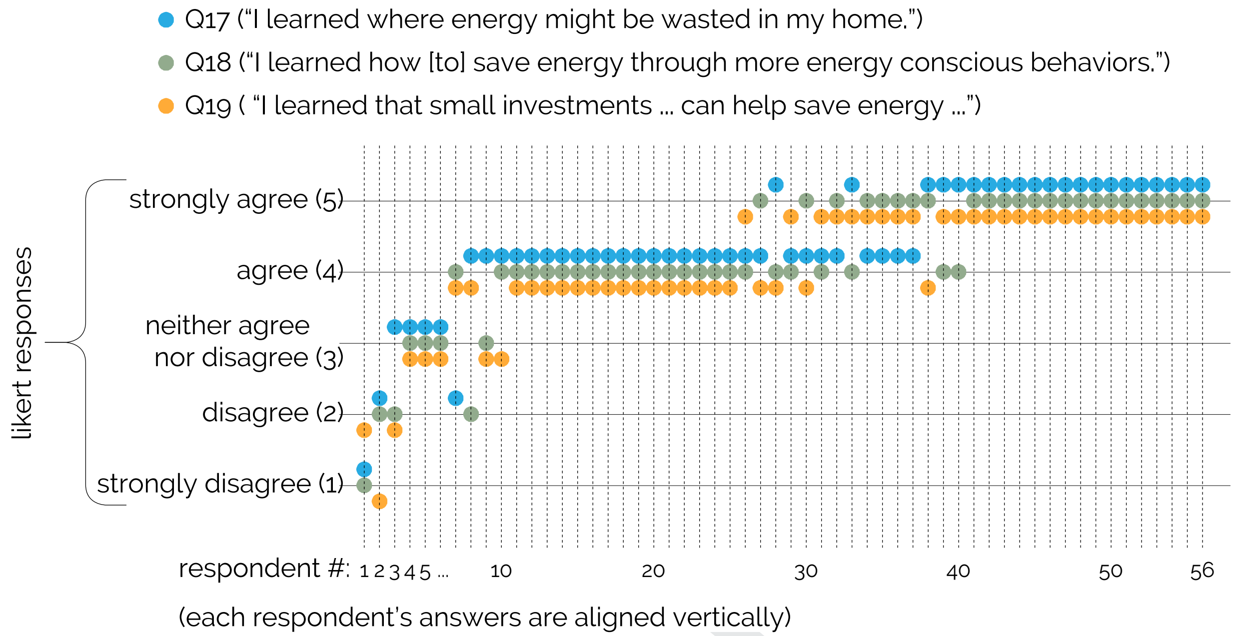


Figure 5.7. Cross-question reliability for three questions relevant to Learning and Awareness from the efargo post-game survey (Q17, Q18, and Q19). Respondents sorted by mean-value response to the composite of all three questions.

Figure 5.8 illustrates the responses to the three questions, graphically sorted by response. Inspection of Figure 5.8 suggests that the mean response to the three questions is higher than a hypothesized mean response of 3.0. To verify this, the mean of numerical values assigned to responses from all three questions was computed to form a composite variable. The composite variable's range is from 1.33 to 5 (where large values indicate more agreement), with a mean of 4.21, a median of 4.33, and a standard deviation (SD) of 0.83. The observed mean (4.21) is greater than the hypothesized mean (3.00).

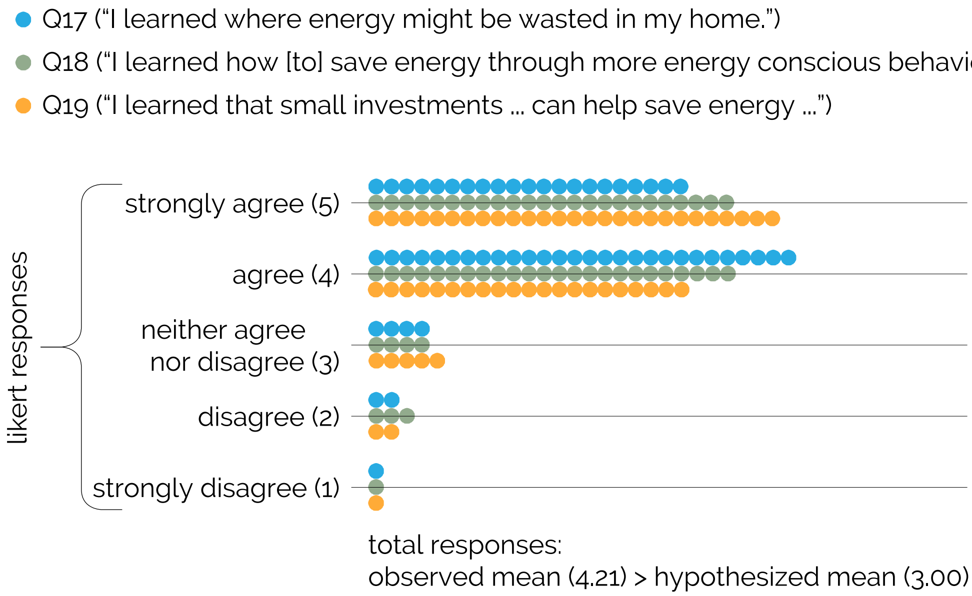


Figure 5.8. Mean-value responses for three questions relevant to Learning and Awareness from the efargo post-game survey (Q17, Q18, and Q19).

To test the statistical significance of these observations, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (3). For the sample size of 56, the t-critical value was calculated as 2.004, and the t-statistic was calculated as 11.047. The p-value is less than 0.01, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 3 is outside of the 95% confidence interval of [3.994, 4.434], i. e., the observed mean response to the three very well-correlated questions concerning Learning and Awareness is significantly greater than a hypothesized neutral response.

Thus, with respect to the efargo post-game survey data, playing an open, pervasive game led to gamers' perception of Learning and Awareness about energy-savings, and this result was statistically significant.

5.4 efargo gamers' willingness to engage in energy-saving behavior (Hypothesis 2) and make energy-saving investments (Hypothesis 3)

The game provided a structure, incentives, public dashboards, competition and a limited timeline (creating a race against other gamers and time) in order to adopt energy-saving behaviors that result in energy savings (Table 5.6). Along the ascending hierarchy of game levels, gamers needed fewer resources to complete action items on the Lower Levels (Levels 10-30) and greater resources for the Higher Levels (Levels 40-70). Typically, it was assumed that gamers' ability to use lighting and electricity to save energy would be easier to engage than controls, cooling, or water heating. The game was designed so that the hierarchy of action items would allow gamers flexibility to align their game play with their resources, while simultaneously providing visual and quantitative incentives to complete the game's more challenging aspects.

Table 5.6. Number of activities and associated points reported completed by gamers (action items highlighted)

Week	# of Players	Token/Topic	# of activities completed by gamers: Lvl 10 # of activities	Lvl 10 # of points	Lvl 20 # of activities	Lvl 20 # of points	Lvl 30 # of activities	Lvl 30 # of points	Lvl 40 # of activities	Lvl 40 # of points	Lvl 50 # of activities	Lvl 50 # of points	Lvl 60 # of activities	Lvl 60 # of points	Lvl 70 # of activities	Lvl 70 # of points	All activities: TOTAL (count of activities)	All activities: TOTAL (points earned from activities)	Action Items only: TOTAL count of action items (educational activities & survey (red) not included)	Action Items only: TOTAL (points earned by action items, educational points & survey (red) not included)
1		Go / Key	198	1980	155	3100	113	3390	96	6840	96	7700	84	7590	81	9470	823	40070	113	3390
1	129	Lighting	107	1070	79	1580	62	1860	52	3530	50	4000	51	4560	45	5150	446	21750	339	20680
2	160	Heating	70	700	61	1220	50	1500	49	3010	43	3500	42	3670	43	4860	358	18460	288	17760
3	182	Water	58	580	47	940	42	1260	42	2130	38	2750	35	3100	35	3950	297	14710	239	14130
4	198	Electrical	43	430	43	860	37	1110	37	1880	36	2600	37	3370	36	4070	269	14320	226	13890
5	227	Controls	42	420	36	720	35	1050	32	1480	31	1850	32	2370	31	3320	239	11210	197	10790
6	256	Cooling	40	400	39	780	36	1080	36	1640	36	2150	36	2810	34	3880	257	12740	217	12340
7	266	Gamer Choice	38	380	34	680	32	960	30	1250	29	1500	29	1990	27	2340	219	9100	219	9100
8	284	City	30	300	30	600	30	900	30	1250	30	1650	30	2050	30	2550	210	9300	180	9000
9	300	Celebrate	26	260	26	520	26	780	25	1000	26	1350	25	1600	24	1780	178	7290	0	0
Total			652	6520	550	11000	463	13890	429	24010	415	29050	401	33110	386	41370	3296	158950	2018	111080

*educational activities & survey (red) not included

Notable is that in most of the tokens, the Level 10 has the greatest number of reported completions for a total of 652. This could be possibly due to these educational activities being completely within the game interface or within the gamers' computer or device which means that gamers don't have any pervasive action items associated with them which would involve making changes to the physical environment around the gamers. It could also be because the educational items were placed early in every token implementation (associated with a lower number of points) and there was attrition as the activities got harder within each token and within the overall game, with the last Level 70 activities adding up to 386 completed action items or 41,370 points. Of all the Tokens, Lighting (339) earned the greatest number of completed actions followed by Heating (288). Most other tokens were fairly close to each other ranging between 239 (Water) and 197 (Controls) actions reported completed. Controls (197) and the CIty interactions (180) tokens had the least number of actions reported completed. Overall, the gamers reported completing a total of 2,375 action items through the game interface, earning a total of 142,680 points.

5.4.1 Post-game survey regarding efargo gamers' willingness to engage in energy-saving behavior (Hypothesis 2) and make energy-saving investments (Hypothesis 3)

The post-game survey tested gamers' perception regarding completion of energy-saving actions, willingness to complete energy-saving behaviors and make energy-saving investments. Two different tests were conducted within the post-game survey. Gamers were asked a general question about their willingness to make investments and a combination of four questions asked them about their willingness to engage in energy-saving behaviors. Both these questions included a Likert scale for responses. Gamers were also asked a series of specific action-related questions in three major categories, no- and low-cost improvements, medium-cost improvements and high-cost improvements. While all the action items incorporated a willingness to change behavior, the no- and low-cost action items specifically required energy-saving behaviors on an ongoing basis.

5.4.2 Behavior questions in post-game survey

In addition to the specific action items and the no-cost, behavior change measures that post-game survey respondents affirmed, perception of willingness to engage in energy-saving behavior was measured and assessed in the efargo game by means of a combination of four questions from a post-game survey given to efargo gamers (Table 5.7). The total number of respondents (n) was 56.

Table 5.7. Questions relevant to Behavior Change from the efargo post-game survey.

#	question text
Q8	Playing the game helped me lower my energy use and environmental impact.
Q11	The game motivated me to take action in order to reduce my household energy use.

Q12	The game motivated me to take energy-saving actions in areas other than household energy use such as transportation (using a bike more often) in order to reduce my overall environmental impact.
Q20	My willingness to change behavior in order to save energy has increased since I played the efargo game (for example: switching off lights when leaving a room).

Question responses were on a five-point Likert scale ("Strongly agree," "Somewhat agree," "Neither agree nor disagree," "Somewhat disagree," "Strongly disagree"). For purposes of analysis, the responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). Figure 5.9 illustrates the responses to the three questions, graphically sorted by respondent. Inspection of Figure 5.9 suggests that the responses show good cross-question reliability. To test this observation, Cronbach's alpha for the four questions (Q8, Q11, Q12, and Q20) was calculated as .881, indicating a good level of reliability across the questions, i. e., that the responses to the four questions in Table 5.7 are well-correlated.

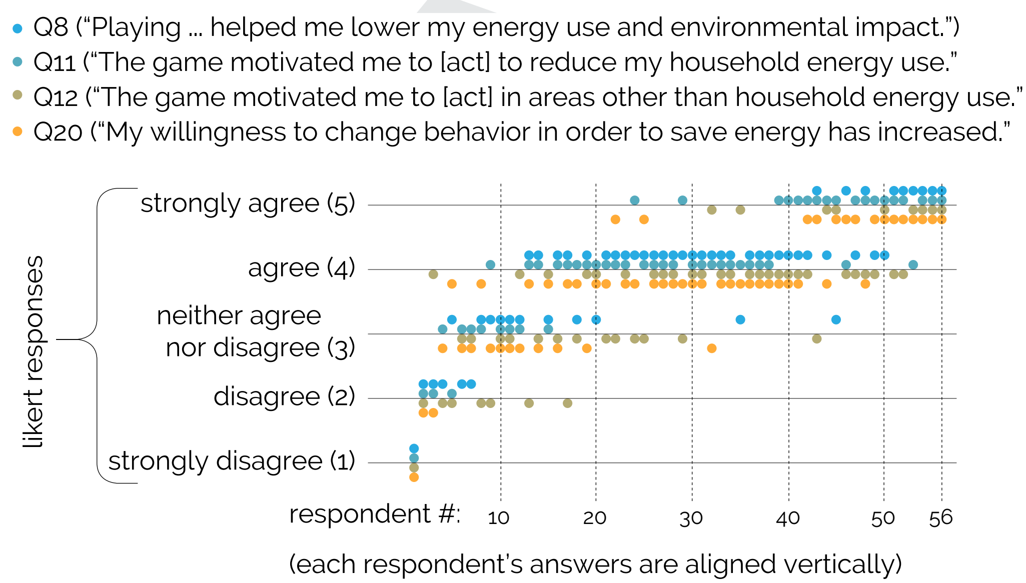


Figure 5.9. Cross-question reliability for four questions relevant to Behavior Change from the efargo post-game survey (Q8, Q11, Q12, and Q20). Respondents sorted by mean-value response to the composite of all four questions.

Figure 5.10 illustrates the responses to the four questions, graphically sorted by response. Inspection of Figure 5.10 suggests that the mean response to the four questions is higher than a hypothesized mean response of 3.0.

- Q8 ("Playing ... helped me lower my energy use and environmental impact.")
- Q11 ("The game motivated me to [act] to reduce my household energy use."
- Q12 ("The game motivated me to [act] in areas other than household energy use."
- Q20 ("My willingness to change behavior in order to save energy has increased."

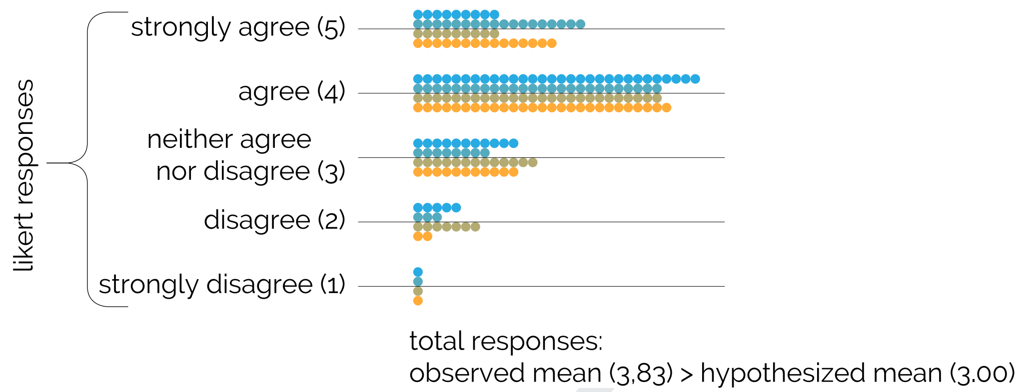


Figure 5.10. Mean-value responses for four questions relevant to Behavior Change from the efargo post-game survey (Q8, Q11, Q12, and Q20).

To verify this, the mean of numerical values assigned to responses from all four questions (Q8, Q11, Q12, and Q20) was computed to form a composite variable. Table 5.8 includes the descriptive statistics for this variable. Note that higher values indicate more agreement.

Table 5.8. Descriptive statistics for responses to a composite of three questions relevant to Behavior Change from the efargo post-game survey.

variable	n	range	mean	median	standard deviation
compound of Q8, Q11, Q12, and Q20	56	1.00 to 5.00	3.83	4	0.78

The observed mean (3.83) is greater than the hypothesized mean (3.00). To test the statistical significance of this observation, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (3). For the sample size of 56, the t-critical value was calculated as 2.004, and the t-statistic was calculated as 7.941. The p-value of 0.001 is less than 0.01, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 3 is outside of the 95% confidence interval of [3.621, 4.039], i. e., the observed mean response to the four well-correlated questions concerning willingness to engage in energy-saving behavior is significantly greater than a hypothesized neutral response.

Thus, with respect to the efargo post-game survey data, we conclude that playing an open, pervasive game can engender a perception of willingness to engage in energy-saving behavior and this result is statistically significant.

5.4.3 General investment question in post-game survey

The prediction that playing an open, pervasive game can lead to a willingness to make energy saving investments (Hypothesis 3) was tested using a single question from the efargo post-game survey (Table 5.9). The total number of respondents (n) was 56.

Table 5.9. Question relevant to Willingness to Invest from the efargo post-game survey.

#	question text
Q21	My willingness to make small energy-saving investments has increased since I played the efargo game.

Question responses were on a five-point Likert scale (“Strongly agree,” “Somewhat agree,” “Neither agree nor disagree,” “Somewhat disagree,” “Strongly disagree”). For purposes of analysis, the responses were assigned numerical values from 1 (for “Strongly disagree”) to 5 (for “Strongly agree”). Table 5.10 includes the descriptive statistics for this variable.

Table 5.10. Descriptive statistics for responses to question relevant to Willingness to Invest from the efargo post-game survey.

variable	n	range	mean	median	standard deviation
Q21	56	1.0 to 5.0	3.98	4	0.9

The observed mean (3.98) is greater than the hypothesized mean (3.00). To test the statistical significance of this observation, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (3). For the sample size of 56, the t-critical value was calculated as 2.004, and the t-statistic was calculated as 8.199. The p-value of 0 is less than 0.05, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 3 is outside of the 95% confidence interval of [3.742, 4.222], i. e., the observed mean response to the question concerning willingness to make energy-saving investments is significantly greater than a hypothesized neutral response.

Thus, with respect to the measurement of question responses on the efargo post-game survey, we conclude that playing an open, pervasive game can lead to a willingness to make energy-saving investments.

5.5 Specific investment and behavior related action items taken as a result of the efargo game

The relationship of gamers' willingness to invest in energy-savings with specific behaviors, actions or investments was assessed by means of specific action-related questions from the efargo post-game survey (Table 5.15). In particular, respondents were asked to indicate whether they had completed several different behaviors or home improvement tasks as a result of playing the efargo game. For each of these items, participants could select the following response options: "Implemented during or after [the game]", "Planning to complete," "Had already completed [before the game]," "Willing to consider," or "Not willing to consider." Of particular interest to assess the effectiveness of the game were the options "implemented during or after" and "planning to complete". The questions were grouped into three categories,namely, no-cost action items (Table 5.11), low-medium cost action items (Table 5.12), and high-cost action items (Table 5.13). No-cost action items were focused on behavior shifts and included the following questions:

Table 5.11. No-cost action items in the efargo game related to behavior change.

Use "air dry" selection on your dishwasher
Wash clothes in cold water
Turn up your thermostat 5 degrees Fahrenheit in the summer

Put on an extra sweater and slippers instead of turning up the heat
Switch off power-strips that appliances and devices are plugged into
Unplug second or third refrigerator
Hang clothes up to dry inside in the winter
Switch off lights as you leave a room
Hang clothes up to dry outside in the summer

Table 5.12. Low-Medium cost action items in the efargo game.

Replaced old incandescent bulbs with LED bulbs
Replaced old holiday lighting with LED lighting
Weather-stripped or caulk windows to make them more airtight
Installed smart plug strips for home entertainment equipment
Installed smart plug strips for home office equipment
Completed a full energy assessment of the home, including identifying air leaks
Installed timers on exhaust fans
Installed solar powered outdoor lighting (landscaping or holiday)
Installed occupancy/motion sensors or timers on outdoor lighting
Installed dimmers on most used lighting

Table 5.13. High-cost action items in the efargo game.

Insulate attic/roof
Replace windows with double glazed or storm windows
Install solar electric panels
Replace furnace or boiler with high-efficiency furnace
Install solar hot water heating
Replace hot water tank with heat pump water heater or tankless water heater
Have a heat recovery ventilator
Install a geothermal system

While most of the high-cost action items were in the lowest range of gamers who reported either implementing the action item either during or after the game or were planning to implement it during or after the game, the numbers of respondents making or willing to make high cost investments was substantive given the resource investment some of these action items entail (Table 5.14). 8.9% (n=56) had insulated their attics/roofs; 7.1% (n=56) had replaced windows with double glazed or storm windows; and 7.1% (n=56) had replaced an old furnace or boiler with a high-efficiency boiler. Smaller numbers of respondents installed solar panels, solar water heating, heat pump water heaters, tankless water heaters, or geothermal systems. These are all efforts that not only require substantive investments but also require a substantive research, planning, design, and implementation process. The fact that these action items were pursued by respondents during or after the game is an indicator of willingness to make investments in energy-saving measures.

Table 5.14. High-cost action items in the efargo game, sorted in decreasing order of total percentage of gamers who selected the options "implemented during or after" or "planning to complete".

Action items or investments	Percentage of gamers who implemented the action item during or after the game intervention	Percent of gamers who are planning to implement the action item during or after the game intervention	Total percentage of gamers who selected the options "implemented during or after" or "planning to complete"
Insulate attic/roof	8.9	5.4	14.3
Replace windows with double glazed or storm windows	7.1	5.4	12.5
Install solar electric panels	1.8	5.4	7.2
Replace furnace or boiler with high-efficiency furnace	7.1	0	7.1
Install solar hot water heating	3.6	1.8	5.4
Replace hot water tank with heat pump water heater or tankless water heater	1.8	3.6	5.4
Have a heat recovery ventilator	3.6	0	3.6
Install a geothermal system	3.6	0	3.6

For the no-cost and low-cost measures, the percentage of respondents who had either implemented the action item during or after the game, as well as the percentage of gamers who were planning to implement the action item during or after the game, were more substantive than for the high-cost action items. More importantly, the percentages of respondents were mixed, in the sense that it wasn't the case that the no-cost items had the highest percentage of respondents and the low- and medium-cost items had fewer respondents. In fact, the action item with the greatest percentage of respondents was a low-medium cost investment for replacing old incandescent bulbs with LED bulbs. 42.9% (n=56) of respondents completed this action item during or after the game, and 21.4% indicated that they planned to implement the item during or after the game. The two action items with the next best results were respondents' willingness to turn down their thermostat 2 degrees Fahrenheit in the winter, and their willingness to use the "air dry" selection on their dishwasher. The former had 41% respondents who had either completed or were planning to complete the action item, and the latter had 39.3% respondents who had either completed or were planning to complete the action item. These were both no-cost action items, indicating a willingness to change behavior and definitions of comfort range. The next action item, replacing old holiday lights with LED light strings, was reported as completed (21.4%) or as something that gamers were willing to complete (14.3%), for a total of 35.7% of the respondents.

The next 10 action items, ranging from 28.6% - 21.4% respondents who had either implemented or were willing to implement the action items, were a mix of no-cost behavior change efforts and low-cost investment efforts. The no-cost, behavior change actions included washing clothes in cold water, turning up the thermostat 5 degrees Fahrenheit in the summer, putting on an extra sweater and slippers instead of turning up the heat, switching off power-strips that appliances and devices are plugged into, unplugging a second or third refrigerator, and hanging clothes up to dry inside in the winter. Low-medium cost items for investment included weather-stripping or caulking windows to make them more airtight, installing smart plug strips for home entertainment equipment, installing smart plug strips for home office equipment, and completing a full energy assessment of the home, including identifying air leaks.

Finally, the set of action items that garnered affirmative responses from 14.3%-19.7% respondents who had either completed implementation or expressed willingness to implement during or after the game, included two no-cost, behavior-changing efforts and four low-medium cost investments. The no-cost action items were switching off lights (19.7%, n=56) and hanging up clothes to dry outside in the summer (17.9%, n=56). The low-medium cost action items were installing timers on exhaust fans (19.6%, n=56), installing solar powered outdoor lighting (landscaping or holiday) (14.3, n=56), installing occupancy/motion sensors or timers on outdoor lighting (14.3, n=56), and installing dimmers on most used lighting (14.3, n=56).

Table 5.15. Summary of percentage responses to questions from efargo game postgame survey, from gamers who either implemented action items or expressed willingness to implement action items during or after the game. Sorted in descending order based on the percentage of gamers who implemented the action item during or after the game intervention.

no-cost items
low-cost items
high-cost items

Action items or investments	Percentage of gamers who implemented the action item during or after the game intervention	Percent of gamers who are planning to implement the action item during or after the game intervention	Total percentage of gamers who selected the options "implemented during or after" or "planning to complete"
Replaced old incandescent bulbs with LED bulbs	42.9	21.4	64.3
Wash clothes in cold water	25	3.6	28.6
Turn down thermostat 2 degrees Fahrenheit in the winter	21.4	19.6	41
Use "air dry" selection on your dishwasher	21.4	17.9	39.3
Replaced old holiday lighting with LED lighting	21.4	14.3	35.7
Turn up your thermostat 5 degrees Fahrenheit in the summer	19.6	8.9	28.5
Unplug second or third refrigerator	19.6	1.8	21.4
Switch off power-strips that appliances and devices are plugged into	16.8	8.9	25.7
Put on an extra sweater and slippers instead of turning up the heat	16.1	10.7	26.8
Switch off lights as you leave a room	16.1	3.6	19.7
Installed smart plug strips for home entertainment equipment	14.3	10.7	25
Hang clothes up to dry inside in the winter	12.5	8.9	21.4

Action items or investments	Percentage of gamers who implemented the action item during or after the game intervention	Percent of gamers who are planning to implement the action item during or after the game intervention	Total percentage of gamers who selected the options "implemented during or after" or "planning to complete"
Installed timers on exhaust fans	8.9	10.7	19.6
Installed solar powered outdoor lighting (landscaping or holiday)	8.9	5.4	14.3
Installed occupancy/motion sensors or timers on outdoor lighting	8.9	5.4	14.3
Insulate attic/roof	8.9	5.4	14.3
Installed smart plug strips for home office equipment	7.1	16.1	23.2
Replace windows with double glazed or storm windows	7.1	5.4	12.5
Replace furnace or boiler with high-efficiency furnace	7.1	0	7.1
Weather-stripped or caulk windows to make them more airtight	5.4	21.4	26.8
Installed dimmers on most used lighting	5.4	8.9	14.3
Hang clothes up to dry outside in the summer	3.6	14.3	17.9
Install solar hot water heating	3.6	1.8	5.4
Have a heat recovery ventilator	3.6	0	3.6
Install a geothermal system	3.6	0	3.6
Completed a full energy assessment of the home, including identifying air leaks	1.8	21.4	23.2
Install solar electric panels	1.8	5.4	7.2
Replace hot water tank with heat pump water heater or tankless water heater	1.8	3.6	5.4

Figure 5.11 summarizes this data graphically.

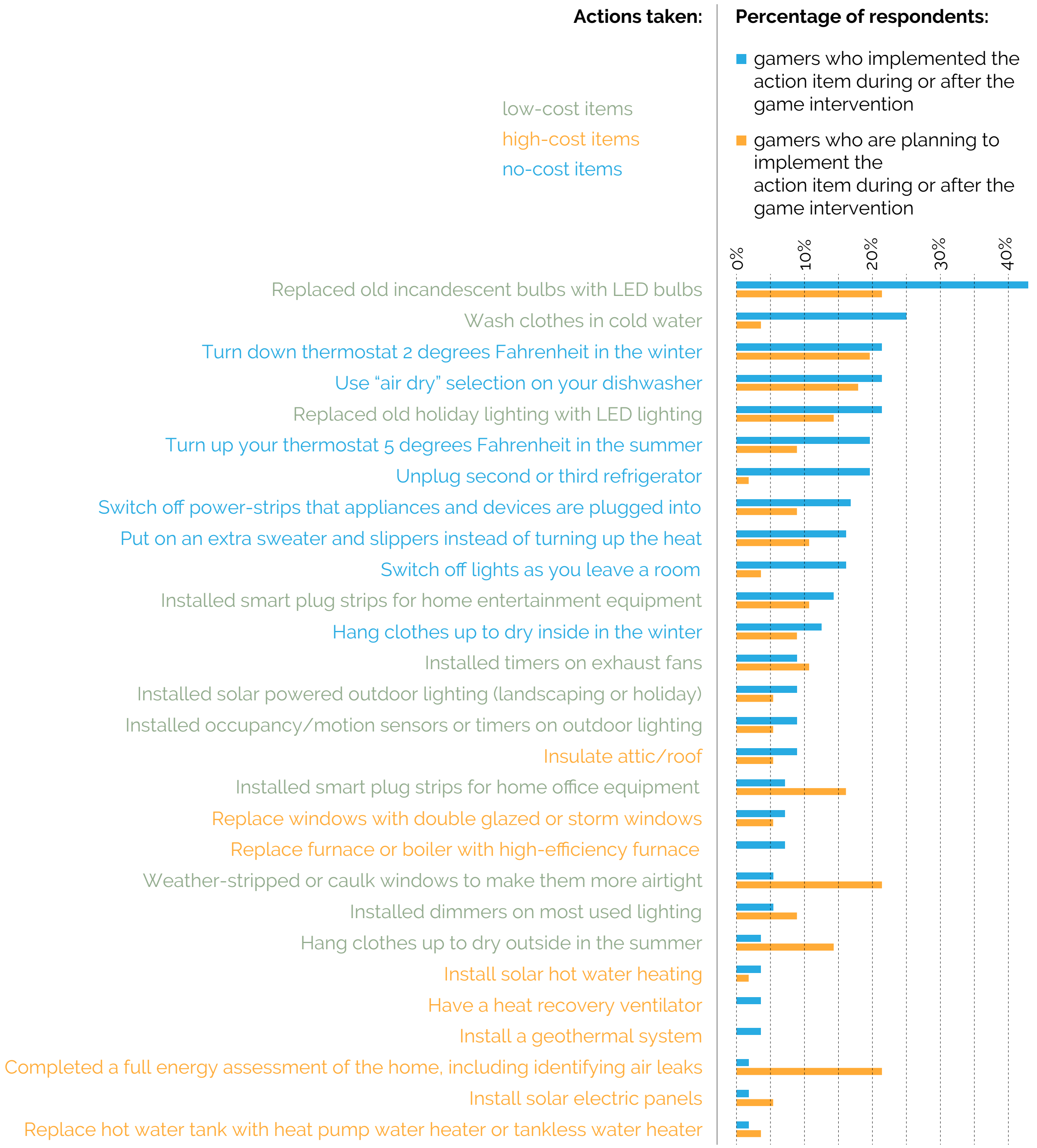


Figure 5.11. Summary of percentage responses to questions from efargo game postgame survey, from gamers who either implemented action items or expressed willingness to implement action items during or after the game.

The only action item that did not garner any positive response from gamers was a no-cost behavior shift of lowering the temperature of the water heater to 120 degrees Fahrenheit in the post-game survey. The post-game survey indicates that in several cases respondents were more willing to make low-medium cost investments rather than complete no-cost practices requiring behavior change. For example, 64.3% of the respondents were willing to change to LED light bulbs, while only 19.7% respondents were willing to switch off lights when they leave the room.

5.6 Impacts of gamers' perception of whether the efargo game was fun and meaningful to them

In the game surveys, gamers were asked whether they found the efargo game to be fun and meaningful to their needs. Further analysis was conducted in order to find out whether there was correlation between the game being perceived as fun or meaningful, and whether this impacted gamers' Learning and Awareness about energy savings in the game. Such correlation could suggest that gamers' consideration of the game as either fun or meaningful,or both, led to greater perceptions about Learning and Awareness. However, although analysis demonstrated that gamers considered the efargo game to be both fun and meaningful, no statistically significant correlation was found between either of these conclusions and the conclusion that the efargo game impacted Learning and Awareness. Table 5.16 and Table 5.17 summarize the data sources and results for this analysis, which is discussed in detail in the following sections.

Table 5.16. Data Sources and Results, Impact of Fun on Learning and Awareness.

data source	Basis for Determination	Implications for the impact of Fun on Learning and Awareness
efargo game (2016)	Comparison of (a) responses to three questions on post-game surveys completed by gamers, to (b) responses to a single question on post-game surveys completed by gamers (n = 56; p = 0.51)	not confirmed

Table 5.17. Data Sources and Results, Impact of Meaning on Learning and Awareness.

data source	Basis for Determination	Implications for the impact of Meaning on Learning and Awareness

efargo game (2016)	Comparison of (a) responses to three questions on post-game surveys completed by gamers, to (b) responses to a single question on post-game surveys completed by gamers (n = 56; p = 0.51)	not confirmed

5.6.1 The impact of fun on learning and awareness in the efargo game

This section analyzes whether higher outcomes in perceptions of how fun the efargo game is are positively correlated with results for Learning and Awareness about energy savings. From analysis described earlier in this chapter, the measurement of Learning and Awareness by means of a composite variable (Q17, Q18, and Q19 from the efargo post-game survey) was found to be statistically significant. In this section this composite variable is referred to as V1. Figure 5.12 (left) illustrates the responses to the three questions composing V1, graphically sorted by response. As a composite variable, V1 ranged from 1.33 to 5 (where large values indicate more agreement), with a mean of 4.21, a median of 4.33, and a standard deviation (SD) of 0.83.

Two additional questions from the efargo post-game survey concerned the impact of fun on gameplay generally (Table 5.18). The total number of survey respondents (n) was 56.

Table 5.18. Questions relevant to the impact of Fun on Learning and Awareness from the efargo post-game survey.

#	question text
Q9	The efargo game was fun to play.
Q10	The home energy actions were fun to complete.

Question responses used a five-point Likert scale ("Strongly agree," "Somewhat agree," "Neither agree nor disagree," "Somewhat disagree," "Strongly disagree"). For purposes of analysis, responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). The calculation of Cronbach's alpha for the two questions (Q9 and Q10) was .849, indicating a good level of reliability across the questions, i. e., that the responses to the two questions in Table 5.18 are well-correlated. Figure 5.12 (right) illustrates the responses to the two questions, graphically sorted by response.

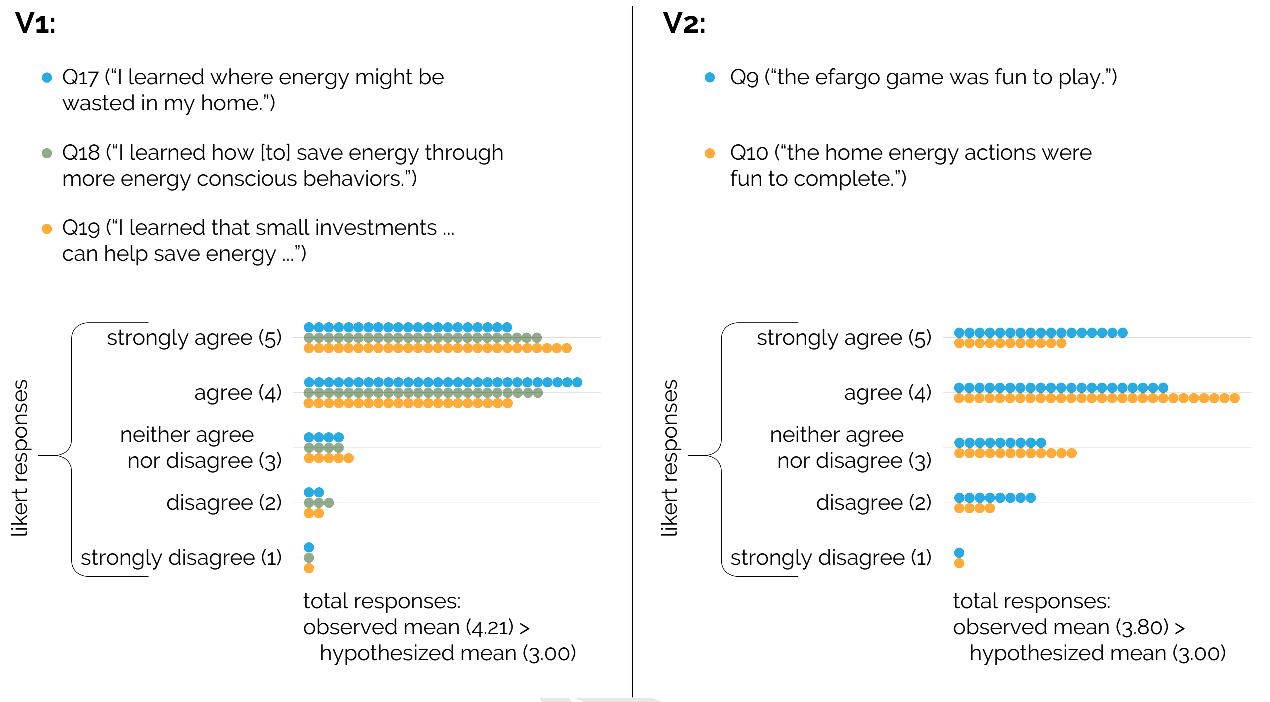


Figure 5.12. LEFT: Mean-value responses for three questions relevant to Learning and Awareness from the efargo post-game survey (Q17, Q18, and Q19). RIGHT: Mean-value responses for two questions relevant to the impact of Fun on Learning and Awareness from the efargo post-game survey (Q9 and Q10).

Inspection of Figure 5.12 (right) suggests that the mean response to the two questions is higher than a hypothesized mean response of 3.0. The mean of the two questions (Q9 and Q10) was computed to form a composite variable, V2. Table 5.19 includes the descriptive statistics for this variable. Note that higher values indicate more agreement.

Table 5.19. Descriptive statistics for responses to composite of two questions relevant to the impact of Fun on Learning and Awareness from the efargo post-game survey.

variable	n	range	mean	median	standard deviation

V2 (compound of Q9 and Q10)	56	1.00 to 5.00	3.8	4	0.93

The observed mean (3.80) is greater than the hypothesized mean (3.00). To test the statistical significance of this observation, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (3). For the sample size of 56, the t-critical value was calculated as 2.004, and the t-statistic was calculated as 6.433. The p-value is less than 0.01, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 3 is outside of the 95% confidence interval of [3.547, 4.043], i. e., the observed mean response to the two well-coordinated questions concerning Fun is significantly greater than a hypothesized neutral response. Thus, gamers' responses to Q9 ("The efargo game was fun to play") and Q10 ("The home energy actions were fun to complete"), as combined in composite variable V2, suggest that playing the efargo game is fun.

To analyze whether there was a statistically significant relationship between (a) the conclusion that the efargo game impacted Learning and Awareness, as registered in composite variable V1, and (b) the conclusion that the efargo game was fun, as registered in composite variable V2), a two-sample t-test was conducted, assuming equal variances.[1] For a sample size of 55, the t-value was calculated as 2.515. The t-critical value (two-tail) was calculated as 1.982. This suggests that the null hypothesis can be rejected, i. e., that the responses concerning Learning and Awareness (V1) and the responses concerning Fun (V2) differ significantly. The p-value was calculated as 0.013 (<0.05), suggesting that this result is statistically significant.

Thus, while independent analysis of Learning and Awareness (V1) and Fun (V2) suggests, respectively, that:

(a) playing the efargo game can lead to Learning and Awareness about energy-savings; and

(b) playing the efargo game is fun;

the relationship between these two conclusions is not clear. In particular, it cannot be

1 Prior to conducting the t-test, an F-test was conducted to determine whether the variances of the two composite variables were equal. The variance of V1 was calculated as 0,689, and that of V2 as 0.871. The F-test returned a calculated F-value of 1.26 and an F-statistic of 1.56. The p-value was calculated as 0.193 (>0.05), so the null hypothesis that the variances of V1 and V2 are equal, cannot be rejected. This, the t-test was conducted assuming equal variances.

concluded that this relationship is statistically significant.

5.6.2 The impact of meaning on learning and awareness in the efargo game

This section considers gamers' perceptions of the meaning of the efargo game, and whether those perceptions positively impacted the game results for Learning and Awareness about energy savings. Meaning was measured by asking a question about flexibility or suitability of the game for the gamer in other words did the gamer find it suitable within their life and resource (time, finances, skills, knowledge) constraints or availability. From analysis described earlier in this chapter, it was concluded that the measurement of Learning and Awareness by means of a composite variable (Q17, Q18, and Q19 from the efargo post-game survey) is statistically significant. In this section this composite variable is referred to as V1. Note that V1 ranged from 1.33 to 5 (where large values indicate more agreement), with a mean of 4.21, a median of 4.33, and a standard deviation (SD) of 0.83.

The impact of Meaning or meaningfulness of the game to the gamer was measured by means of a single question from a post-game survey given to efargo gamers (Table 5.20). The total number of survey respondents (n) was 56.

Table 5.20. Question relevant to Meaning from the efargo post-game survey.

#	question text
Q7	The game gave me the flexibility to choose which energy-saving actions would be best suited for my family and my home.

Question responses used a five-point Likert scale ("Strongly agree," "Somewhat agree," "Neither agree nor disagree," "Somewhat disagree," "Strongly disagree"). For purposes of analysis, responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). Table 5.21 includes the descriptive statistics for this variable. Note that higher values indicate more agreement.

Table 5.21. Descriptive statistics for responses to questions relevant to the impact of Meaning on Learning and Awareness from the efargo post-game survey.

variable	n	range	mean	median	standard deviation
Q7	56	1.00 to 5.00	4.11	4	0.88

The observed mean (4.11) is greater than the hypothesized mean (3.00). To test the statistical significance of this observation, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (3). For the sample size of 56, the t-critical value was calculated as 2.004, and the t-statistic was calculated as 9.415. The p-value is less than 0.01, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 3 is outside of the 95% confidence interval of [3.871, 4.343], i. e., the observed mean is significantly different from the neutral point of the scale.

The difference between the mean level of agreement and the neutral point of the scale is therefore statistically significant.

Thus, as a preliminary conclusion, it is noted that gamers' responses to Q7 ("The game gave me the flexibility to choose which energy-saving actions would be best suited for my family and my home") suggest that playing an open, pervasive game is meaningful.

To analyze whether there was a statistically significant relationship between V1 (i. e., a composite of Q17, Q18, and Q19) for Awareness & Learning and Q7 for Meaning, a two-sample t-test was conducted assuming equal variances.[1] For a sample size of 56, the t-value was calculated as 0.660. The t-critical value (two-tail) was calculated as 1.982. This suggests that the null hypothesis (i. e., that the means of V1 and Q7 do not differ significantly) cannot be rejected. However, the p-value was calculated as 0.51 (>0.05), suggesting that this result is not statistically significant.

Thus, while independent analysis of V1 and Q7 suggests, respectively, that:

1 Prior to conducting the t-test, an F-test was conducted to determine whether the variances of V1 and Q15 were equal. The F-test returned a F-critical value of 1.56 and an F-statistic of 1.14. The F-statistic is less than the F-critical value, suggesting that the null hypothesis cannot be rejected and that the variances of V1 and V2 are equal. However, the p-value was calculated as 0.31 (>0.05), suggesting that this result is not statistically significant. Thus the null hypothesis concerning variances cannot be rejected. Thus, a two-sample t-test was conducted assuming equal variances.

(a) playing an open, pervasive game can lead to Learning and Awareness about energy-savings (Learning and Awareness);

(b) playing an open, pervasive game is meaningful;

the relationship between these two conclusions is not clear. In particular, it cannot be concluded that this relationship is statistically significant.

5.7 Summary of efargo game outcomes

The results of the efargo game for all the hypotheses were aligned. Positive energy saving results align with the findings that playing the efargo game, an open, pervasive energy game, led to learning and awareness of energy savings; a willingness to engage in energy-saving behavior and willingness to make energy-saving investments.

5.7.1 Learning and Awareness

A total of 723 action items related to didactic educational activities were reported completed by gamers in efargo game. These activities included gamers' reviewing their own energy bills in order to establish a personal energy-saving target and be aware of their energy use; summary information, tutorials and quizzes about lighting, heating, cooling, devices, controls and water; and in-person learning activities included workshops, exhibit, a town hall meeting, an educational improv comedy show and a panel with City of Fargo commissioners. A post-game survey which included three questions about gamers' perceptions of Learning and Awareness about energy waste and energy savings resulted in confirming Hypothesis 1, i. e., that playing a serious pervasive game can lead to Learning and Awareness about energy-savings, was confirmed ($n = 56$; $p < 0.01$) (Table 5.22).

Table 5.22. Post-game survey results for Learning and Awareness

data source	Basis for Determination	Implications for Hypothesis 1

efargo game (2016)	Responses to three questions on post-game surveys completed by gamers	"Confirmed (n = 56; $p < 0.01$)"

5.7.2 Willingness to engage in energy-saving behavior

A total of 2,375 action items were reported to be completed by gamers in efargo game. These action items were energy-saving behaviors in various areas of energy waste in the residential sector such as Lighting (339 action items); Heating (288 action items); energy use related to water heating/cooling (239 action items); electrical devices (226 action items); controls (197 action items); cooling (217 action items); gamer choices of any of the above (219 action items); and providing feedback to the city regarding community-wide energy issues (180 action items). A post-game survey which included four questions about lowering energy use, motivation to take action, and changing behavior regarding energy use resulted in a confirmation of Hypothesis 2, i. e., that playing a serious pervasive game can engender willingness to engage in energy-saving behavior (n = 56; $p = 0.001$) (Table 5.23).

Table 5.23. Data Sources and Results, Behavior Change.

data source	Basis for Determination	Implications for Hypothesis 2
efargo game (2016)	Responses to four questions on post-game survey	"Confirmed (n = 56; $p = 0.001$)."

5.7.3 Willingness to engage in energy saving behavior and make energy-saving investment

The survey questions (n=56) concerning gamers' completion of 28 different behaviors or tasks addressed actions over a range of investment cost (i. e., no-cost to high-cost). When the responses for individual action items are considered relative to the percentage of gamers who implemented the action item during or after the game intervention (Table 5.15), the highest-ranking item, "Replaced old incandescent bulbs with LED bulbs," a low-cost item, was identified by 42.9% of gamers. No other action item, irrespective of cost, was identified by more than 21.4% of gamers. When the responses for the 28 items are considered in this way, the top-ranked

15 items (i. e., roughly half of the list) were either low-cost or no-cost items. No high-cost item was identified by more than 8.9% of gamers. The indication is that gamers largely favored the implementation of no-cost or low-cost items.

When the responses for individual action items are considered relative to the percentage of gamers who planned to implement the action item during or after the game intervention, the three highest-ranked items were each identified by 21.4% of the gamers. Two of these high-ranked items were low-cost items ("Replaced old incandescent bulbs with LED bulbs" and "Weather-stripped or caulk windows to make them more airtight"), and the third was a high-cost item ("Completed a full energy assessment of the home, including identifying air leaks"). No other high-cost item was identified by more than 5.4% of gamers. The relative interest in completing energy assessment suggests that gamers were interested in learning about new opportunities to save energy.

When the responses are considered relative to the total percentage of gamers who selected the options "implemented during or after" or "planning to complete," the top-ranked item, the action of replacing old incandescent bulbs with LED bulbs, was identified by 64.3% of gamers. Only one of the high-cost actions (the completion of the energy assessment) was identified by more than 14.3% of gamers.

Although the action-item responses were not tested for statistical significance, the analysis described above generally supports the conclusion that gamers were willing to invest in energy savings, though largely in the form of no-cost or low-cost actions. Responses to a post-game survey question about gamers' increased willingness to make energy-saving investments due to playing the efargo game were tested for statistical significance (Table 5.24), and they confirmed Hypothesis 3, i. e., that playing a serious pervasive game can engender willingness to invest in energy savings ($n = 56$; $p < 0.05$).

Table 5.24. Data Sources and Results, Willingness to Invest).

data source	Basis for Determination	Implications for Hypothesis 3

efargo game (2016)	Responses to a single question from the efargo post-game survey ($n = 56$; $p < 0.05$).	confirmed

5.7.4 Energy Savings

Based on the energy data for a small sample of gamers, Hypothesis 4, i. e., that playing a serious pervasive game can lead to energy savings, showed positive results. The energy use of the efargo gamers started to show small reductions during the game period (Mar 2016 - Apr 2016) and substantive savings were recorded in the post-game period from May 2016-December 2016: 10 of the 13 gamers achieved household energy savings averaging 12%. However, the results were not statistically significant, most likely due to the small sample size of gamers.

5.7.5 Fun, Meaning

In post-game surveys, the gamers perceived the efargo game is fun ($n = 55$, $p = 0.013$) and that playing the efargo game was meaningful to them ($n = 56$, $p < 0.01$). Both results were statistically significant. However, the correlation of these results to learning or behavior hypotheses was not statistically significant.

5.8 Conclusions

The results of the efargo game for all the hypotheses for learning and awareness, energy-saving behavior and investments, were positive with varying degrees of statistical significance. Gamers reported completion of several action items that required awareness of energy waste, learning about energy savings, and making behavior changes and investments leading to positive energy saving results that started during the game and increased after the game. Gamers also reported that they had fun with the game and that it was meaningful (flexible/suitable) for their needs.

6.0 Game Design: The K-12 Energy Challenge for Schools

Summary

This chapter discusses the design model, design process, structure, and timelines of a public pervasive game called the K-12 Energy Challenge that was tested in the City of Fargo Public Schools district as part of the efargo effort.

The K-12 Energy Challenge was a targeted pervasive energy game implemented in elementary schools and a middle school. Four implementations of the K-12 Energy Challenge were tested from 2016-2018. Each of the implementations asked participating schools to complete various educational and energy-saving activities over a 3-6 week period in their schools. The game design, game tools, reporting structures, and timeline were refined in response to feedback from teachers and students every year. The four implementations are outlined in this chapter.

6.1 Introduction

The K-12 Energy Challenge grew out of an opportunity to test Pervasive Energy Games as a way of bridging the energy efficiency gap (Hirst & Brown, 1990), through the venue of the nationwide Georgetown University Energy Prize (GUEP) competition.[1] The effort to research, design, test and implement a game targeted at the Fargo Public schools was aimed at the dual goals of achieving energy savings and fostering energy-saving behavior and learning. The K-12 Energy Challenge was first implemented in 2016 after a research and iterative design process that started in Fall 2015. The original K-12 Energy Challenge was followed by three more implementations, one in 2017 and two in 2018. Each implementation was developed as much as the resources allowed in response to feedback from teachers and administrators, ongoing discussion and critique of the design, information gleaned from the observation of the game play, and the outcomes of the surveys and interviews conducted with the game

1 See Chapter 3.

implementation.

6.2 The Game Environment: A Pervasive Game for K-12 Schools

Characteristic of a pervasive game, the K-12 Energy Challenge straddled the boundary between game and ordinary life: selected school buildings served as the targeted game environment. The schools offered a promising testbed, in part because Fargo schools collectively consumed over 30% of Fargo's electricity and more than 40% of its gas with respect to total municipal energy expenditures during the GUEP baseline years (Figure 6.1). Moreover, the opportunity to work with children in the K-12 public schools to test the potential of the games in terms of learning, behavior change and energy saving was part of the research design.

Figure 6.1: Baseline (per GUEP requirements) energy use share of K-12 schools

The concept was presented to educators and administrators to identify participant schools. The first implementation, K-12 Energy Challenge 1.0, from February 2016 – April 2016 involved four schools which actively participated in various formats. The second implementation, K-12 Energy Challenge 2.0, from February 2017 – May 2017 added two new schools alongside three schools as repeat participants. While the first two implementations of the K-12 Energy Challenge focused on an inter-school challenge, the next two implementations experimented with an inter-classroom challenge as well as an inter-school challenge. The last two implementations also experimented with shorter time durations. In addition, the third and fourth implementations focused on introducing the game at a single grade level. K-12 Energy Challenge 3.0 lasted three weeks from mid-April 2018 to early May 2018 and was played by fifth-graders. K-12

Energy Challenge 4.0 also experimented with playing the game in Fall (increasingly colder weather), and was implemented over four weeks from October 2018 to November 2018. This implementation was planned for fifth-graders but was actually implemented by fourth-graders. In all the implementations, specific classes were identified on the basis of teacher interest and the ease of curricular integration: participating teachers engaged efargo's goals within already-established curricula (Figure 6.2). By aligning with pedagogical goals, energy-saving behavior and learning could be pursued while partially fulfilling curriculum requirements.

NEXT GENERATION SCIENCE INTEGRATION

- included
- closely relates to overall

Kindergarten

K-PS2	Motion and Stability: Forces and Interactions
K-PS3	Energy
K-LS1	
K-ESS2	Earth's Systems
K-ESS3	Earth and Human Activity

1st Grade

1-PS4	Waves & Their Applications in Tech.
1-LS1	From Molecules to Organisms
1-LS3	Heredity: Inheritance & the Variation of Traits
1-ESS1	Earth's Place in the Universe

2nd Grade

2-PS1	Matter and its Interactions
2-LS2	Ecosystems: Interactions, Energy, & Dynamics
2-LS4	Biological Evolution: Unity and Diversity
2-ESS1	Earth's Place in the Universe
2-ESS2	Earth's Systems
K-2-ETS1	Engineering Design

3rd Grade

3-PS2	Motion and Stability: Forces and Interactions
3-LS1	From Molecules to Organisms
3-LS2	Ecosystems: Interactions, Energy & Dynamics
3-LS3	Heredity: Inheritance and Variation of Traits
3-LS4	Biological Evolution: Unity and Diversity
3-ESS2	Earth's Systems
3-ESS3	Earth and Human Activity

4th Grade

4-PS3	Energy
4-PS4	Waves & Their Applications in Tech.
4-LS1	From Molecules to Organisms
4-ESS1	Earth's Place in the Universe
4-ESS2	Earth's Systems
4-ESS3	Earth and Human Activity

Fifth Grade

5-PS1	Matter and its Interactions
5-PS2	Motion and Stability: Forces & Interactions
5-PS3	Energy
5-LS1	From Molecules to Organisms
5-LS2	Ecosystems: Interactions, Energy, & Dynamics
5-ESS1	Earth's Place in the Universe
5-ESS2	Earth's Systems
5-ESS3	Earth and Human Activity
3-5-ETS1	Engineering Design

Physical Sciences

MS-PS1	Matter and its Interactions
MS-PS2	Motion and Stability: Forces & Interactions
MS-PS3	Energy
MS-PS4	Waves & Their Applications in Tech.
HS-PS1	Matter and its Interactions
HS-PS2	Motion and Stability: Forces & Interactions
HS-PS3	Energy
HS-PS4	Waves & Their Applications in Tech.

Life Sciences

MS-LS1	From Molecules to Organisms
MS-LS2	Ecosystems: Interactions, Energy, & Dynamics
MS-LS3	Heredity: Inheritance and Variation of Traits
MS-LS4	Biological Evolution: Unity and Diversity
HS-LS1	From Molecules to Organisms
HS-LS2	Ecosystems: Interactions, Energy, & Dynamics
HS-LS3	Heredity: Inheritance and Variation of Traits
HS-LS4	Biological Evolution: Unity and Diversity

Earth & Space Sciences

MS-ESS1	Earth's Place in the Universe
MS-ESS2	Earth's Systems
MS-ESS3	Earth and Human Activity
HS-ESS1	Earth's Place in the Universe
HS-ESS2	Earth's Systems
HS-ESS3	Earth and Human Activity

Eng., Tech., & Applications of Science

MS-ETS1	Engineering Design
HS-ETS1	Engineering Design

Figure 6.2. Integration of curricular goals within K-12 Energy Challenge (After K-12 energy challenge toolkit, 2016, 32-33)

6.3 Game narrative

The game narrative was centered around the Waste-A-Watt character.[1] The narrative was

1 See Chapter 4.

provided to schools in the K-12 Energy Challenge Toolkit, a booklet containing guidance for gameplay (K-12 energy challenge toolkit, 2016). An excerpt from the K-12 Energy Challenge Toolkit reads:

> "Waste-A-Watt is a greedy super-villain who gains power from energy that is wasted. When energy is wasted throughout the city, Waste-a-Watt grows stronger. His goal is to make us waste more energy so he can become super-powerful and take over the city. Luckily, we have the ability to stop this madness! All we need to do is make sure that we are not wasting energy ... Efargo is inviting all schools to help defend the City of Fargo and surrounding community and defeat the evil Waste-a-Watt ... We have the power to make a big change!" (K-12 energy challenge toolkit, 2016, 14)

6.4 The gamers, AKA efargo heroines/heroes

With Waste-a-Watt as the villain representing energy waste, the gamers (K-12 students, teachers and staff) were responsible for his defeat. Student-led teams including teachers, administration, and facility managers, designated at least one project champion – either a teacher, a facility manager, or an administrator. The game participation diagram (Figure 6.3) suggested that the best outcomes would happen when students were supported by teachers (partnered with administrators to meet educational goals), administrators (partnered with facility managers to enable changes to building system controls, and possible system upgrades) and facilities managers (partnered with teachers to provide expert knowledge, feedback and assistance with technical functions and actions on the school building's operations and planning). The classroom was suggested as the place to organize K-12 Energy Challenge activities, but schools could decide whether the competition was better placed as a student-led, after-school club activity. In order to provide flexibility to teachers and administrators with respect to pedagogical goals, schools could organize participants by grade or by interest. The game also encouraged each school to designate a student champion for each team, space, or tasks in the school.

Figure 6.3 Model of The K-12 Energy Challenge as a student-led activity.

Participation was tracked by project champions along with the activities (game objects) that students completed.[1] Several schools optimally engaged community volunteers, e. g., architects, interior designers, engineers, parents, and facilities managers to engage and teach students about energy efficiency.

6.5 Game time and duration

Each of the four implementations was structured on a week-to-week schedule (Table 6.1).

Table 6.1. Weekly structure of four implementations of the K-12 Energy Challenge.[2]

	Pre-game / Baseline Week	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Post-game

1 See Chapter 7.

2 This structure is typical, although in the first two implementations, schools and classrooms participated in various ways, creating their own participation structures).

Energy Challenge 1.0 (Spring 2016)	Plan	Design & Pledge	"Energy-saving activities"	"Energy-saving activities"	"Energy-saving activities"	"Energy-saving activities"	"Energy-saving activities"	Celebrate
Energy Challenge 2.0 (Spring 2017)	Organize, Pre-game survey	Tag the Waste	Fix The Waste	Fix The Waste	Fix The Waste	Fix The Waste	Fix The Waste	Post-game survey, celebrate
Energy Challenge 3.0 (Spring 2018)	"Introduc-tion, pre-game survey"	Preparing & Learning / Tag is one of the activities	Energy saving activities	Energy Saving activities	N/A	N/A	N/A	Celebrate, Post-game survey
Energy Challenge 4.0 (Fall 2018)	"Introduc-tion, pre-game survey"	Kick-off week, Tag the waste	Lighting Week (Fix lighting waste)	"Devices Week (Fix Devices waste)"	Heating / Cooling Week (Fix HVAC waste)	N/A	N/A	Celebrate, Post-game survey

In the first two implementations (K-12 Energy Challenge 1.0 and K-12 Energy Challenge 2.0), in order to provide maximum flexibility, participating schools could join the game at any point prior to or during the game period. In Week 1 of K-12 Energy Challenge 1.0, gamers were asked to organize a pledge event. Over the next five-week period (weeks 2-6), gamers were asked to follow steps beginning with the implementation of energy-saving activities and the commencement of energy-use measurements. Schools were asked to promote actions and events through public service announcements (PSAs), to start Energy Patrols throughout the school, to commence a "power hour" where only natural lighting was used in the school if possible, to start daily shading controls, and to add and commence any activities suggested in the Toolkit. The final week of K-12 Energy Challenge 1.0 ended with a celebratory event coinciding with Earth Day events at the schools.

K-12 Energy Challenge 2.0 incorporated the events and activities from the previous implementation but organized the timeline into three phases: the pregame Organize phase, a week-long Find & Tag Waste phase, and a final Fix the Waste phase. The Organize phase included suggested activities such as "setting goals," "preparing and learning" (i. e., a pedagogical opportunity), and most importantly "creating an energy-saving plan." In the week-long Find & Tag Waste phase, schools designated as many spaces or rooms as possible to be part of the game space. Each of these spaces received one game tile, and within each space, student teams tagged all the points of potential energy waste using the game tiles and stickers.

The Find & Tag Waste phase repeated several of the kick-off activities from the K-12 Energy Challenge 1.0, such as designating a student champion, promoting events through school media, and producing an introductory film or demonstration videos. In the final phase (Fix the Waste), students recorded energy-saving actions on game tiles.

While the K-12 Energy Challenge 1.0 divided activities by age group, K-12 Energy Challenge 2.0 organized activities (by class) as daily or weekly goals or as general, anytime activities. Daily goals included school Energy Patrols (for lighting, and for unused plugged-in devices), announcements, and recording activities on the game tiles. Weekly goals included energy meter readings, announcements, a weekend unplug, a weekly black-out (i. e., power consumption was turned off unless needed), and finally, an emailed report of activities and participation was submitted weekly. The ongoing activities included surveys, quizzes, and other activities designed to boost understanding and awareness of building energy waste and use.

K-12 Challenge 3.0 and 4.0 started to experiment with shorter timelines (3 weeks and 4 weeks, respectively). In addition, the games were open for participation only until the beginning of the game. Once the game had started, schools were not allowed to join in the game. Aside from limited resources, this was in order to ensure that the pre- and post-game surveys were being answered by people who participated in the full duration of the game play. In the 3.0 and 4.0 implementations, the game timeline was clearly divided into phases such as planning week, kick-off week, tagging-the-waste week, and finally fixing-the-waste week. K-12 Energy Challenge 3.0 also focused on inter-classroom play rather than inter-school play in order to test the idea of having asynchronous deployment of the game, where schools and classrooms could decide when they wanted to play the game during the school year rather than having to adjust classroom schedules with other schools. The inter-classroom play forced the competition in the game to be about engagement and participation points rather than energy use reduction. Since schools had common meters, the energy saving contributions of any one classroom could not be separated from other classrooms in the same school. K-12 Challenge 4.0 went back to the inter-school competition structure, but incorporated other engagement and participation scorecard-focused documentation and other ideas from K-12 Challenge 3.0. Like the previous two implementations, the third and fourth Challenges ended with a celebration event where post-game surveys were conducted, in addition to awards and certificates.

6.6 Game tools: Four implementations, three years

The Battle of Buildings, an energy game implemented in the Burnsville, MN School District (Vasquez, n. d.) was the initial inspiration of the K-12 Energy Challenge for efargo. Other efforts such as the nationwide Campus Conservation Nationals (Vine & Jones, 2016, 166-169), the San Diego School Energy Conservation Competition (San Diego school energy conservation competition, 2016), the Washington, DC-based Sprint to Savings (Sussman & Chikumbo, 2016, 32, 47), the Green Cup Energy Challenge (Green cup challenge, n. d.), the California K-12 Kilowatt Challenge (2013), the U. S. Army's ECybermission (Ecybermission, 2019), and the Schools for Energy Efficiency (SEE) project (Changing behavior to save energy and money, 2008), were case studies prior to the design of the Challenge. These were also made available as resources for teachers, administrators and staff participating in the energy challenge (See page 42-45, Appendix 6.a).

6.6.1 First implementation (K-12 Energy Challenge 1.0)

The first implementation of the K-12 Energy Challenge, in Spring 2016, relied on three major game tools. The first was the Toolkit (Figure 6.4, Figure 6.5) Appendix 6.a), a booklet provided to participants in digital or printed form. Intended as a comprehensive guide, the Toolkit incorporated an energy use summary of Fargo public schools, a Waste-a-Watt narrative and graphics, relevant curriculum standards, two lists of "Top Ten" energy-saving activities (one for no-cost activities and the other for long-term strategies), a discussion of case study competitions, a timeline, and a list of resources such as workshops for adult volunteers and facilitators at the schools.

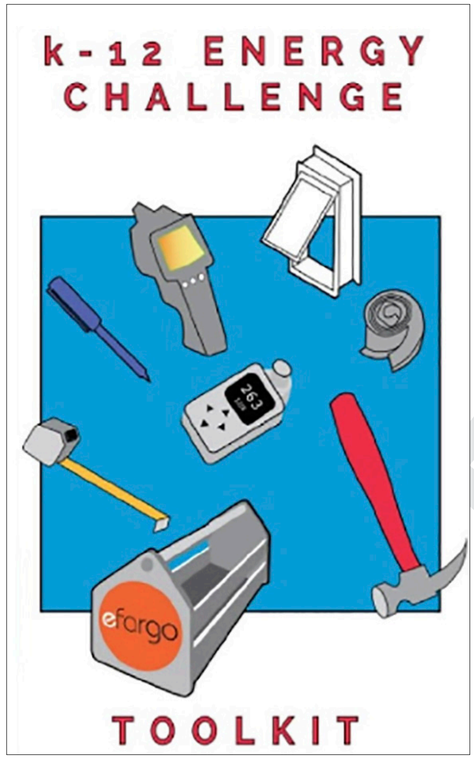


Figure 6.4 Fall 2016 K-12 Energy Challenge 1.0 Toolkit cover.

Figure 6.5 Fall 2016 K-12 Energy Challenge 1.0 Table of Contents.

The other two tools were offered in digital format only: an online dashboard (Figure 6.6) based on weekly meter readings, and a weekly emailed report (Figure 6.7, Appendix 6.b) based on reported activity and manual meter readings. Weekly reports summarized impact and informed participants on their performance compared to other schools in the previous weeks.

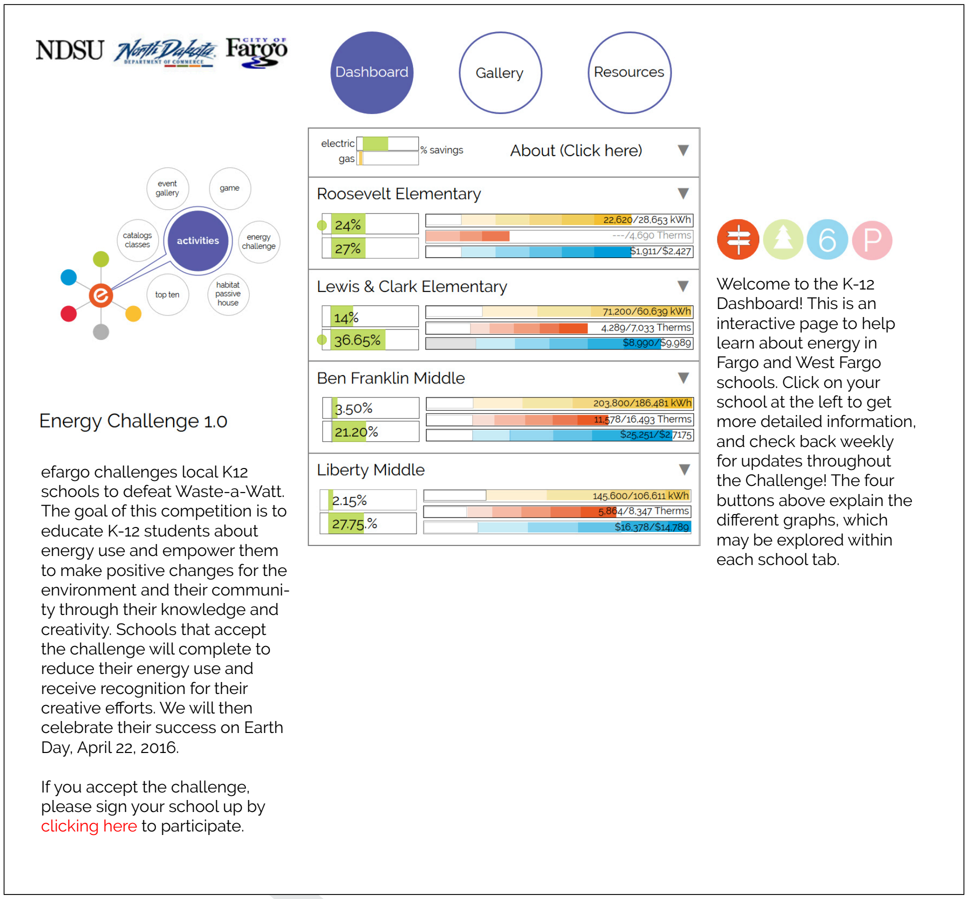


Figure 6.6 2016 K-12 Energy Challenge 1.0 online Dashboard (http://www.efargo.org/k12challenge.html) The weekly energy data reported at the time was not weather normalized using the Woodcock ENEROC Method.[1]

1 See Chapter 3.

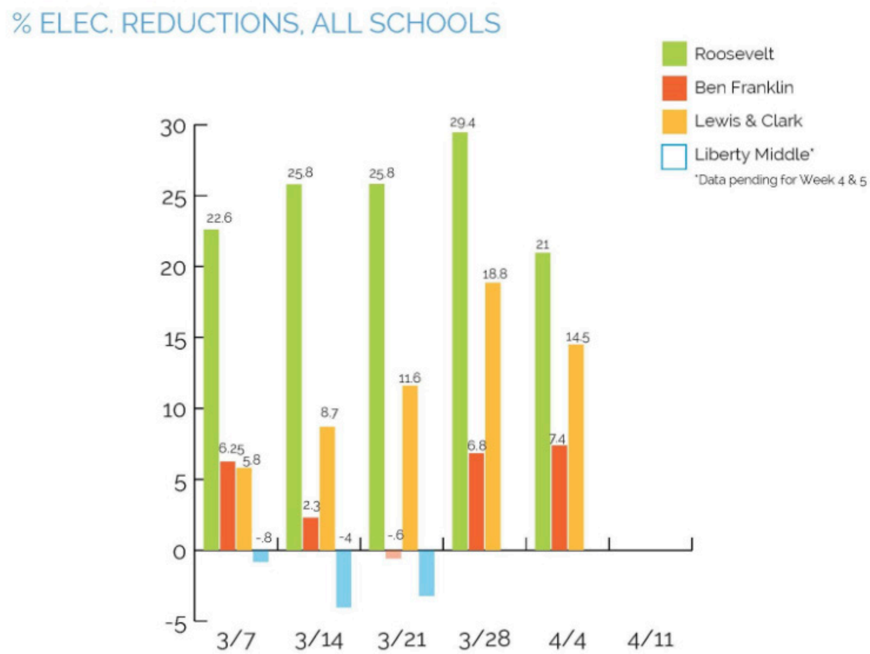


Figure 6.7. Fall 2016 K-12 Energy Challenge 1.0, Weekly report (sample page, for a complete weekly report, see Appendix 6.b). The weekly energy data reported at the time was not weather normalized using the Kissock Method.[1]

In terms of Harteveld's Triadic Game Design model (Harteveld, 2011)[2], the world of reality was addressed through the toolkit's extensive resources concerning real-life implications of energy use in schools. However, the game did not take advantage of the fact that the ordinary and actual space of the school buildings could directly become a representational structure for the game. K-12 Energy Challenge 1.0 was meaningful as it related students' actions to the energy use and energy savings in the school. It included game elements such as competition with other schools through the weekly reports and online dashboards but did not include play tools such as game boxes, devices or game boards.

6.6.2 Second implementation (K-12 Energy Challenge 2.0)

The second implementation of the K-12 Energy Challenge, in Spring 2017, introduced a game box containing game tools (Figure 6.8), including an energy meter, an energy-efficient light bulb, the K-12 Energy Challenge 2.0 Toolkit (efargo 2017, Appendix 6.c), a How to Play booklet (Figure 6.9, Appendix 6.d) explaining the schedule of the Challenge, instructions in a Timeline booklet

1 See Chapter 3.

2 see Chapter 4, Section 4.2

(Figure 6.10, Appendix 6.e), and game tiles (Figure 6.11, Appendix 6.f). A video introducing the game play was posted to the efargo website.[1] The game was presented using a video outlining the "Find and Tag the Waste" and "Fix the Waste" concepts.

Figure 6.8. Fall 2017 K-12 Energy Challenge 2.0 game box contents

1 http://www.efargo.org/k12challenge2-0.html

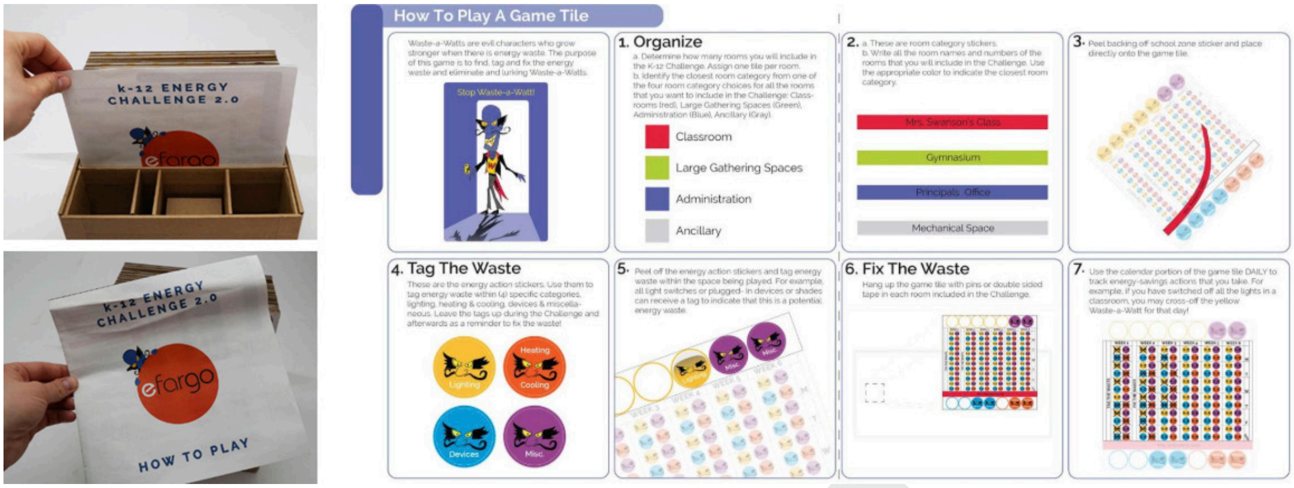


Figure 6.9 Fall 2017 K-12 Energy Challenge 2.0 How to Play booklet

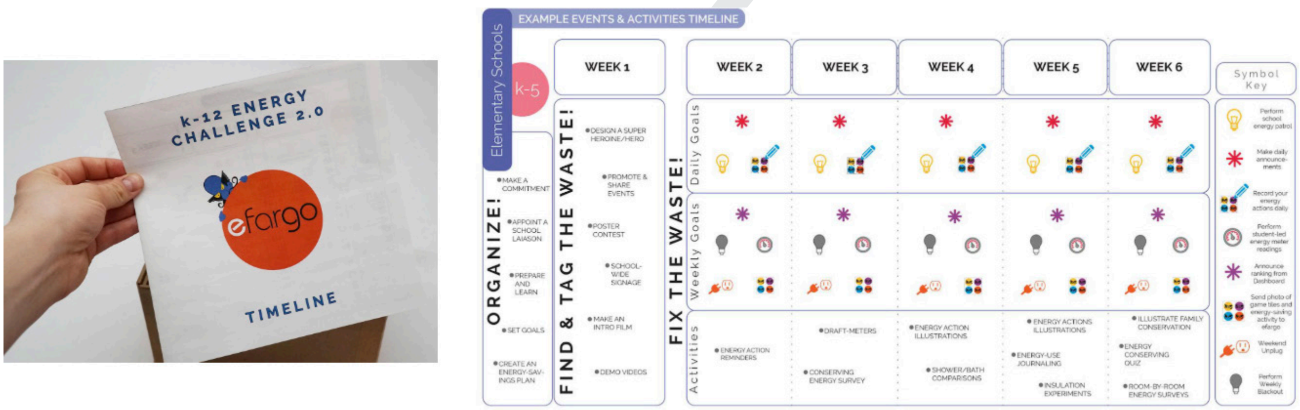


Figure 6.10 Fall 2017 K-12 Energy Challenge 2.0 Timeline (Appendix 6.e).

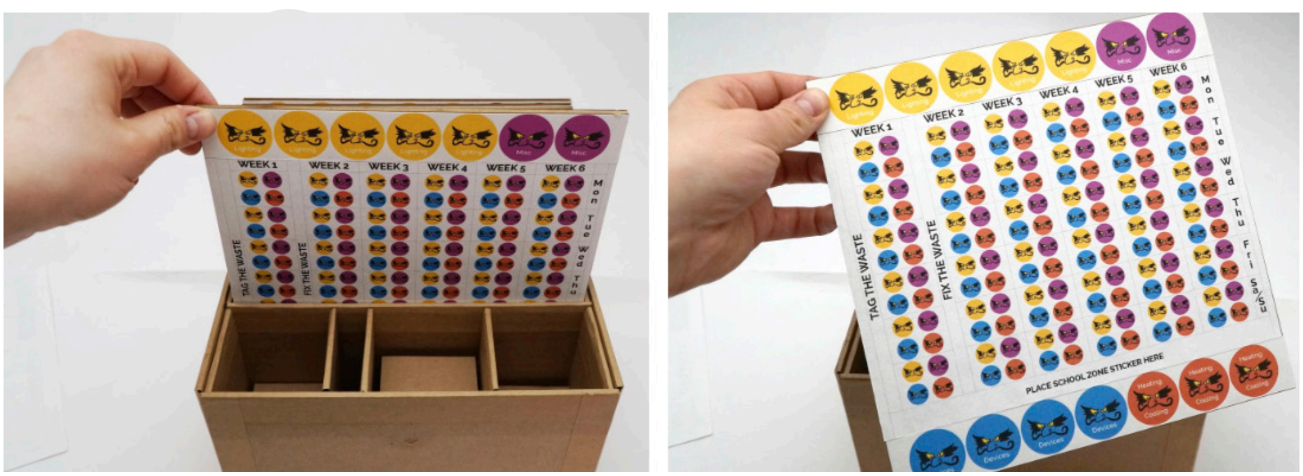


Figure 6.11 Fall 2017 K-12 Energy Challenge 2.0, game tiles

Game tiles contained the game objects, the Waste-a-Watt icons that were crossed off as a way to record energy-saving activity and to challenge gamers to achieve incremental energy savings. Each tile prompted gamers to use a color-coded sticker to place individual rooms in one of four categories (classrooms, large gathering spaces, administration, or ancillary). Gamers were encouraged to "Find and Tag the Waste" by placing additional color-coded stickers directly on energy-waste such as devices left plugged in when not in use (e. g., computers, slide projectors, smart boards) or other problems such as air infiltration around windows or inner vestibule doors left open. Yellow stickers were for lighting waste, blue for devices, red for heating and cooling (HVAC) and purple for miscellaneous, gamer-defined waste. Each tile had a calendar for gamers to record their tagging activities which acted as the game scorecard. Once tagged, the gamers were asked to engage in activities that caused energy savings in their school for which they could cross-off additional Waste-a-Watt icons. Finally, the game box included pins and double-sided tape to enable gamers to display a tile within each room.

The toolkit had several energy-saving activities and facts listed (Figure 6.12, Figure 6.13). However, the students, teachers and staff were free to devise their own activities per the needs of their schools and classrooms, making the game more flexible and thus meaningful to their particular reality.

TOP TEN **NO-COST** SCHOOL ENERGY-SAVING TIPS

Primarily focused on energy-awareness and energy-use planning, the strategies above describe simple ways energy can be saved without incurring additional operating costs or investments. The ten tips are listed along with the percentage of energy use they affect. For example, turning off unused lights affects electricity use, which for lighting averages 26 percent. These actions involve raising awareness and creating and following-up with an energy plan.

	ACTION	CURRENT USE
1	shading devices	34% gas 5% elec.
2	close openings	
3	special-use rooms	
4	clear vented areas	
5	HVAC settings	
6	sleep mode on	26% elec.
7	off for holidays	
8	turn off lights	26% elec.
9	use natural daylight	
10	reduce water-heater temp on wknds	8% gas 2% elec.

Figure 6.12 Fall 2017 K-12 Energy Challenge 2.0, energy-saving tips

TOP TEN NO-COST ENERGY SAVING TIPS

1. SHADING DEVICES	Use shading devices to help control heat loss and gain through building windows. Open blinds at the beginning of the school day to allow the sun to help heat the building. After the school day is over, close blinds to avoid heat loss through the windows. http://www.nrel.gov/tech_deployment/pdfs/commercial_building_checklists.pdf
2. CLOSE OPENINGS	Make sure that all windows and doors remain closed when the HVAC system is running. By allowing conditioned air to escape the building, energy and money are being lost. For some systems, this can also negatively impact the temperature of other spaces. http://www.coolcalifornia.org/article/save-energy-schools
3. SPECIAL USE ROOMS	Some spaces of school buildings are only used during specific hours of the day; such as the cafeteria, auditorium and gymnasium. Ensure that your HVAC system is programmed around this schedule so that it is not heating or cooling an unused space. http://www.ase.org/resources/energy-saving-tips-schools
4. CLEAR VENTED AREAS	Ensure that all airflow is left unblocked. Keep bulky furniture as well as personal items away from the vents so that spaces can be properly heated or cooled. http://www.ase.org/resources/energy-saving-tips-schools
5. HVAC SETTINGS	Have building maintenance personnel adjust HVAC temperature settings outside of regular school hours to save energy on space heating and cooling. The high percentage of energy used for heating and cooling can be greatly impacted by making this small change. http://www.eere.energy.gov/buildings/info/schools/index.html www.cacx.org/resources/documents/CA_Commissioning_Guide_Existing.pdf
6. DISCARD EXTRAS	If certain equipment or electronics are being under-utilized, perhaps it's time for them to go. It can be expensive and wasteful to power equipment even when in standby or off mode. For example, if there are certain areas of the building which have excessive lighting, it would be within your best interest to remove the unused bulbs. http://syroy/businessCustomers/saveEnergy/smallBusiness/noCostTips.html

Figure 6.13 Fall 2017 K-12 Energy Challenge 2.0, energy-saving tips

As in the first implementation of the Energy Challenge, the other two tools were offered in digital format only; an online dashboard (Figure 6.14) based on weekly meter readings, and a weekly emailed report (Appendix 6.g) based on reported activities and the weekly meter readings. Weekly reports, as in K-12 Energy Challenge 1.0, summarized impact and informed participants on their performance compared to other schools in the previous weeks.

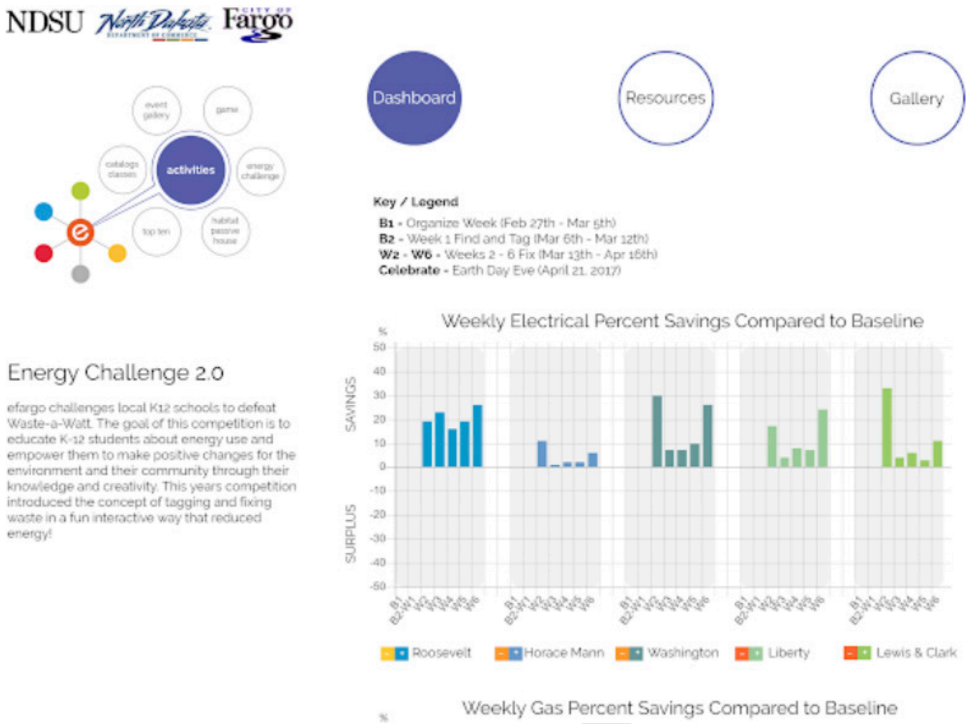


Figure 6.14 Fall 2017 K-12 Energy Challenge 2.0, online dashboard

The second implementation of the K-12 Energy Challenge focused on imparting educational and relevant information, while encouraging participants to reduce wasted energy in their schools, i. e., within the gaming environment. This implementation treated the physical space as an educational opportunity through the tagging of the waste, including the Reality of the game object, the school building, through the tagging or educational component of the game. The game tiles identified different kinds of waste (lighting devices, heating/cooling and miscellaneous), however, the scorecard (game tile) did not differentiate between different levels of activity or impact. For example, easy everyday activities had the same returns on the scorecard as harder, multi-person activities. While it allowed flexibility for the students and their teachers deciding what the game activities should be allowing it to be meaningful within their limitations and reality, it did not create challenge, hierarchy, that would make the game objects more aligned with the Play world of the Triadic game model. Also, the entire duration of the Challenge was captured in one game tile, based on a weekly cycle and did not have a way to include or capture all the activities the students might engage in , for example, daily recurring activities.

6.6.3 Third implementation (K-12 Energy Challenge 3.0)

The third implementation of the K-12 Energy Challenge, in Spring 2018, maintained some components of K-12 Energy Challenge 1.0, such as the toolkit, and also of K-12 Energy Challenge 2.0, such as the game tiles or scorecards. Some of these were improved in order to incorporate play elements in addition to the educational pieces. The major game tools were the game box (Figure 6.15), online dashboard (Figure 6.16) and the weekly reports (Appendix 6.j) similar to the first two implementations of the Energy Challenge. However, the game box design was transformed to contain several game tools within it and also act as the armature to hang the game tiles (Figure 6.17, Appendix 6.k). This armature also contained the instructions to play, making them continuously visible during the game play. The game box contained booklets in parts (Figure 6.18). The toolkit book contained in the game box was created in two parts, one for students and one for teachers (Figure 6.19, Appendices 5.h, 5.i), including more detail about the advanced play activities in the teacher book, making the student book easier to access and playful.

Figure 6.15 Spring 2018 K-12 Energy Challenge 3.0, game box

Figure 6.16. Spring 2018 K-12 Energy Challenge 3.0, online dashboard (Accessed on 7/23/2019, http://www.efargo.org/energy-challenge-3.0.html)

Figure 6.17 Fall 2018 2017 K-12 Energy Challenge 3.0, game tiles, armature, scorecard (Appendix 6.k)

Figure 6.18. Spring 2018 K-12 Energy Challenge 3.0, Toolkit booklet covers

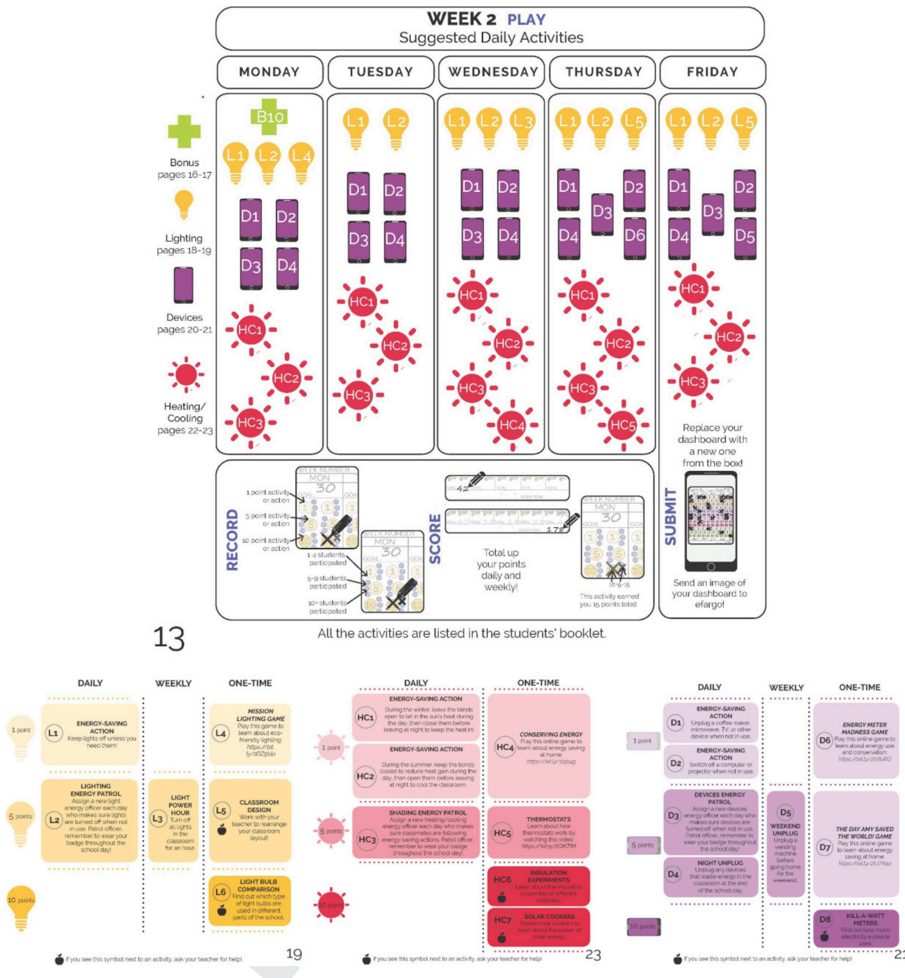


Figure 6.19. Spring 2018 K-12 Energy Challenge 3.0, Toolkit points related to difficulty level of activity multiplied by the participation (Appendices, 5.h, 5.i)

Several different types of stickers were included in the game box with different backing materials like, velcro, sticky-back and magnets. This was done to address the teacherrs' occasional reluctance in K-12 Energy Challenge 2.0 to use the stickers to avoid damage to painted surfaces. Larger cling film decals were also included for smooth surfaces like glass and mirrors. Like previous years these were used for tagging the waste and had categories such as yellow for lighting, purple for devices and red for HVAC (heating and cooling). An Energy Patrol activity was emphasized by including buttons for the students to wear (making the gamers visibly part of the game). The “Find, Tag and Fix” concepts were continued in K-12 Energy Challenge 3.0 but were not as overtly tied to the points earned in the game. The points related to the educational activities in the Toolkit booklets were earned based on the difficulty level of the activity and how many people participated in the activity. This hierarchical points system was meant to reward gamers for levels of difficulty of the activities completed and also encourage participation in greater numbers, creating more challenge as play elements.

In addition to the hierarchy in the game structure, a shorter game period and an inter-classroom was introduced, again adding more play elements to strengthen the Play world of the Triadic Game Design model. Three new educational tools were added to the game box. The first new tool was a deck of energy cards including tips about energy waste, efficiency and savings (Figure 6.20). The second new tool was a set of Virtual Reality goggles in the game box allowing students to use a VR file (Figure 6.21) to learn about potential energy waste in their classrooms and schools and recognize them in their classrooms. The third new tool was a one-page game that students could take home to learn about their energy waste and potential for energy savings with their family (Figure 6.22). This game, developed by efargo Fellow Dylan Neururer, compared the student’s estimated home energy use to a national median.

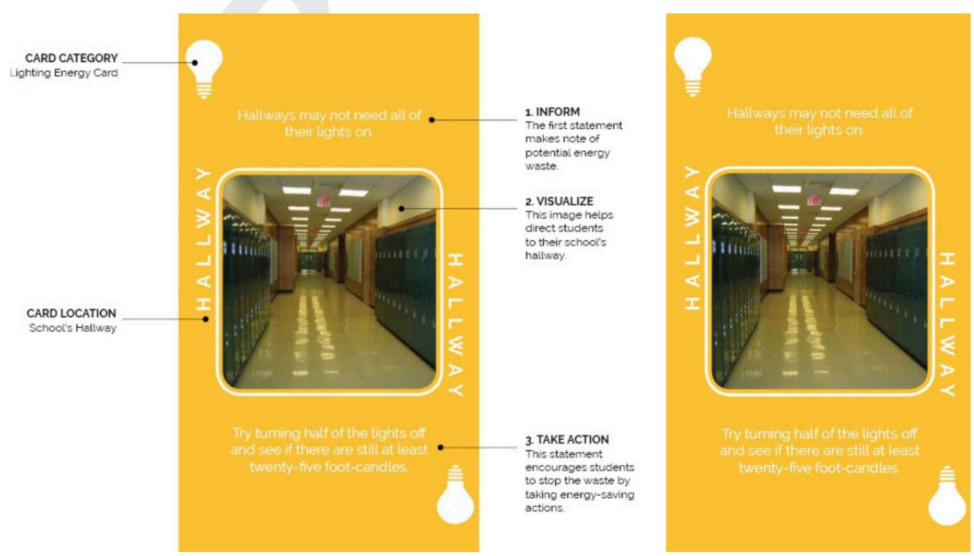


Figure 6.20. Spring 2018 K-12 Energy Challenge 3.0, sample of Energy Cards

Figure 6.21. Spring 2018 K-12 Energy Challenge 3.0, sample of VR file images.

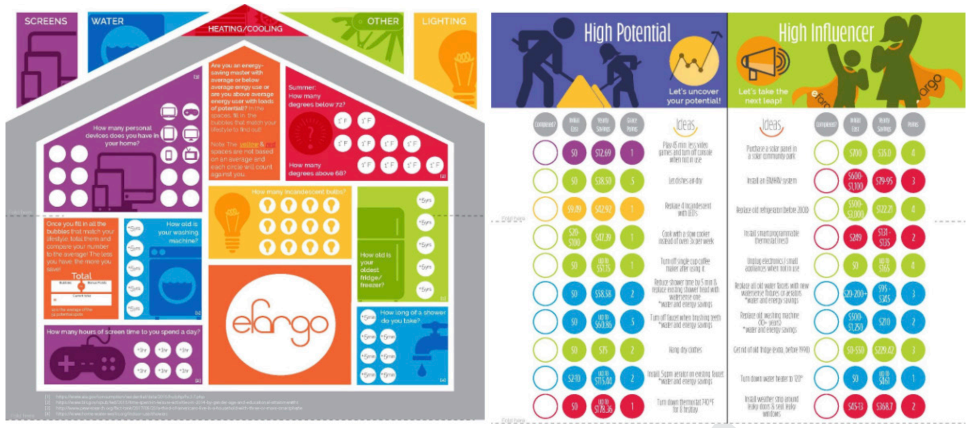


Figure 6.22. Spring 2018 K-12 Energy Challenge 3.0, home energy game.

K-12 Energy Challenge 3.0 incorporated several play elements such as the inter-classroom competition and useful expansions in the game such as the home game, in order to make it flexible and meaningful to teachers and classrooms with various needs. It also included multiple modalities to address variable interests or learning habits for the students, such as providing an educational component which taught the students about common energy waste in school buildings through Virtual Reality file and glasses, physical cards and website-based graphics. The same information was repeated in the three modalities. However, the pervasiveness of the waste tags and the actions to cause energy savings still remained separated in the game. While the tagging of the waste worked well by pervading the building space and allowing students to enjoy the physical activity of play by tagging the building, the energy saving actions were not related to the tags.[1] Those actions were still accessed through the toolkit from lists of potential actions and translated to the scorecard on the game tile when completed. The next implementation of the Energy Challenge addressed problems that arose in the third implementation (made the scorecard and point recording calculations less confusing and improved the overall readability of the graphics) and experimented with a new timeline (implemented in the Fall rather than Spring). However, it did not adequately address the disconnect between the tagging and fixing activities in terms of pervasive gaming and tying the reality, meaning and play worlds together closely in the game space. While the tags existed in the school building, the energy-saving activities were directed by the lists in the toolkits rather

1 See Chapter 7 for a full description of results, including activity points.

than directly related to the tags. As a result, while the tags were educational and served as reminders of the game throughout the game implementation, they were not meaningfully tied to the energy-saving activities. In other words, the tags pervaded the space initially, but then were not part of the "capturing and fixing" that allowed the students to achieve the energy-saving goals.

6.6.4 Fourth implementation (K-12 Energy Challenge 4.0)

The fourth implementation of the K-12 Energy Challenge, in Fall 2018, maintained several components of the first three implementations, such as the game box with all its component game tools (Figure 6.23), the toolkit booklets (now called guides for students and teachers) (Figure 6.24, Appendix 6.l, 5.m), and the game tiles located on the back of the game box cover (Figure 6.25, Figure 6.26). The main changes in K-12 Energy Challenge 4.0 were focused on simplifying and improving the score-keeping system and its alignment with the game activities. In addition, the game was tried in a period of cooling temperatures rather than in Spring, as were the first three implementations. Several of the game tools were iterated in order make them graphically more clear and appealing. For example, the weekly activities were now thematically arranged (Figure 6.27). Since the teachers felt that the timeline for the K-12 Energy Challenge 3.0 was too short, the duration was increased by a week. Week 1 was the kick-off for developing Daily Habits that recurred throughout the game period (and hopefully beyond), week 2 was lighting, week 3 was devices and week 4 was heating and cooling. When it was learned late in the planning process that the game confined to 5th graders was actually going to be used by 4th graders, they quickly included a light meter in the game kit, in order to provide a device that would be easier to read and understand as opposed to the energy-use meters.

Figure 6.23 Fall 2018 K-12 Energy Challenge 4.0, Game box;
1. Waste-a-Watt stickers; 2. Energy cards (heating/cooling, devices, lighting, home energy cards; 3. How to play instructions (part of the game box cover); 4. Weekly scorecard armature; 5. LED light bulb; 6. Electricity meter; 7. VR Goggles; 8. Home Energy game; 9. Student guide (toolkit in previous implementations); 10. Energy Patrol buttons; 11. Velcros/hangers; 12. Light meter; 13. Weekly scorecards (Appendix 6.n); 14. Teacher guide (toolkit in previous implementations)

Figure 6.24. Fall 2018 K-12 Energy Challenge 4.0, Student and teacher guides (previously toolkits)

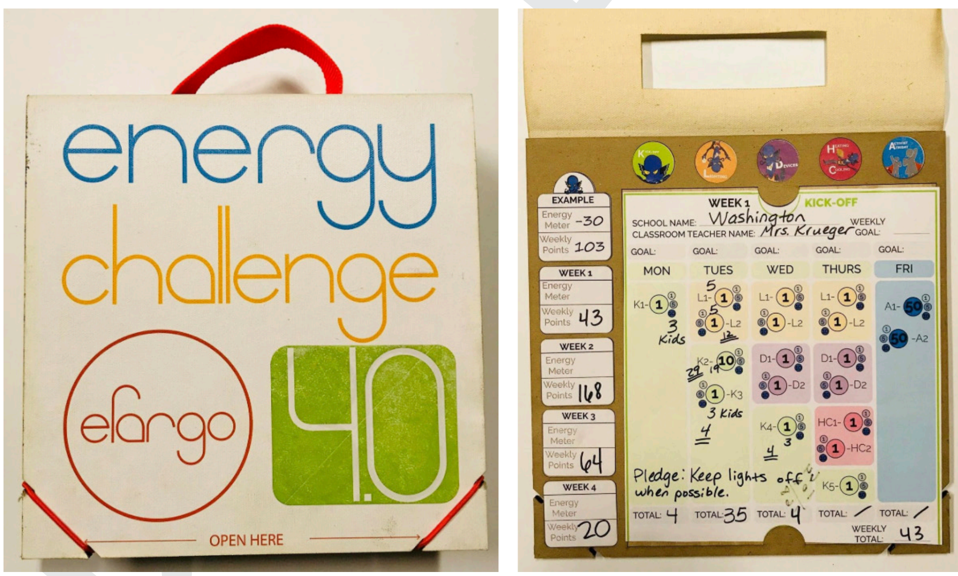


Figure 6.25. Fall 2018 K-12 Energy Challenge 4.0, Game box, tiles or scorecards (Appendix 6.n)

Figure 6.26. Fall 2018 K-12 Energy Challenge 4.0, Game tiles or scorecards (Appendix 6.n)

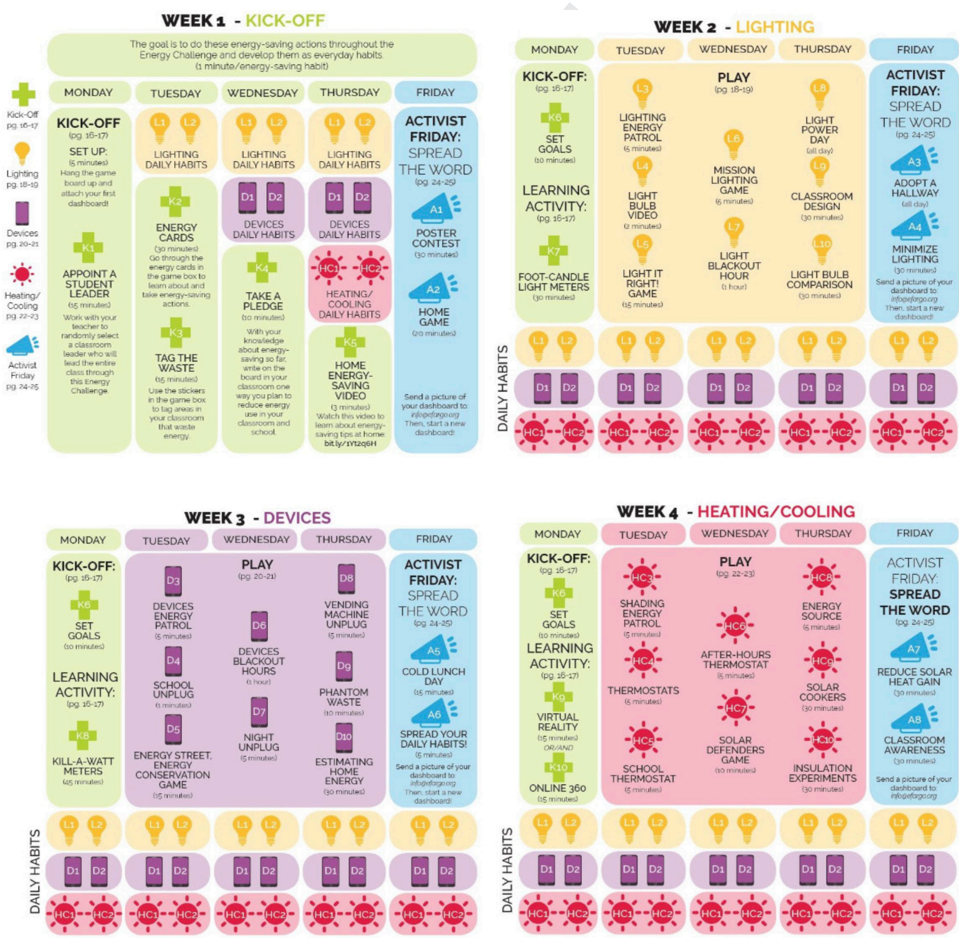


Figure 6.27. Fall 2018 K-12 Energy Challenge 4.0, Weekly themes

Like previous implementations, K-12 Energy Challenge 4.0 included a weekly report (Figure

6.28, Appendix 6.p) to the schools and classrooms that had comparisons of game activity points earned. Energy Challenge 4.0 included an activity called activist Friday, which was specifically about communicating about the concepts learned in the game beyond the playing group of students. These points were reported separately in the weekly report. Lastly, energy savings and use calculations compared to a baseline were reported to the schools as well. If there were any events or activities that put an energy use burden on the schools which was greater than what normal activities would entail, these were explained in the weekly reports. Unlike previous years, which included a dashboard designed specifically for the efargo website, in K-12 Energy Challenge 4.0, the weekly reports were uploaded as pdf links to the website (Figure 6.29). Therefore the online dashboard was a replication of the weekly email-based report and accessed through buttons on the website like the other tools such as the toolkits or guides, online and VR files tagging files and photo galleries.

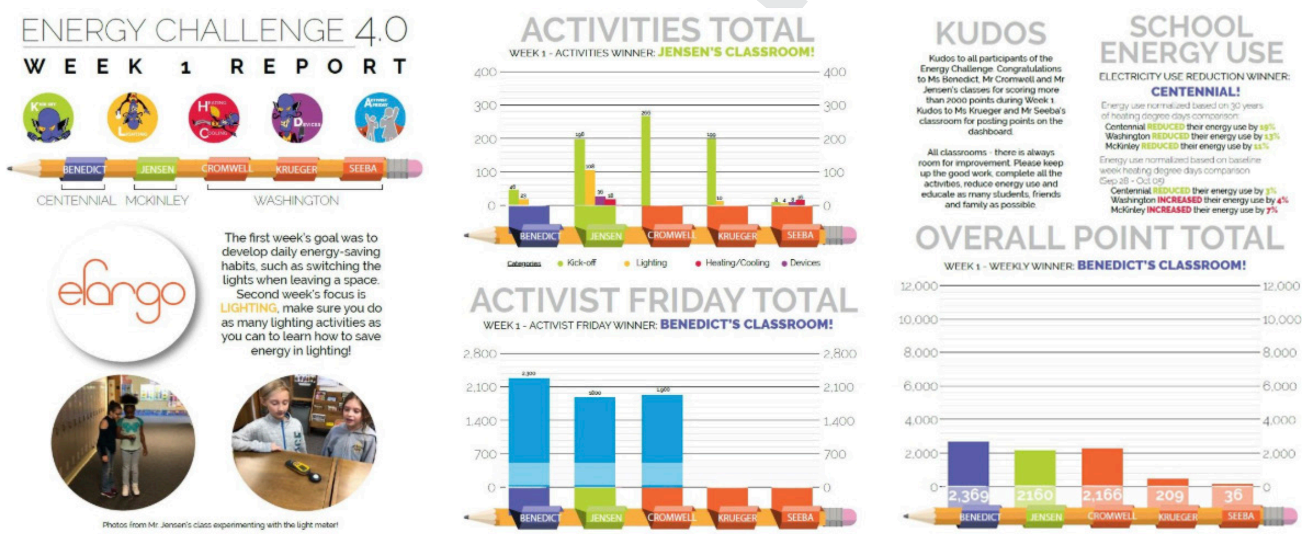


Figure 6.28. Fall 2018 K-12 Energy Challenge 4.0, Weekly reports

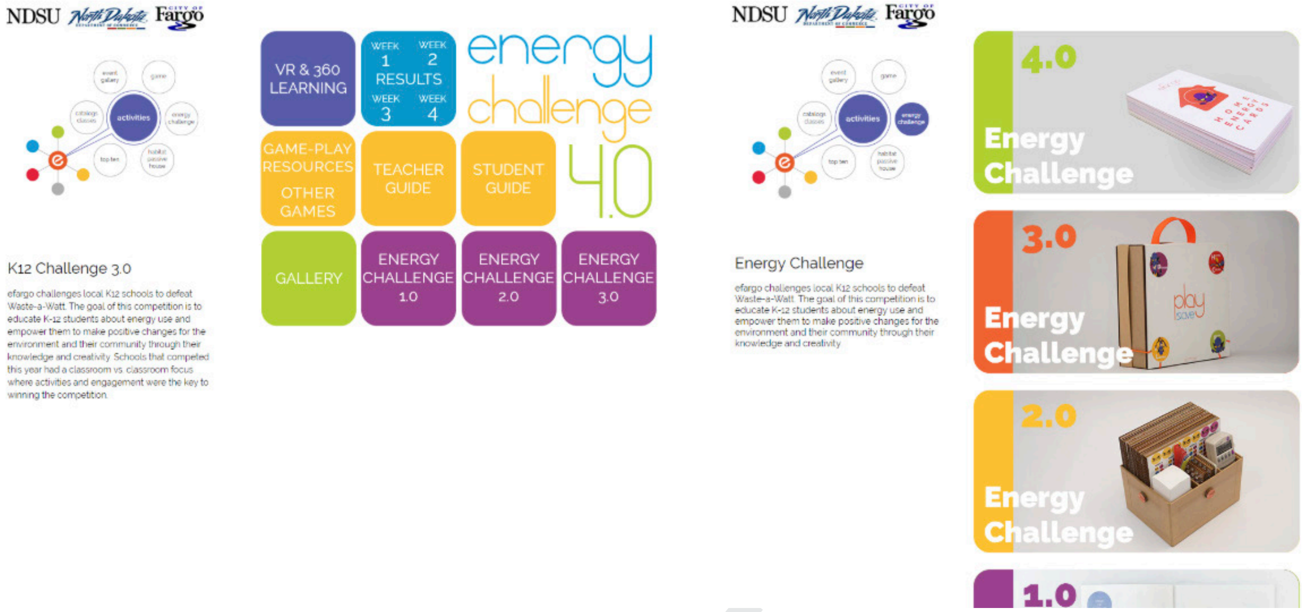


Figure 6.29. Fall 2018 K-12 Energy Challenge 4.0, Online game dashboard

6.7 The game objects

Game objects (Poplin, 2012) are physical objects such as buildings, and also stakeholders and events. This dissertation extends that definition to any activity that has a material (physical or digital) representation in the game or on which there is a material impact of the game. For example the game tiles which acted as the scorecards are the objects of the K-12 Energy Challenges, where all engagement, participation and activity was recorded. The school buildings, occupants and community impacted by the actions of the gamers, are also game objects. ultimately, the city and community that is impacted by reduced emissions would be game objects. Physical space became the subject of energy-saving actions and events because it contains game activities; it served as a pedagogical tool because it taught students how and most importantly, where energy waste was happening. The stakeholders were the participating schools and their students and staff; the events and activities were organized and completed by participating schools. Although events and activities were suggested to schools, the students and designated champions and teams were asked to plan and design their own activity packages. The schools were asked to report via email on activities undertaken during the week. These activities were then packaged and sent back to all the schools in weekly reports to create a comparison and competition. Spaces, occupants, game tiles, events, activities, and exercises as game objects served two simultaneous functions: they enabled K-12 students to learn about energy efficiency, and they made it possible for students to act upon and with mixed success create support systems for their ideas and efforts from the teaching, administrative and facilities staff groups. These collaborations, when they worked, empowered students to lead, initiate, and develop creative concepts and also follow the suggestions in the Toolkit to save energy in their schools while working to defeat Waste-a-Watt.

6.8 The game rules

In K-12 Energy Challenge 1.0, two game rules were common to all schools: the efargo research assistants conducted weekly meter readings in cooperation with facilities personnel, and each school submitted the weekly activities report. The game's overall structure afforded flexibility, as schools could innovate within the overall schedule, optionally incorporating activities suggested in the toolkit. The K-12 Energy Challenge 2.0 incorporated additional rules. Prior to the game start, participating schools were asked to organize in teams, appoint liaisons, set goals for energy-use reduction, and create energy-saving plans. In the week-long Organize phase, teams found energy waste in their schools and tagged it using stickers from game tiles. One game tile was placed in each room included in the Challenge as an action or subject space where improvements could be made and goals achieved. The tiles became the method by which student teams could track progress by crossing off the appropriate Waste-a-Watt on the game tiles from Week 2-Week 6. The rules were incorporated into a "How to Play" booklet included in the game box (Figure 6.30), and an introductory video explained the rules to the gamers. The main rule that distinguished the third and fourth implementations from the first two, was that the game play was confined to just one grade level in various schools. During K-12 Energy Challenge 3.0, fifth-grade classrooms from various schools participated. In addition, the number of classrooms was kept limited and controlled to ensure that any students that played the game also answered the pre- and post-game surveys with the limited resources that efargo had. K-12 Energy Challenge 4.0 was also designed for fifth graders but was switched to fourth graders by the schools' request. Once again, all the participating classrooms were fourth grade level and the game was only open to those who could participate in it from the game start. All other rules such as game kick-off, tag-the-waste week, fix-the-waste week were incorporated into the game toolkits or guides. For the third and fourth implementations, these toolkits or guides were separated for students and teachers. Therefore game activities that had a greater level of complexity were detailed in the teacher guides while the student guides were kept simple.

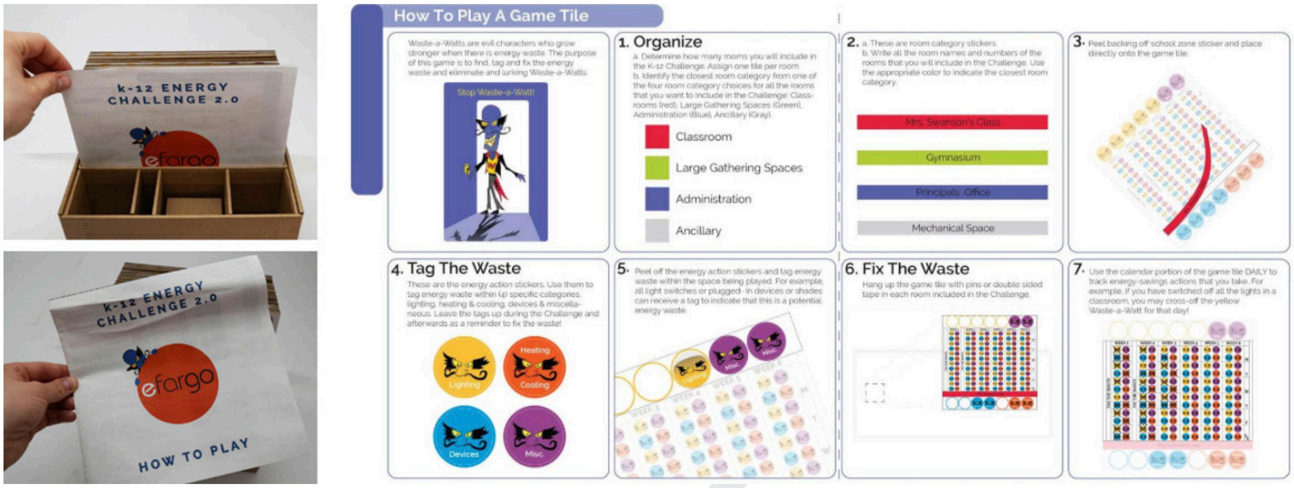


Figure 6.30. The K-12 Energy Challenge 2.0 "How To Play" booklet.

6.9 The game (& gamer) goals

The K-12 Energy Challenge established game goals (Poplin, 2012) dedicated simultaneously to real-life solutions and the need to educate gamers in the consequences of their actions. The first of efargo's goals was to overcome the informational and behavioral challenges responsible for the energy efficiency gap (Hirst & Brown, 1990). To achieve this goal, game designers worked to heighten awareness within the K-12 community about building energy use and impacts. Second, the K-12 Energy Challenge sought to empower students to create and sustain change to their own environments through everyday practices. Third, the K-12 Energy Challenge served as a data-collection method for research on the effectiveness of Pervasive Energy Games as learning and energy-use reduction tools. Finally, the K-12 Energy Challenge sought to reduce energy use in schools, in turn reducing schools' environmental impact and helping Fargo become a more energy-efficient community. This goal was contextualized by the GUEP competition.

FOr the students, the game included two goals. First, gamers learned how energy is consumed by occupants and by buildings; second, they learned that they had agency and knowledge to make changes in buildings and in their own behavior to reduce energy waste and use. For the gamers who were teachers and administrators, the curricular and educational goals of the environmental science unit and some social science unit needed to be met. Irrespective of gamers' motivations, reduction in energy use was the measurable criterion to determine the winner. The Facilities Director hoped for energy use reduction through the game. The prizes for the winner included a tree planted on their school grounds or a thermographic camera. Students who served with consistency and dedication were given certificates as "efargo energy heroes." Each participating student was also given a sapling to take home to plant, reinforcing the message that any learning would be transmitted to the home.

Acknowledgements

While the errors and omissions are mine, it would have been impossible to complete this work without the contributions made by Troy Raisanen, Ian Schimke, Dylan Neururer, Mike Christenson, Peter Atwood, Samantha Marihart, Ryan Gapp and Sarah Watson. Efargo work described in this paper was funded by the North Dakota Department of Commerce and the City of Fargo.

7.0 K-12 Energy Challenge game results

Summary

This chapter examines the K-12 Energy Challenge, a serious pervasive energy game open to voluntary participation by schools in the Fargo Public School District from 2016-2018.[1]

This game design was implemented four times over a period of three years. These implementations examined whether playing an open serious pervasive energy game such as the K-12 Energy Challenge can lead to Learning and Awareness about energy savings; can engender a willingness to engage in energy-saving behavior; and can result in energy-savings; based on the data collection prior to, during, and after the game implementation.

(a) Playing the K-12 Energy Challenge, an open serious pervasive energy game, resulted in weather-normalized energy savings. Savings ranged from 16.23% to 6.51% for the four times that the K-12 Energy Challenge was implemented (Table 7.1).

Table 7.1. Data Sources and Results, Energy Savings

data source	Basis for Determination	Changes in Energy Use	Implications for Hypothesis 4
K-12 Energy Challenge 1.0	normalized K-12 schools energy-use data (Spring 2016)	All fully and partially participating schools performed better than the control school, with the best-performing school achieving 9.05% decrease in energy use in the competition period	positive support*
K-12 Energy Challenge 2.0	normalized K-12 schools energy-use data (Spring 2017)	All fully and partially participating schools performed better than the control school, with the best-performing school achieving 16.23% decrease in energy use in the competition period	positive support*
K-12 Energy Challenge 3.0	normalized K-12 schools energy-use data (Spring 2018)	The best-performing school achieved a 6.51% decrease in energy use in the competition	positive support*

1 See Chapter 6.

K-12 Energy Challenge 4.0	normalized K-12 schools energy-use data (Fall 2018)	All fully and partially participating schools performed better than the control school, with the best-performing school achieving 15.75% decrease in energy use in the competition period	positive support*

* These results were not tested for statistical significance.

(b) Playing the K-12 Energy Challenge, an open serious pervasive energy game, resulted in Learning and Awareness about energy waste and savings. This was positively supported through surveys that examined perception of Learning and Awareness, dissemination of knowledge and quiz questions with factual answers (Table 7.2). Both teachers and students were surveyed at various times. In addition this result was supported with engagement in various educational activities that the participating schools conducted. In addition, teachers and staff reported participation in several educational activities during the game play.

Table 7.2. Data Sources and Results, Learning and Awareness.

data source	Basis for Determination	Status of Hypothesis 1
K-12 Challenge 1.0 (2016)	Responses to five questions on post-game surveys completed by teachers, measuring the teachers' own experience ($n = 14$; $p < 0.01$)	confirmed
	Responses to six questions on post-game surveys completed by teachers, measuring the teachers' perception of student experience ($n = 14$; $p < 0.01$)	confirmed
K-12 Challenge 2.0 (2017)	Responses to seven paired questions on pre-game surveys ($n=135$) and post-game surveys ($n=125$) completed by students at L. Middle School ($p < 0.05$)	confirmed
	Responses to a single paired question on pre-game surveys ($n=138$) and post-game surveys ($n=128$) completed by students at L. Middle School ($p < 0.05$)	confirmed
	Responses to two questions concerning dissemination and spatial expansion from post-game surveys completed by students at L. Middle School ($n = 97$; $p < 0.05$)	confirmed
K-12 Challenge 3.0 (2018 Spring)	Responses to five paired questions on pre-game surveys and post-game surveys completed by students at L. F. Elementary School and W. Elementary School (F classroom) ($n = 134$; $p = 0.010$)	confirmed

	Responses to eight questions on post-game surveys completed by students at L. F. Elementary School and W. Elementary School (n = 133; $p < 0.01$)	confirmed
	Responses to two questions concerning dissemination from post-game surveys completed by students at L. F. Elementary School and W. Elementary School (F classroom) (n = 129; $p < 0.01$)	confirmed
K-12 Challenge 4.0 (2018 Fall)	Responses to five paired questions on pre-game surveys and post-game surveys completed by students at C. Elementary School, M. Elementary School, and W. Elementary Schools (n = 93; $p = 0.02$)	confirmed

(c) Playing the K-12 Energy Challenge, an open serious pervasive energy game, resulted in the students, teachers and in some schools staff engagement in energy-saving behaviors and activities, including repetitive energy-saving actions practiced by entire groups or classrooms of students. An inspection of the descriptive statistics from pre- and post-game surveys that examined the perception of willingness to engage in energy-saving behavior showed that the mean response and median response increased in the post-test responses, these responses were not statistically significant. In addition, teachers and staff reported engagement in various activities that required either repetitive or one-time engagement in energy saving behaviors during the game play.

7.1 Data collection

In order to test the impact of the K-12 Energy Challenge on energy savings (Hypothesis 4), direct meter readings were conducted prior to and during the game implementation period, if permissions were available from schools. Data sources are highlighted in Table 7.3.

Table 7.3. Year-by-year collection of energy-use data
(boldface check marks indicate year game was played) fdskj fdsjkfkdsjkfdsjk

intervention	weekly meter readings from game site for duration of game only		
	2016	2017	2018
K-12 Energy Challenge 1.0	✓		
K-12 Energy Challenge 2.0		✓	
K-12 Energy Challenge 3.0			✓

K-12 Energy Challenge 4.0			✓

Prior to and during the K-12 Challenge game implementations, for the participating Fargo-area schools, data collection for gas and electricity usage was attempted on a weekly basis. This made it possible to provide weekly reports to the schools of meter readings and energy usage throughout game play. Prior to game play, the weekly meter readings were collected for one or two baseline weeks. Weekly readings continued during game implementation. Because the participating schools lacked smart meters, manual weekly meter readings were conducted, presenting several challenges. These challenges included the need for training (for facilities staff and efargo research assistants) as well as inaccuracies in recording, transcription, understanding, and interpretation. Consequently, it was necessary to train efargo researchers to understand meter equipment. In addition, facilities staff were not consistently available to allow access to the readers, presenting a challenge especially for gas meters (due to their secure locations). Despite these barriers, weekly meter readings were completed for electricity and reported to the schools over the game period. For the following analyses, weekly energy use was normalized using Woodcock's method (Woodcock, 2015).[1]

7.2 K-12 Energy Challenge 1.0 (Spring 2016), saves energy

The K-12 Energy Challenge 1.0 included a timeline, a goal of reducing energy use, and several suggested educational activities structured around the timeline.[2] Beyond the suggested activities, participating schools were free to engage in any energy-saving activities that they deemed interesting and relevant.

Four Fargo schools participated in K-12 Energy Challenge 1.0 (R. Elementary School, L. C. Elementary School, J. Elementary School, and L. Middle School).[3] Over the time period of the game, the four participating schools were measured against a control school, B. F. Middle

1 See Chapter 3 for a description of the method.

2 See Chapter 5 for a discussion of the K-12 Energy Challenge.

3 School names are anonymized throughout the chapter.

School. Emulating the GUEP model, a baseline time period of energy use was established immediately prior to the game implementation.[1] Each school's performance was compared to its own baseline using the percentage of change (decreases or increases in energy use) as the basis for comparison. During the K-12 Energy Challenge 1.0 study period, the control school's normalized energy use (NEU) increased by 15.7%, representing an increase in energy use. By comparison, the four participating schools increased their NEU by an average of 3.52%. As summarized in Table 7.4, R. Elementary School's NEU decreased by 9.05%, while the remaining three schools increased their NEU: L. C. Elementary School by 3.13%; J. Elementary School by 9.41%; and L. Middle School by 10.6%.

Table 7.4. Analysis of weekly meter readings (weather normalized using Woodcock's method) from schools participating in K-12 Energy Challenge 1.0.[2]

dates	period	R. Elementary School	L. C. Elementary School	J. Elementary School	L. Middle School	B. F. Middle School (control)	units[3]
Feb 22 - Feb 28, 2016	Baseline Week	21.29	59.227	51.85	106.44	151.07	kWh/ HDD + CDD
Feb 29 - Apr 10, 2016	Competition period Week 1 - 6	19.36	61.08	56.72	117.72	174.79	kWh/ HDD + CDD
increase or decrease		decrease of 9.05%	increase of 3.13%	increase of 9.41%	increase of 10.60%	increase of 15.7%	

All fully and partially participating schools performed better than the control school (Figure 7.1).

1 The GUEP model is described in Chapter xxxx.

2 See Appendix x.xxx for a more detailed data analysis.

3 "Kilowatt-hours per (Heating Degree Days plus Cooling Degree Days)."

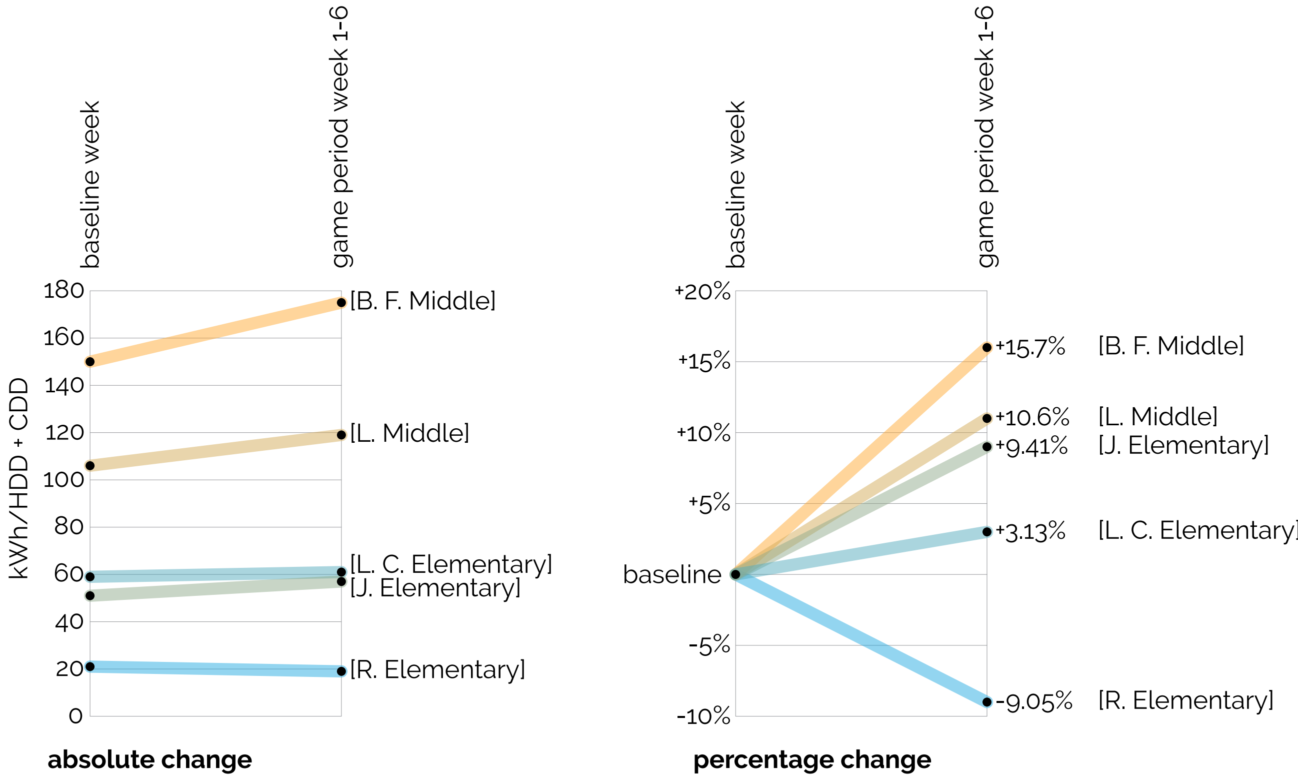


Figure 7.1. Absolute and percentage change in normalized energy use (NEU), compared to baseline week, for schools participating in K-12 Energy Challenge 1.0.

7.2.1 Engagement in learning and energy-saving behaviors during K-12 Energy Challenge 1.0

Each of the four participating schools engaged in activities, events, and actions related to the K-12 Energy Challenge (Table 7.5). The school with the greatest energy savings, R. Elementary School, had the greatest number of activities across most areas of energy waste (e. g., heating, ventilation, lighting, and other electrical usage) and earned the greatest number of activity points. L. C. Elementary School had the next-best ranking, both in terms of energy performance and activity points. J. Elementary School and L. Middle School were the next best, but one school achieved better energy performance while the other achieved more activity points. J. Elementary School was ranked third based on energy performance and fourth based on activity points, whereas L. Middle School was ranked third in activity points and fourth in energy performance. A detailed examination of the activity points reveals that while L. Middle School had a greater focus on educational activities such as appointing classroom leaders, designing an energy-efficient school, making energy-saving announcements, and creating posters about energy-savings, J. Elementary School focused their efforts in the Lighting, Heating/Cooling, and Devices categories, specifically on action items that repeated daily and student energy patrols that monitored compliance where unused lights and devices were turned off or unplugged (Table 7.5).

Also of note is that R. Elementary School and L. F. Elementary School engaged in activities including Daily Habits and Energy Patrols, but went further such as removing light bulbs permanently, unplugging vending machines containing non-perishable items during off-hours, switching off air-handling systems when they were not in use, instituting a thermostat setback for the school, etc. R. Elementary School went as far as shutting off hallway lights throughout the school unless the lights were needed, following a pattern more typical of residential than institutional energy use.

Table 7.5. Point summary of activities (game objects) in schools participating in K-12 Energy Challenge 1.0.[1]

Activity category	Activity detail	R. Elementary School	L. C. Elementary School	L. Middle School	J. Elementary School	TOTAL
KICK-OFF / LEARNING / AWARENESS	Leader: Appoint a classroom leader			28		
	Daily Habit: Make daily energy-saving announcement	25		14		
	Take a Pledge	25				
	Brainstorm & Plan: Ways to save energy in the school		26		2	
	Presentation: Presented energy-saving plan to local architects and engineers' jury			3	2	
	Kill-a-Watt Meters: Use meters to study which are the greatest energy users in the school				5	
	Design: A sustainable school building			3		
	Research: With visiting architects, consultants for energy-saving measures			3	2	
	Blackouts: Instituted and enacted energy blackout periods			5		
	TOTAL - KICK-OFF	50	26	56	11	143
LIGHTING	Daily Habit: keep lights off	25	26		5	
	Lighting Energy Patrol: Energy patrol officer	25	26	14	5	
	Light Blackout Hour: all classroom lights off for an hour	0		5		
	Hallway: Switch off hallway lights (except secure areas)	25	26		5	
	Bathrooms: Switch off bathroom lights (except secure areas)	25	26		5	
	Light Power Day: full day no lights (except secure and low-light areas)	21				
	Light Bulb Removal: Removed several light bulbs in classrooms and corridors	21				
	TOTAL LIGHTING	142	104	19	20	285

1 Points were based on activity reports from teachers and staff during phone interviews with efargo researchers. One point was awarded for (a) each day that the activity was conducted in the school, and (b) each day on which an activity conducted in the school continued to have a meaningful impact.

Activity category	Activity detail	R. Elementary School	L. C. Elementary School	L. Middle School	J. Elementary School	TOTAL
DEVICES	Daily Habit: unplug device	25			5	
	Daily Habit: switch off device	25	26		5	
	Devices Energy Patrol: Turn off all unused devices	25	26	14	2.5	
	School Unplug: unplug outside classroom (offices etc)	25	26		5	
	Devices Blackout Hour			5		
	Smartboards: Use whiteboards instead of smartboards unless needed		26			
	Night Unplug: unplug class devices overnight	14				
	Vending Machine: Unplug when school is closed	14				
	Water Heater: Unplug when school is closed	4				
	TOTAL - DEVICES	132	104	19	17.5	272.5
HEATING/ COOLING	Daily Habit: morning blind control	25	26		5	
	Daily Habit: afternoon blind control	25	26		5	
	Shading Energy Patrol: remind staff/teachers to close/open blinds or students responsible for closing/openingblinds	21	26	14	5	
	After-hours Thermostat: enact school reset schedule	30				
	Vestibule Doors: Closed all vestibule doors which were typically propped open	30				
	Gymnasium: Switched off gym air handler when not in use	25				
	Community/Lunch Room: Switched off air handler when not in use	25				
	TOTAL HEATING & COOLING	181	78	14	15	288
ACTIVIST FRIDAY	Poster Contest: hang signs/posters around school	20		14		
	Announcements: Weekly energy results announced to school	6		5		
	TOTAL ACTIVIST FRIDAYS	26	0	19	0	45
	GRAND TOTAL	531	312	63.5	127	1033.5

Key factors in the activities the schools were able to institute and accomplish were, first, the varying degrees of support that students received in various schools, and second, how long and consistently the schools stayed engaged in the game. Table 7.6 summarizes the participation for the schools in K-12 Energy Challenge 1.0.

Table 7.6. Participation in K-12 Energy Challenge 1.0. Spring 2016

	R. Elementary School		L. C. Elementary School		J. Elementary School	L. Middle School		TOTAL
	Week 1	Week 6	Week 1	Week 6	1 week / Single day	Week 1	Week 6	
Students	30	80	12	500	60	80	80	720
Teachers	1		2		5	4		12
Support Staff	1		2		6	4		13
Community Volunteers	0		0		6	12		18
Facility	1		1		1	1		4

The two top-performing schools, R. Elementary School and L. C. Elementary School, participated in the competition for all six weeks. At R. Elementary School, what began as a core group of 30 students from an after-hours school club grew into participation from multiple grades and classrooms with approximately 80 students, whereas at the second school, L. C. Elementary, only one of the grades (but all classrooms from that grade) participated. However, at L. C. Elementary School, enthused by the Energy Patrols, the entire school of approximately 500 participated in the competition around Earth Day celebrations. Students at R. Elementary School had strong support from the principal, facilities manager, teachers, and librarian. Students at L. C. Elementary School were supported by the participating classroom teachers and librarian. The third and fourth participating schools, J. Elementary School and L. Middle School, were only partially active during the game. J. Elementary School participated in one week of learning and energy-use reduction implementation activities; L. Middle School participated in educational and learning activities in most weeks and in some activities (like poster-making about energy use and similar activities) during Weeks 4-6. Students at L. Middle School actively participated in the competition only on Fridays.

Based on the energy performance, schools that reported consistent participation from students, teachers, staff, administration, and facilities managers, together with schools that regularly completed the greatest number of activities, had the best energy results. Thus the most successful social expansions both increased the number of people involved and ensured that various constituencies were involved and actively participating. In such cases, students generated ideas, teachers gave permission for changes in the classrooms, administration approved school-wide changes, and facilities managers provided ideas and skills to complete impactful tasks (such as changes to the heating and cooling systems at R. Elementary School). Temporal expansions with greater impact occurred when energy-saving activities extended beyond the school day into times when school was not in session, such as evenings, nights, and weekends.

7.2.2 Learning and Awareness (K-12 Energy Challenge 1.0 / 2016)

In the first implementation of the K-12 Energy Challenge, Learning and Awareness was measured and assessed in two ways (Table 7.7).

Table 7.7. Data Sources, Learning and Awareness, K-12 Energy Challenge 1.0.

variable	Source: K-12 Energy Challenge 1.0 (2016)
Learning and Awareness	1. five questions from the post-game survey completed by teachers, measuring the teachers' experience. 2. six questions from the post-game survey completed by teachers, measuring the teachers' perception of student experience.

First, Learning and Awareness was measured using a combination of five questions from a post-game survey given to K-12 teachers (Table 7.8), measuring the teachers' perception of the Learning and Awareness gained from the game. The total number of survey respondents (n) was 14.

Table 7.8. Questions relevant to Learning and Awareness from the post-game survey given to teachers participating in K-12 Energy Challenge 1.0, relating to teachers' own experience.

#	question text

Q8	To what extent did participating in the K-12 Energy Challenge make you aware of where energy was being wasted in your school?
Q9	To what extent did participating in the K-12 Energy Challenge make you aware of how occupant behavior might impact and potentially save energy in your school?
Q10	To what extent did participating in the K-12 Energy Challenge make you aware of how devices and appliances might impact and potentially save energy in your school?
Q11	To what extent did participating in the K-12 Energy Challenge increase your understanding of how the school building might be made more efficient?
Q18	To what extent did participating in the K-12 Challenge increase your willingness to conserve energy in your home?

Question responses used a five-point Likert scale ("None," "Low," "Moderate," "High," "Strong"). For purposes of analysis, responses were assigned numerical values from 0 (for "none") to 4 (for "strong"). Figure 7.2 illustrates the responses to the five questions, graphically sorted by the mean-value response to a composite of all five questions. Inspection of Figure 7.2 suggests that the responses show good cross-question reliability. To test this observation, Cronbach's alpha for the five questions (Q8, Q9, Q10, Q11, and Q18) was calculated as .886, indicating a good level of reliability across the questions, i. e., that the responses to the five questions in Table 7.8 are well-correlated.

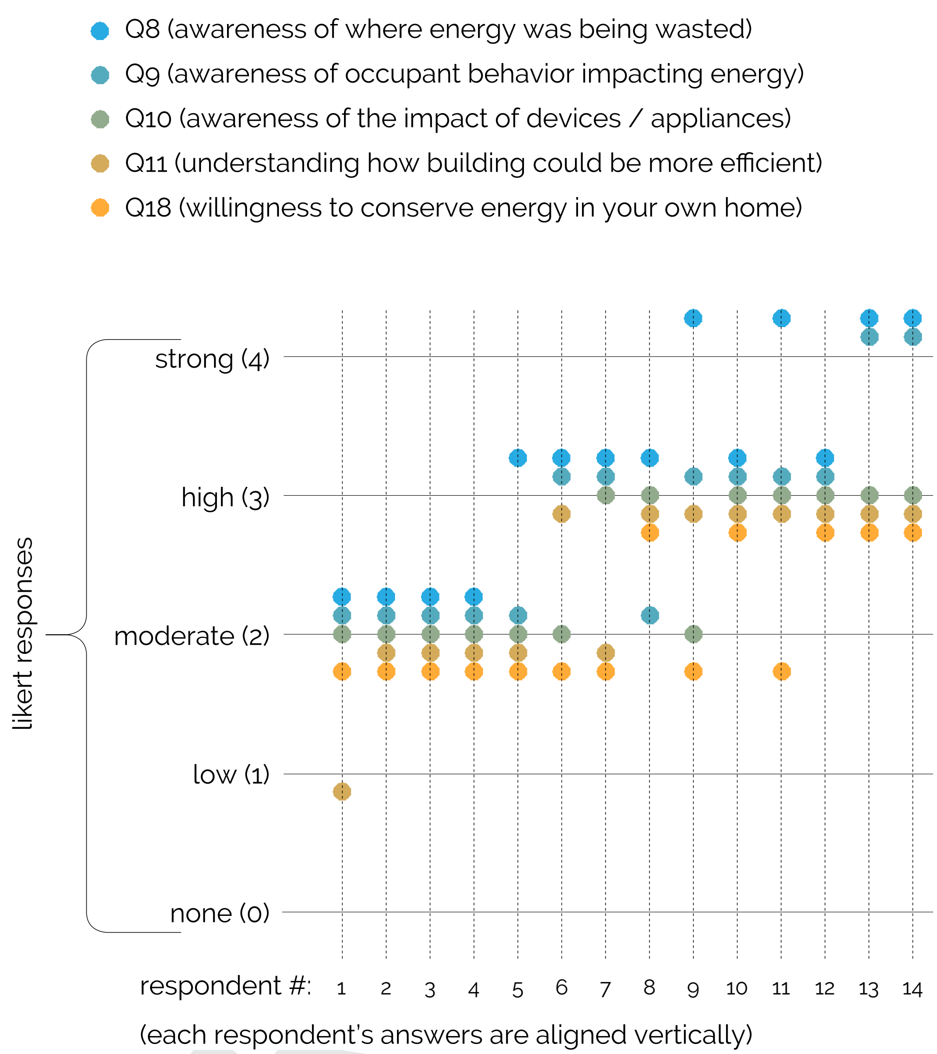


Figure 7.2. Cross-question reliability for five questions relevant to Learning and Awareness from the post-game survey given to teachers participating in K-12 Energy Challenge 1.0, relating to teachers' own experience. Respondents sorted by mean-value response to composite of all five questions.

Figure 7.3 illustrates the responses to the five questions, graphically sorted by response. Inspection of Figure 7.3 suggests that the mean response to the five questions is higher than a hypothesized mean response of 2.0. To verify this, the mean of numerical values assigned to responses from the five questions (Q8, Q9, Q10, Q11, and Q18) was computed to form a composite variable. The composite variable's range is from 1.80 to 3.40 (where large values indicate stronger extent), with a mean of 2.61, a median of 2.70, and a standard deviation (SD) of 0.52. The observed mean (2.61) is greater than the hypothesized mean (2.00).

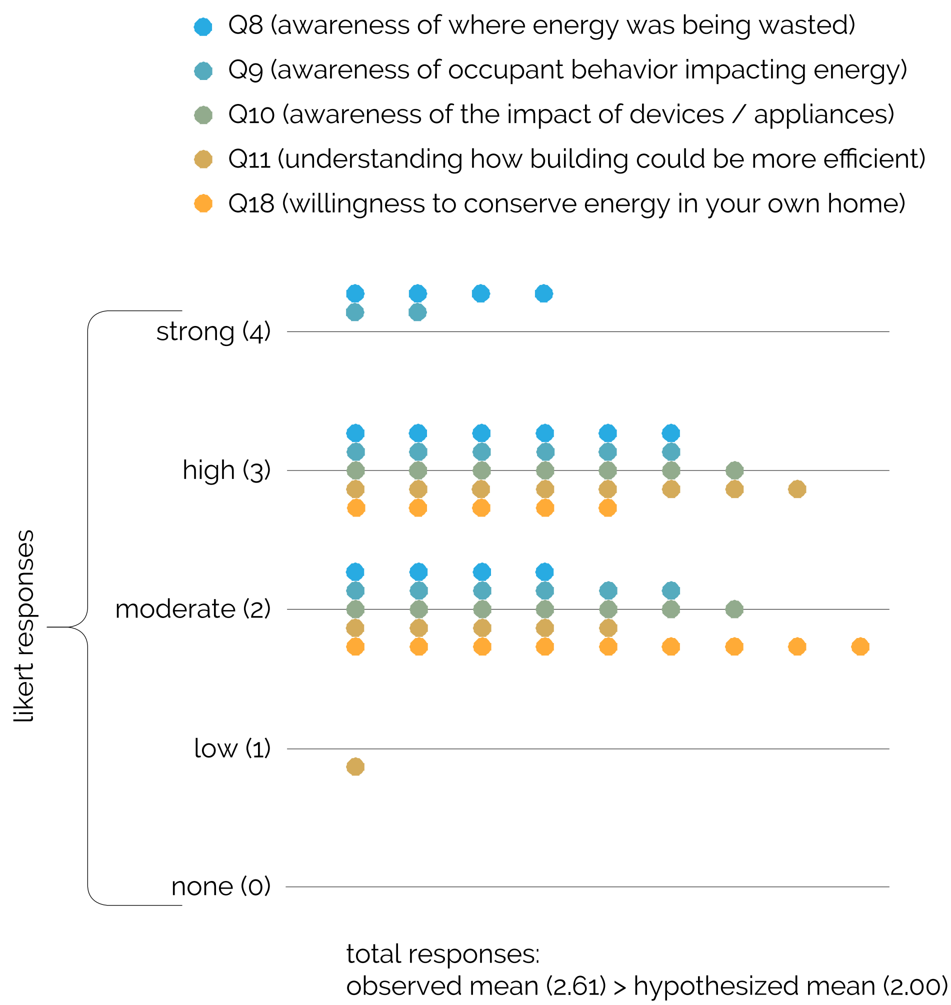


Figure 7.3. Mean-value responses for five questions relevant to Learning and Awareness from the post-game survey given to teachers participating in K-12 Energy Challenge 1.0, relating to teachers' own experience..

To test the statistical significance of these observations, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (2). For the sample size of 14, the t-critical value was calculated as 2.16, and the t-statistic was calculated as 4.459. The p-value of 0.001 is less than 0.05, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 2 is outside of the 95% confidence interval of [2.317, 2.911], i. e., the observed mean is significantly different from the neutral point of the scale. The observed difference between the mean level of agreement and the neutral point of the scale is therefore statistically significant.

Thus, with respect to the measurement of teachers' own experiences in the K-12 energy challenge 1.0, playing an open, pervasive game can lead to Learning and Awareness about energy-savings.

Second, Learning and Awareness was measured using a combination of six questions from a post-game survey given to K-12 teachers, measuring the teachers' perception of student experience (Table 7.9).

Table 7.9. Questions relevant to Learning and Awareness from the post-game survey given to teachers participating in K-12 Energy Challenge 1.0, relating to teachers' perception of student experience.

#	question text
Q11	To what extent did participating in the K-12 Energy Challenge make the students aware of where energy was being wasted in the school?
Q12	To what extent did participating in the K-12 Energy Challenge make the students aware of how occupant behavior might impact and potentially save energy in the school?
Q13	To what extent did participating in the K-12 Energy Challenge make the students aware of how devices and appliances might impact and potentially save energy in the school?
Q14	To what extent did participating in the K-12 Energy Challenge increase the students' understanding of how the building could be made more efficient?
Q15	To what extent did participating in the K-12 Energy Challenge increase the students' willingness to spend time and effort learning about energy and environmental issues?
Q23	To what extent were students concerned about the impact of building energy use on the environment after the K-12 Energy Challenge?

Question responses used a five-point Likert scale ("None," "Low," "Moderate," "High," "Strong"). For purposes of analysis, responses were assigned numerical values from 0 (for "none") to 4 (for "strong").

Figure 7.4 illustrates the responses to the six questions, graphically sorted by the mean-value response to a composite of all six questions. Inspection of Figure 7.4 suggests that the responses show good cross-question reliability. To test this observation, Cronbach's alpha for the six questions (Q11, Q12, Q13, Q14, Q15, and Q23) was calculated as .893, indicating a good level of reliability across the questions, i. e., that the responses to the six questions in Table 7.9 are well-correlated.

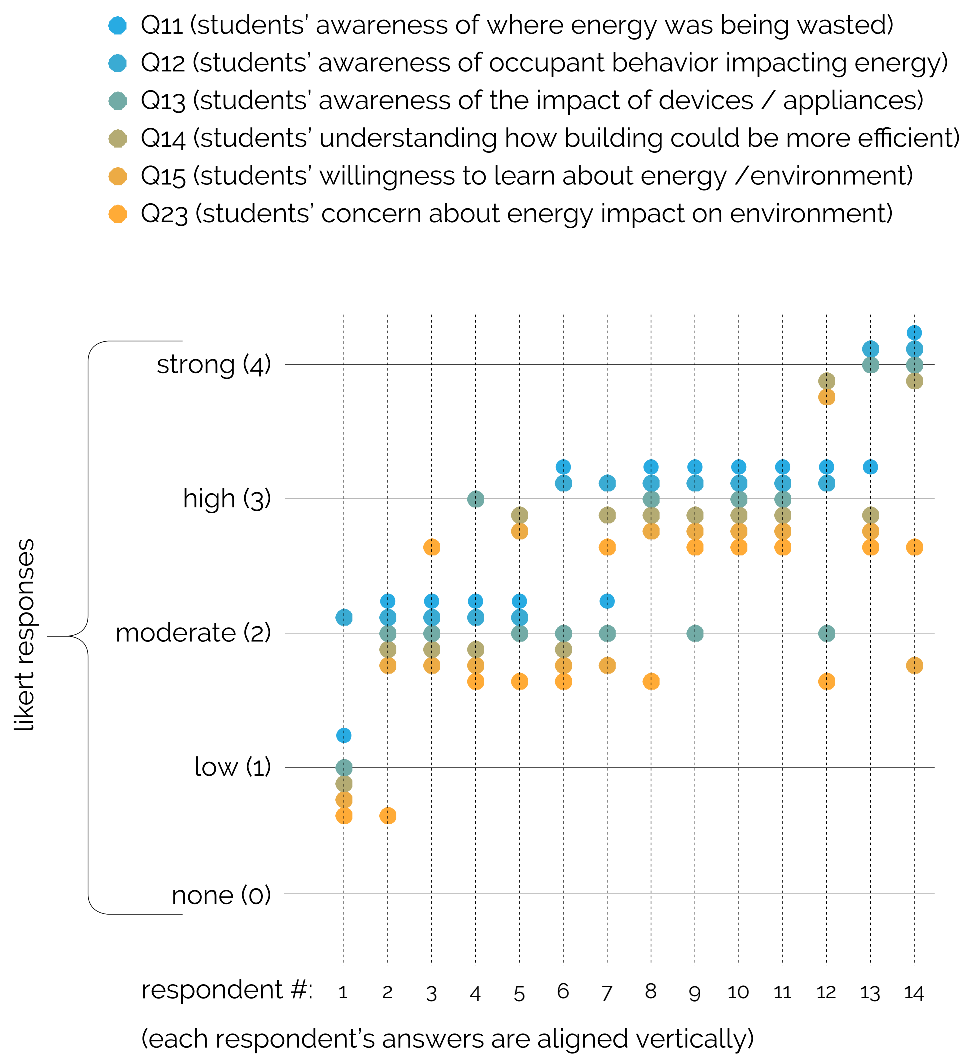


Figure 7.4. Cross-question reliability for six questions relevant to Learning and Awareness from the post-game survey given to teachers participating in K-12 Energy Challenge 1.0, relating to teachers' perception of student experience. Respondents sorted by mean-value response to composite of all six questions.

Figure 7.5 illustrates the responses to the six questions, graphically sorted by response.

Inspection of Figure 7.5 suggests that the mean response to the five questions is higher than a hypothesized mean response of 2.0. To verify this, the mean of numerical values assigned to responses from the six questions (Q11, Q12, Q13, Q14, Q15, and Q23) was computed to form a composite variable. The composite variable's range is from 1.2 to 3.5 (where large values indicate stronger extent), with a mean of 2.57, a median of 2.67, and a standard deviation (SD) of 0.60. The observed mean (2.57) is greater than the hypothesized mean (2.00).

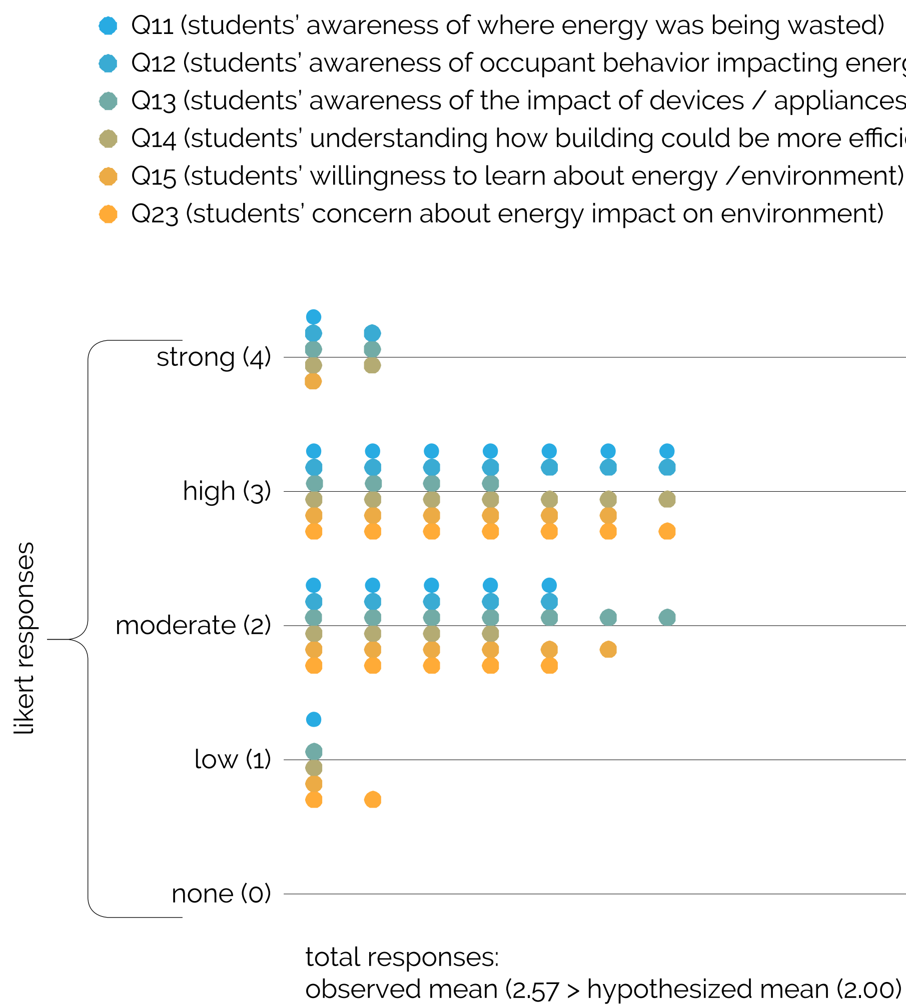


Figure 7.5. Mean-value responses for six questions relevant to Learning and Awareness from the post-game survey given to teachers participating in K-12 Energy Challenge 1.0, relating to teachers' perception of student experience.

To test the statistical significance of these observations, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (2). For the sample size of 14, the t-critical value was calculated as 1.771, and the t-statistic was calculated as 3.541. The p-value of 0.004 is less than 0.05, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 2 is outside of the 95% confidence interval of [2.285, 2.857], i. e., the observed mean is significantly different from the neutral point of the scale. The difference between the mean level of agreement and the neutral point of the scale is therefore statistically significant.

Thus, with respect to the measurement of teachers' perception of student experiences in K-12 Energy Challenge 1.0, playing an open, pervasive game can lead to Learning and Awareness about energy-savings.

7.2.3 Energy-savings behavior (K-12 Energy Challenge 1.0/ 2016)

Engagement and activities that involved changing energy-saving behaviors and one-time activities were charted with weekly interviews and emails with teachers and staff involved in the K-12 Energy Challenge (Table 7.6). In addition, perception of energy-saving behavior was measured and assessed in the K-12 Energy Challenge 1.0 using a single question from a post-game survey given to K-12 teachers, measuring the teachers' perception of student experience (Table 7.10). The total number of survey respondents (n) was 14.

Table 7.10. Question relevant to energy-saving behavior from the post-game survey given to teachers participating in K-12 Energy Challenge 1.0.

#	question text
Q10	To what extent were students motivated to continue energy-saving behaviors and activities after the K-12 Energy Challenge?

Question responses were on a five-point Likert scale ("None," "Low," "Moderate," "High," "Strong"). For purposes of analysis, the responses were assigned numerical values from 0 (for "None") to 4 (for “Strong”). Table 7.11 includes the descriptive statistics for the responses to this question. Note that higher values indicate greater extent.

Table 7.11. Descriptive statistics for responses to question relevant to energy-saving behavior from the post-game survey given to teachers participating in K-12 Energy Challenge 1.0.

variable	n	range	mean	median	standard deviation
Q10	14	1.0 to 3.0	2.29	2	0.59

The observed mean (2.29) is greater than the hypothesized mean (2.00). To test the statistical significance of this observation, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (2). For the sample size of 14, the t-critical value was calculated as 2.16, and the t-statistic was calculated as 1.817. The p-value of 0.092 is greater than 0.05, suggesting that the result of the t-test is not statistically significant. The hypothesized mean of 2 is within the 95% confidence interval of [1.946, 2.626], i. e., the observed mean is not significantly different from the neutral point of the scale.

The difference between the mean level of agreement and the neutral point of the scale therefore cannot be said to be statistically significant. Thus, with respect to the measurement of perception of willingness to change behavior in the post-game period, teacher survey of student experience revealed that although the observed mean was greater than the hypothesized mean (neutral) the results were not statistically significant.

7.2.4 K-12 Energy Challenge 1.0 take-aways

During K-12 Energy Challenge 1.0, the students were involved in several day-to-day energy-saving behaviors such as the daily Energy Patrol, as well as activities which would have longer-term impact such as removing extraneous light bulbs and working with administrators and teachers to change use patterns in the school building, e. g., for air-handling systems and thermostat settings. While the Challenge Toolkit asked the schools to be involved in a long preparation and orientation period that lasted three months and included activities such as appointing a champion for the school, preparing and learning about energy, setting goals for the school, and creating an energy-saving plan, the schools, the actual game-play period was six weeks during which schools engaged in energy-saving activities. In order to make the K-12 Energy Challenge visible in the school, several ideas were suggested in the Toolkit. These included having a poster contest, dressing up as superheroines or superheroes, making films, posting signage, etc. Therefore, awareness activities were completed in parallel with energy-saving activities. For those schools that were unable to have the three-month head start of learning and planning, the game time also became the time to learn about the issue of energy waste and energy-saving actions.

7.3 K-12 Energy Challenge 2.0 (2017), saves more energy than Energy Challenge 1.0

K-12 Energy Challenge 2.0 was implemented during Spring 2017, approximately during the same time of year as Energy Challenge 1.0. K-12 Energy Challenge 2.0 addressed the visibility of the game play period through physical game tags and dashboards, making the energy waste and energy-saving activities visible. A week of learning and tagging the energy waste, incorporated in the first week of Energy Challenge 2.0, addressed several issues, including learning about energy waste, ideating about how to prevent waste and achieve savings, and making problems and solutions visible through game tags and dashboards. This process also allowed game activities to be categorized into lighting, devices, heating, cooling, and miscellaneous (tailored) in order to create awareness of all areas of energy waste and potential energy-saving actions. While the first energy challenge focused on learning activities such as illustrations, posters, quizzes, and surveys, the second energy challenge started to align to the energy-saving actions that the schools were reporting by incorporating daily and weekly action goals within the game structure.

During K-12 Energy Challenge 2.0, school buildings were incorporated into the Waste-a-Watt narrative and explicitly positioned as game space. A physical game box contained tagging stickers to enable learning about and tagging energy waste around schools, and a toolkit and scorecard that allowed capturing Waste-a-Watt by fixing the waste (see Chapter 6 for images of game box). The game was introduced to all the participating schools, classrooms, students, teachers, and staff using a video about tagging energy waste in various categories and fixing the energy waste.[1]

Except for J. Elementary School (which had only limited participation in the first challenge), all of the participating schools from K-12 Energy Challenge 1.0 returned to participate in K-12 Energy Challenge 2.0. Two new schools joined the game (W. Elementary School and H. M. Elementary School). Although permission to take energy readings at the control school (B. F. Middle School), was not received, the minimal participation of H. M. Elementary School and the partial participation of L. Middle School allowed these schools to serve as controls for comparison. In addition, although L. C. Elementary School provided information on their activities, information about numbers of students, teachers, staff, and facility managers was not received.

7.3.1 Energy savings (K-12 Energy Challenge 2.0 / 2017)

Relative to the levels achieved in K-12 Energy Challenge 1.0, the energy savings of all schools improved considerably during the game, even among those schools playing for the first time (Table 7.12).

Table 7.12. Analysis of weekly meter readings (using Woodcock's method) from schools participating in K-12 Energy Challenge 2.0, relative to Baseline Week 0. (See Appendix x.xxx for a more detailed data analysis.)

dates	period	R. Elementary School	L. C. Elementary School	W. Elementary School	H. M. Elementary School	L. Middle School*	units
Feb 14 - Feb 20, 2016	Baseline Week 0	21.7	50.26	43.98	35.6	93	kWh/ HDD + CDD
Feb 21 - Apr 3, 2016	Game period Week 1 - 6	18.24	43.44	39.47	36.48	111.65	kWh/ HDD + CDD
	increase or decrease	decrease of 16.23%	decrease of 13.57%	decrease of 10.26%	increase of 2.47%	increase of 18.2%	

The winning school, R. Elementary School (the same school that won K-12 Energy Challenge 1.0), reduced its NEU by 16.23%. The two next-best performing schools, L. C. Elementary School and W. Elementary School, reduced their NEU by 13.57% and 10.26% respectively. H. M.

1 https://www.youtube.com/watch?time_continue=132&v=WoChVU_uwsE&feature=emb_logo
http://efargo.org/k12challenge2-0.html

Elementary School's NEU increased by 2.47% (Figure 7.6).

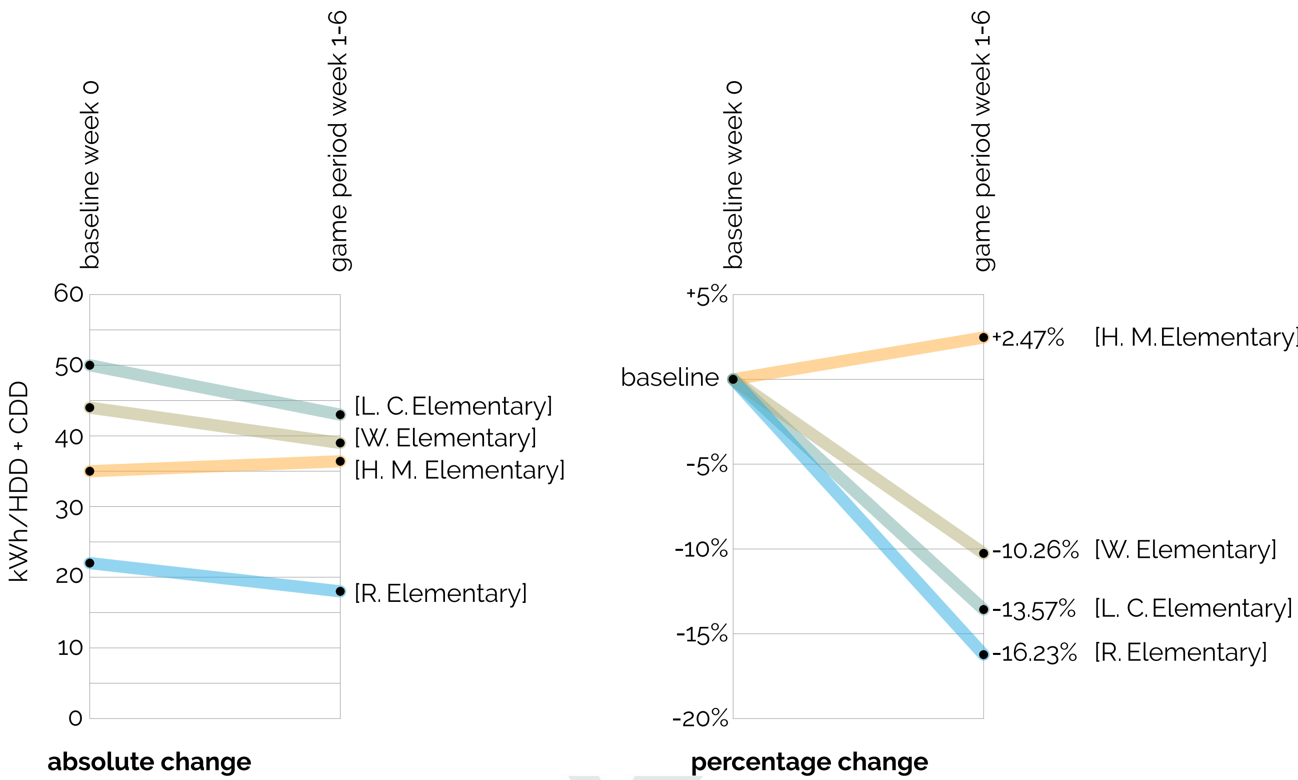


Figure 7.6. Absolute and percentage change in normalized energy use (NEU), relative to Baseline Week 0, for schools participating in K-12 Energy Challenge 2.0

Energy-reading permissions for L. Middle School were only available in the game's final four weeks, while the school was conducting educational activities. Due to its late start, the baseline week for L. Middle School differed from the other schools. In order to have a comparison to a uniform baseline week, Woodcock's method was reapplied to all participating schools using Week 2 of the competition as the baseline week (Table 7.13; Figure 7.xx).

Table 7.13. Analysis of weekly meter readings (using Woodcock's method) from schools participating in K-12 Energy Challenge 2.0, relative to Baseline Week 2. (See Appendix x.xxx for a more detailed data analysis.)

		R. Elementary School	L. C. Elementary School	W. Elementary School	H. M. Elementary School*	L. Middle School*	units

Feb 28 - Mar 6, 2016	Baseline Week	18.05	37.54	39.688	32.06	93.38	kWh/ HDD + CDD
Mar 7 - Apr 3, 2016	Game period Week 3 - 6	15.655	33.68	36.85	37.93	111.65	kWh/ HDD + CDD
	increase or decrease	decrease of 13.28%	decrease of 9.82%	decrease of 7.16%	increase of 18.29%	increase of 19.55%	

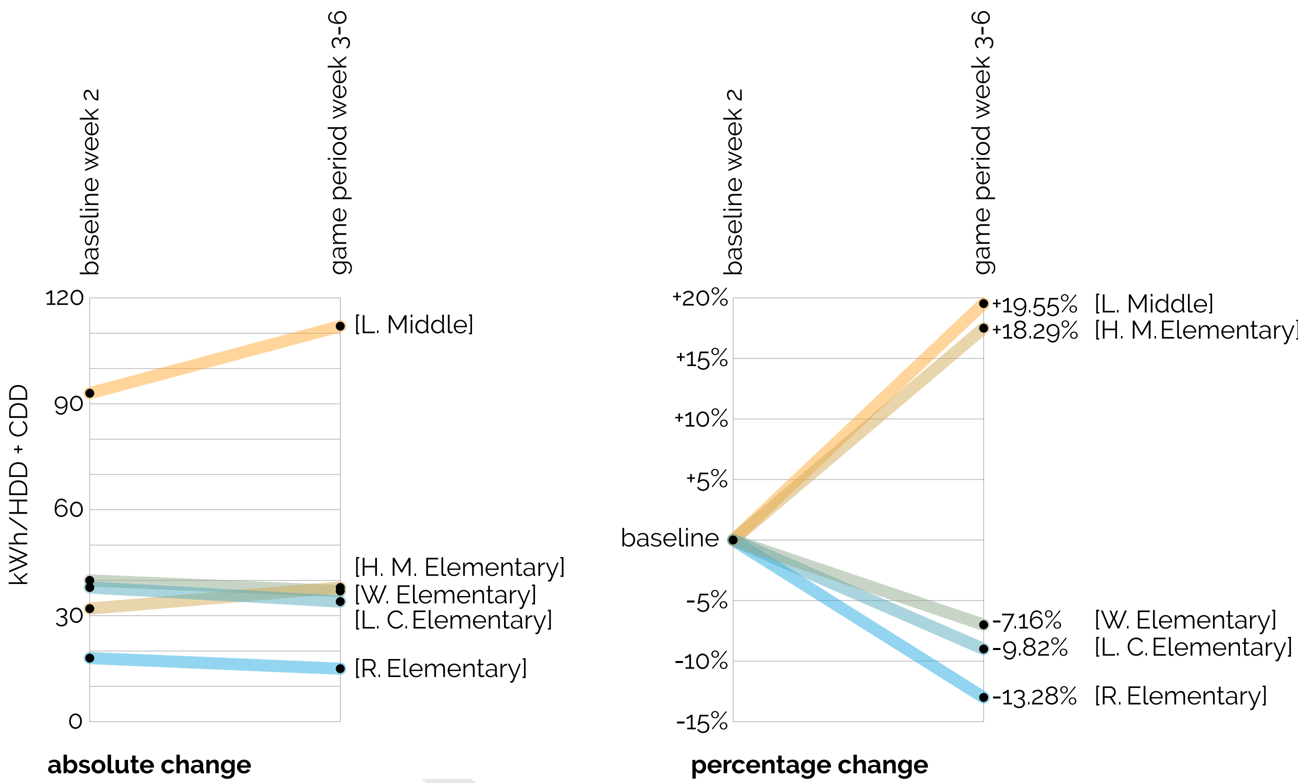


Figure 7.xxx. Absolute and percentage change in normalized energy use (NEU), relative to Baseline Week 2, for schools participating in K-12 Energy Challenge 2.0

Although this recalibration was disadvantageous for the other participating schools (because by Week 2 they had already reduced energy use), schools' relative performance did not change. The three game-playing schools (R. Elementary School, L. C. Elementary School, and W. Elementary School) continued to achieve reductions in the same relative positions, while H. M. Elementary School and L. Middle School increased their energy use.

A comparative increase in H. M. Elementary School's energy use percentage (from 2.47%, calculated relative to Baseline Week 0, to 18.29% calculated relative to Baseline Week 2) likely results from the teachers completing one-day concentrated energy-saving activities within the first two weeks of the game period. Energy-saving activities did not persist beyond the initial action. The NEU increases for L. Middle School and H. M. Elementary School were very similar to each other, 18.29% and 19.55%, indicating that the weather had a large impact in energy use in that time period, making the other schools' energy reductions during the same time more notable.

7.3.2 Engagement in learning, energy-saving behavior (K-12 Energy Challenge 2.0 / 2017)

Three of the schools that achieved energy savings (R. Elementary School, L. C. Elementary School, and W. Elementary School) participated in the game for all six weeks (Table 7.14).

Table 7.14. Participation in K-12 Energy Challenge 2.0. Spring 2017

School Name	R Elementary School		L. C. Elementary School	W. Elementary School		L. Middle School (control)		H. M. Elementary School (control)	TOTAL	
Period	Week 1	Week 6	Participation data unavailable	Week 1	Week 6	Weeks 1-3	Weeks 4-6	Limited participation	Week 1	Week 6
Students	55	360		6	114	160	277	0	221	751
Teachers	11			3		2		6	22	
Support Staff	4			10		1		4	19	
Community Volunteers	0			19		2		0	21	
Facility	1			1		1		1	4	
TOTAL	376			147		283		11	817	

Detailed information about numbers of people participating was not available from L. C. Elementary School. At H. M. Elementary (a school for K-2 students), only the teachers and staff participated; students were not involved. The teachers and staff did not play the game and did not tag the building energy waste with stickers, but they did complete some energy-saving activities listed in the toolkit, such as turning off hallway lights on one of the days early in the game timeline (Table 7.15). Teachers were interviewed but the efargo team did not have permission to complete surveys with students.

The second school, L. Middle School, participated for Weeks 3-6 (due to schedule overload) and only in the educational activities. As at the other schools, the K-12 Energy Challenge was introduced to L. Middle School students in Week 1 with the video and an energy-waste identification activity. Approximately 160 students from the eighth-grade classrooms that led L. Middle School's participation engaged in educational activities in Weeks 3-6, including public announcements on Fridays based on weekly reports. The students created and displayed posters around the school regarding energy efficiency and environmental impact. The students also completed a design workshop (for a "green school") with local architects, engineers, and experts in high-performance design. One of the classrooms conducted presentations in other classrooms regarding the environmental impact of energy use in schools, involving a total of 277 students. However, the students at L. Middle School did not tag the school or classrooms.

Table 7.15. Activities (game objects) in participating schools during K-12 Energy Challenge 2.0.

Activity category	Activity detail	R. Elementary School	L. C. Elementary School	W. Elementary School	L. Middle School	H. M. Elementary School*	TOTAL
KICK-OFF / EDUCATION / DISSEMINATION	Leader: Appoint a classroom leader				14		
	Daily Habit: Make daily energy-saving announcement	28			3		
	Take a Pledge	1					
	Brainstorm & Plan: Ways to save energy in the school		26		4		
	Tag the Waste: Use energy cards, online files or VR files to complete tagging waste in school building		26	26			
	Presentation: Presented energy-saving plan to local architects and engineers' jury			5	4		
	Kill-a-Watt Meters: Use meters to study which are the greatest energy users in the school			5	4		
	FLIR Cameras: Use FLIR cameras to study where energy is being wasted with Facilities Director			5			
	Design: A sustainable school building				28		
	Research: With visiting architects, consultants for energy-saving measures				4		
	Blackouts: Instituted and enacted energy blackout periods				0		
	TOTAL - KICK-OFF	29	52	41	61	0	184
LIGHTING	Daily Habit: keep lights off	24	26				
	Lighting Energy Patrol: Energy patrol officer	24	26		9		
	Light Blackout Hour: all classroom lights off for an hour				3		
	Hallway: Switch off hallway lights (except secure areas)	28	26	15		4	
	Bathrooms: Switch off bathroom lights (except secure areas)	28	26	15		4	
	Classrooms: Switch off classroom lights when not needed	24	26	28		4	
	Light Power Day: full day no lights (except secure and low-light areas)	2		1		1	
	Classroom Design: classroom rearrangement			13			
	Light Bulb Removal: Removed several light bulbs in classrooms and corridors			5			
	TOTAL - LIGHTING	130	130	77	12	13	362

Activity category	Activity detail	R. Elementary School	L. C. Elementary School	W. Elementary School	L. Middle School	H. M. Elementary School*	TOTAL
DEVICES	Daily Habit: unplug device	24					
	Daily Habit: switch off device	24	26				
	Devices Energy Patrol: Turn off all unused devices	24	26	21	9	4	
	School Unplug: unplug outside classroom (offices etc)	28	26	9		4	
	Devices Blackout Hour				3		
	Smartboards: Use whiteboards instead of smartboards unless needed		26				
	Night Unplug: unplug class devices overnight	10					
	Vending Machine: Unplug when school is closed	10					
	Water Heater: Unplug when school is closed	10					
	TOTAL - DEVICES	130	104	30	12	8	154
HVAC	Daily Habit: morning blind control	24	26				
	Daily Habit: afternoon blind control	24	26				
	Shading Energy Patrol: remind staff/teachers to close/open blinds or students responsible for closing/openingblinds	21	26		9		
	After-hours Thermostat: enact school reset schedule	28					
	Vestibule Doors: Closed all vestibule doors which were typically propped open	30		28			
	Gymnasium: Switched off gym air handler when not in use	30					
	Community/Lunch Room: Switched off air handler when not in use	30					
	TOTAL - HVAC	187	78	28	9	0	302
ACTIVIST FRIDAY	Poster Contest: hang signs/posters around school	28		28	3		
	Classroom Awareness: other class presentation				3		
	Announcements: Weekly energy results announced to school	6			3		
	TOTAL - ACTIVIST FRIDAY	34	0	28	9	0	71
	GRAND TOTAL	510	364	204	104	21	1073

As with K-12 Energy Challenge 1.0, the schools with consistent participation, the most activities, and the strongest support from staff, teachers, and administrators showed the greatest energy savings during K-12 Energy Challenge 2.0 (Table 7.14). R. Elementary School once again won the Energy Challenge with the greatest savings. This aligned with their engagement in numbers of activities. Their engagement in action items related to Daily Habits and longer-term ideas (such as switching off all lights in bathrooms, classrooms, and hallways unless they were needed) was noteworthy. These stringent measures created some problems for the school such as lower-than-code light levels in public hallways and bathrooms. Compared to other schools (L. C. Elementary School, W. Elementary School, and L. Middle School), R. Elementary School did not spend as much time and effort focused on educational activities. L. C. Elementary School, like R. Elementary School, spent most of their time on the day-to-day and long-term action items, but spent more time on educational activities than did R. Elementary School. They were ranked second in energy savings and engagement outcomes. W. Elementary School (a new school in the second Challenge) was ranked third in energy savings and engagement reporting. For the last two schools, although L. Middle School had greater engagement outcomes, H. M. Elementary School, with participation only from teachers and staff, had better energy-savings outcomes in the first three weeks. H. M. Elementary's teachers and staff participated in the Energy Challenge in the first week with some activities in the second week, whereas L. Middle School was focused on educational activities in the first three weeks. Towards the end of the Challenge, both schools had very similar energy-use increases when compared to a third-week baseline. By comparison, the other three participating schools that engaged in energy-saving activities continued to save energy commensurate with their activity reports.

7.3.4 Hypothesis 1: Learning, awareness & dissemination of learning during K-12 Energy Challenge 2.0 (2017)

In K-12 Energy Challenge 2.0, Learning and Awareness was measured and assessed through two surveys (Table 7.16). The surveys provided substantive numbers of before and after respondents, as discussed in detail in the following sections.

Table 7.16. Data Sources, Learning and Awareness, in K-12 Energy Challenge 2.0.

variable	source: K-12 Energy Challenge 2.0 (2017)

Learning and Awareness	1. survey given to students at L. Middle School prior to gameplay 2. survey given to students at L. Middle School following completion of gameplay.

For the two surveys, three different statistical comparisons were carried out to assess Learning and Awareness. First, responses to a set of seven questions from the pre-game survey were compared to responses from a corresponding set of questions from the post-game survey. The questions were generally concerned with awareness of energy savings. Second, a single question (about percentage of energy savings) with objectively correct responses was asked in each survey, and the responses were compared. Finally, the responses to two additional questions from the post-game survey were assessed.

7.3.5 Awareness questions in pre-game and post-game surveys

Table 7.17 lists the seven paired survey questions used to assess Learning and Awareness. The same questions appeared in both pre-game and post-game surveys given to students at L. Middle School.

Table 7.17. Questions relevant to Learning and Awareness from the pre-game and post-game surveys given to students at L. Middle School in K-12 Energy Challenge 2.0.

pre-game question #	post-game question #	question text
Q1	Q1	I know where energy is being wasted in my school and want to take action to prevent the waste.
Q3	Q3	Buying LED bulbs would be good for my home and school because they use up to 80% less energy than other bulbs and don't contain mercury like CFL bulbs.
Q7	Q9	I know that among city buildings schools use the most energy and by lowering energy use in my school I will help the city lower energy bills and protect the environment.
Q9	Q10	Schools use both natural gas and electricity to meet their energy needs.
Q11	Q12	Window shades can make a difference to how much energy is used in a building.
Q14	Q15	Lowering the thermostat temperature setting during the winter after school hours means that the building is not using as much gas for heating and this lowers the energy use.

Q17	Q18	Lowering energy use means lowering the demand for fossil fuels which will help protect the environment for the future.

Question responses used a five-point Likert scale ("Strongly agree," "Agree," "Neutral," "Disagree," "Strongly disagree"). For purposes of analysis, responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). The responses to the seven questions, graphically sorted by mean-value response to a composite of all seven questions, are shown from pre-game (Figure 7.11) and post-game surveys (Figure 7.12). Inspection of Figure 7.11 and Figure 7.12 suggests that the responses show good cross-question reliability. (Non-responses were omitted from subsequent analysis.)

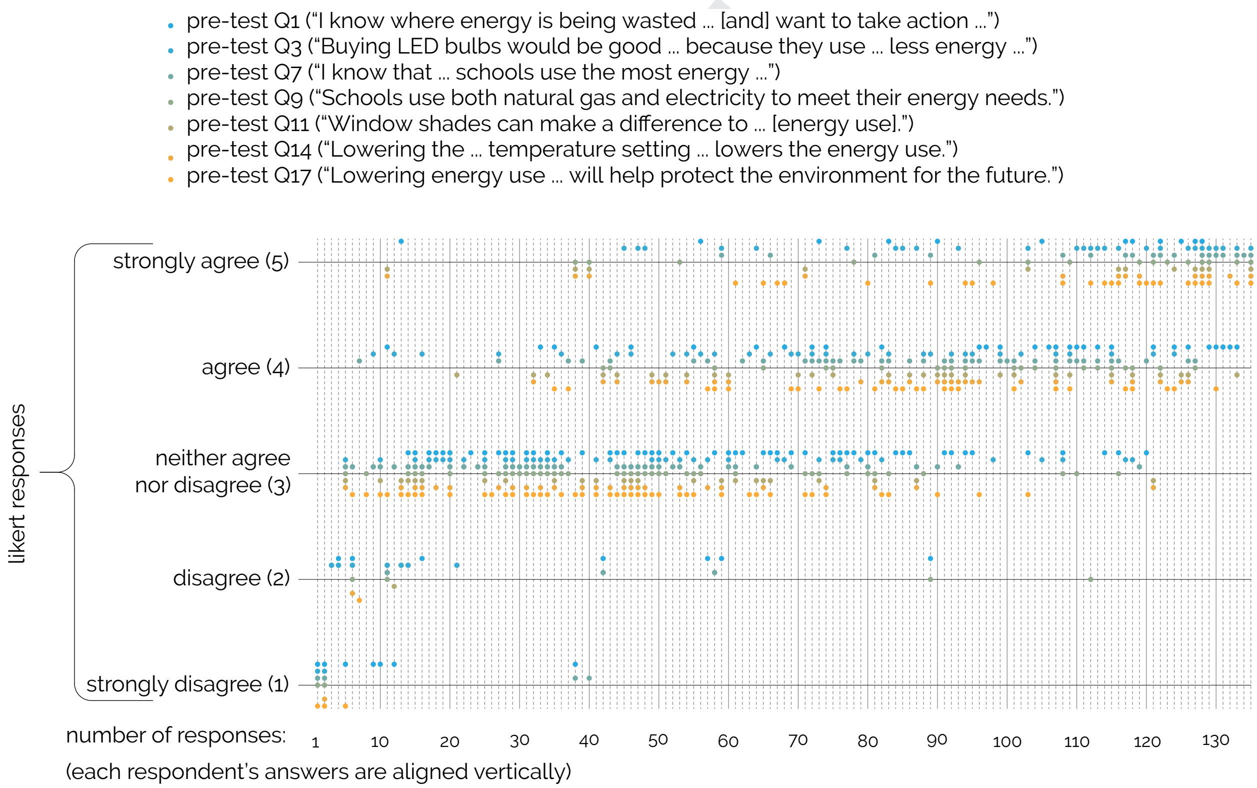


Figure 7.11. Cross-question reliability for seven questions relevant to Learning and Awareness from the pre-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0. Respondents sorted by mean-value response to composite of all seven questions.

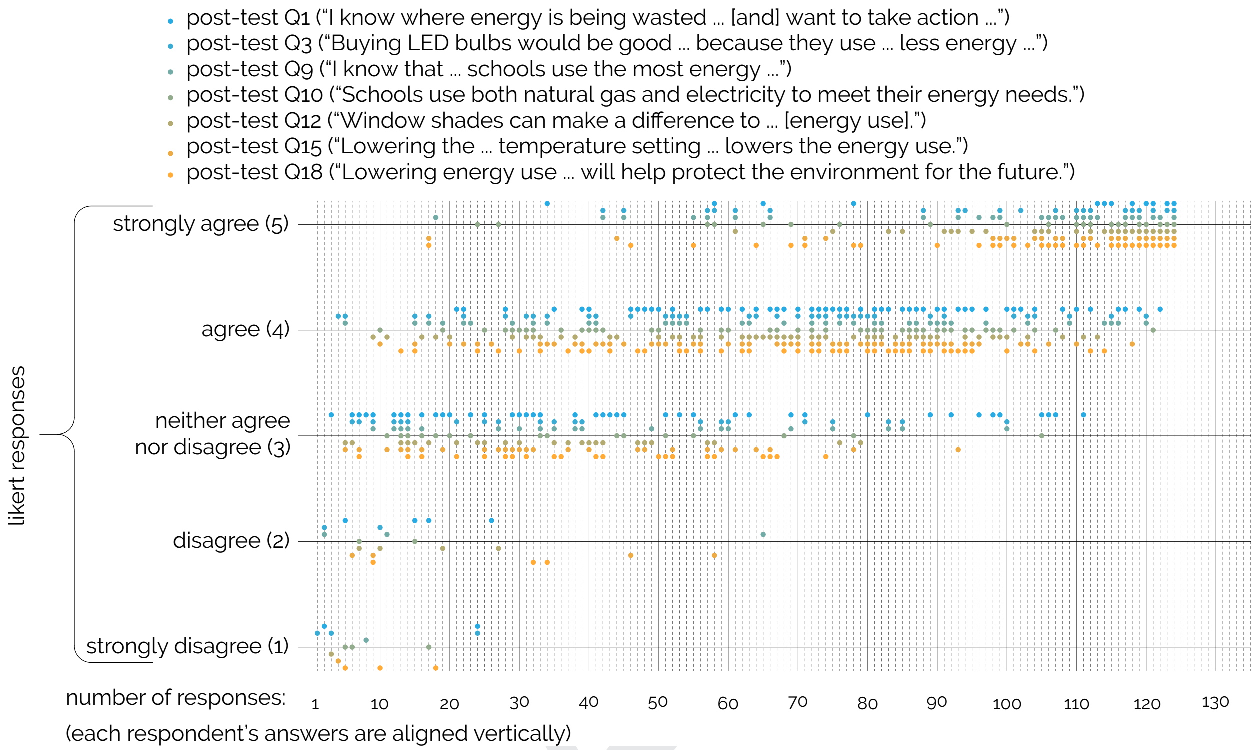


Figure 7.12. Cross-question reliability for seven questions relevant to Learning and Awareness from the post-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0. Respondents sorted by mean-value response to composite of all seven questions.

To test this observation, Cronbach's alpha for the seven pre-game questions listed in Table 7.17 was calculated as 0.898, indicating a good level of reliability across the questions; similarly, Cronbach's alpha for the seven post-game questions listed in Table 7.17 was calculated as 0.823, indicating a good level of reliability across the questions. This suggests that the responses to the seven questions in Table 7.17 are well-correlated, with respect to both pre-game and post-game surveys.

Figure 7.13 illustrates the responses to the six questions, graphically sorted by response. Inspection of Figure 7.13 suggests that the mean response to the five questions is higher than a hypothesized mean response of 3.0.

- pre-test Q1 / post-test Q01 ("I know where energy is being wasted ... [and] want to take action ...")
- pre-test Q3 / post-test Q03 ("Buying LED bulbs would be good ... because they use ... less energy ...")
- pre-test Q7 / post-test Q09 ("I know that ... schools use the most energy ...")
- pre-test Q9 / post-test Q10 ("Schools use both natural gas and electricity to meet their energy needs.")
- pre-test Q11 / post-test Q12 ("Window shades can make a difference to ... [energy use].")
- pre-test Q14 / post-test Q15 ("Lowering the ... temperature setting ... lowers the energy use.")
- pre-test Q17 / post-test Q18 ("Lowering energy use ... will help protect the environment for the future.")

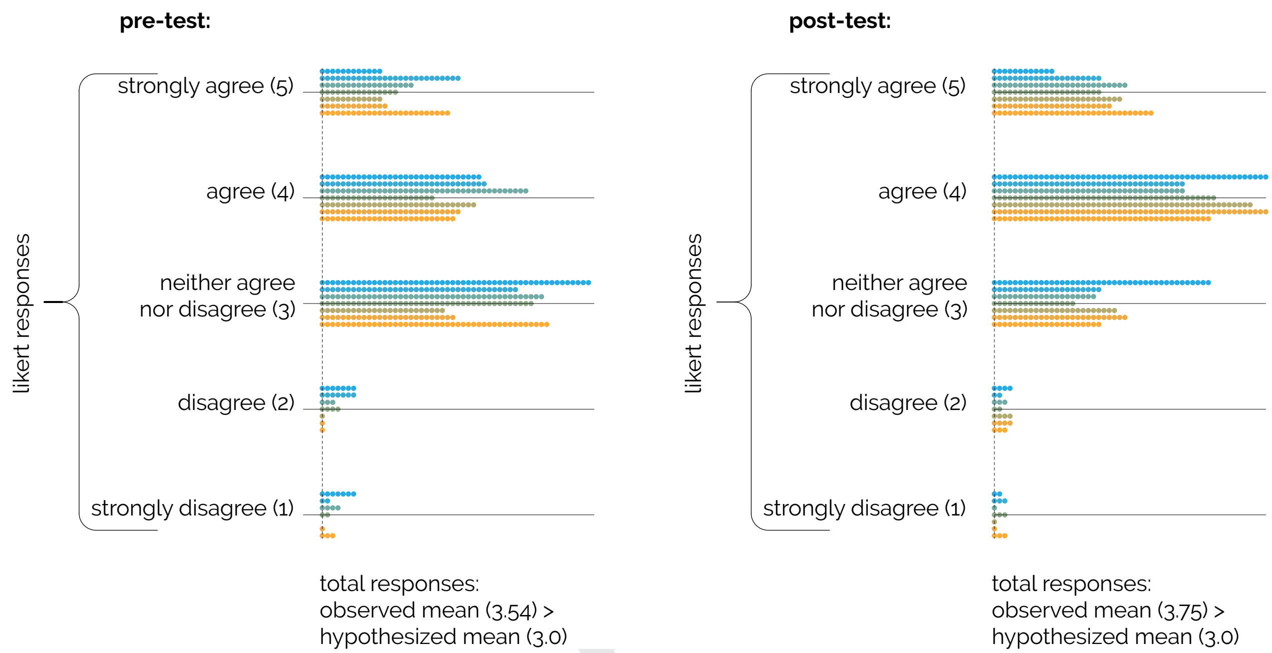


Figure 7.13. Mean-value responses for seven questions relevant to Learning and Awareness from the pre-game survey (at left) and the post-game survey (at right) given to students at L. Middle School in K-12 Energy Challenge 2.0.

To verify this, each question set was combined into a compound variable. Compound variable V1 represents the combined effect of pre-game questions (Q1, Q3, Q7, Q9, Q11, Q14, and Q17) and compound variable V2 represents the combined effect of post-game questions (Q1, Q3, Q9, Q10, Q12, Q15, and Q18). Table 7.18 includes the descriptive statistics for the two compound variables. Note that higher values indicate more agreement.

Table 7.18. Descriptive statistics for responses to composite of seven questions relevant to Learning and Awareness from the pre-game survey and the post-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0.

variable	n	range	mean	median	standard deviation
V1	135	1.00 to 5.00	3.54	3.5	0.688
V2	125	1.00 to 5.00	3.75	3.83	0.693

Inspection of the descriptive statistics shows that in both V1 and V2, the mean response is higher than a hypothesized mean of 3.0. Further inspection of the descriptive statistics shows that the mean response increased (by 5.93%) and the median response increased (by 9.4%) in the post-game responses. The responses to the two variables are summarized in Figure 7.14 (before the game), Figure 7.15 (after the game), and Figure 7.16 (in comparison).

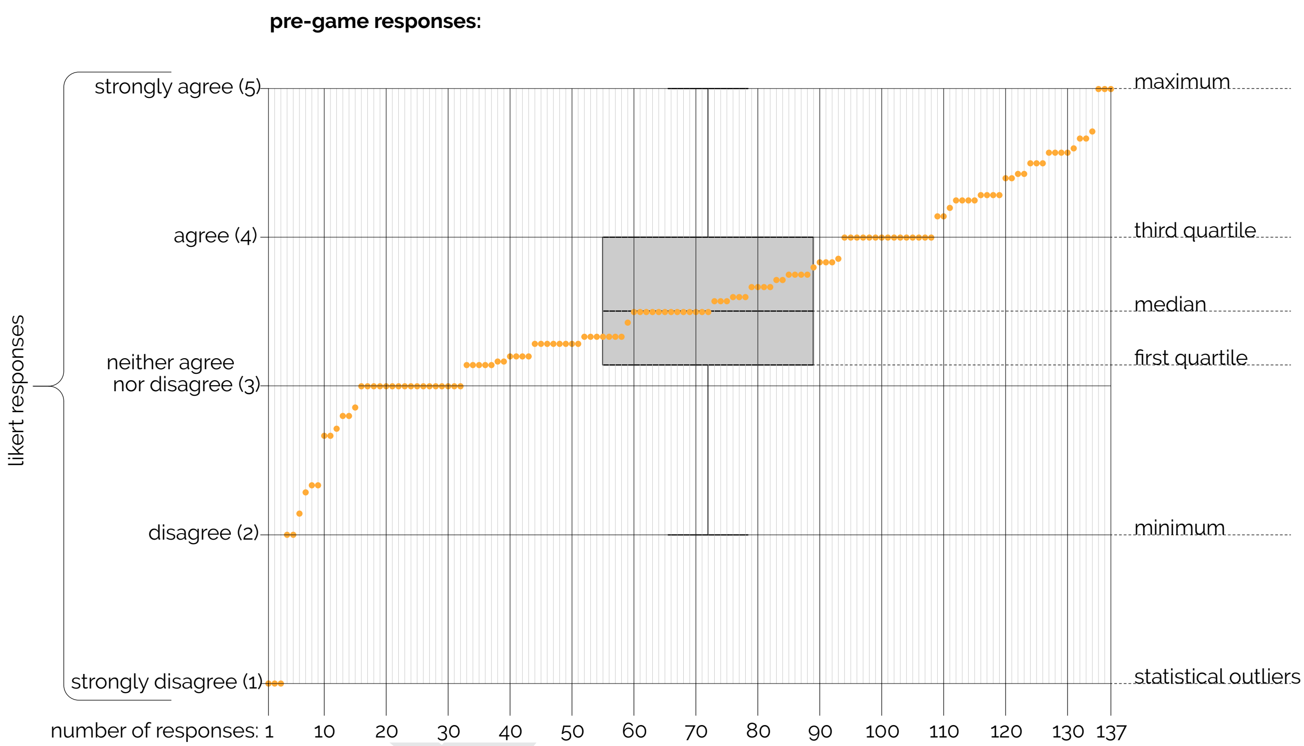


Figure 7.14. Responses to composite of seven questions relevant to Learning and Awareness from the pre-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0.

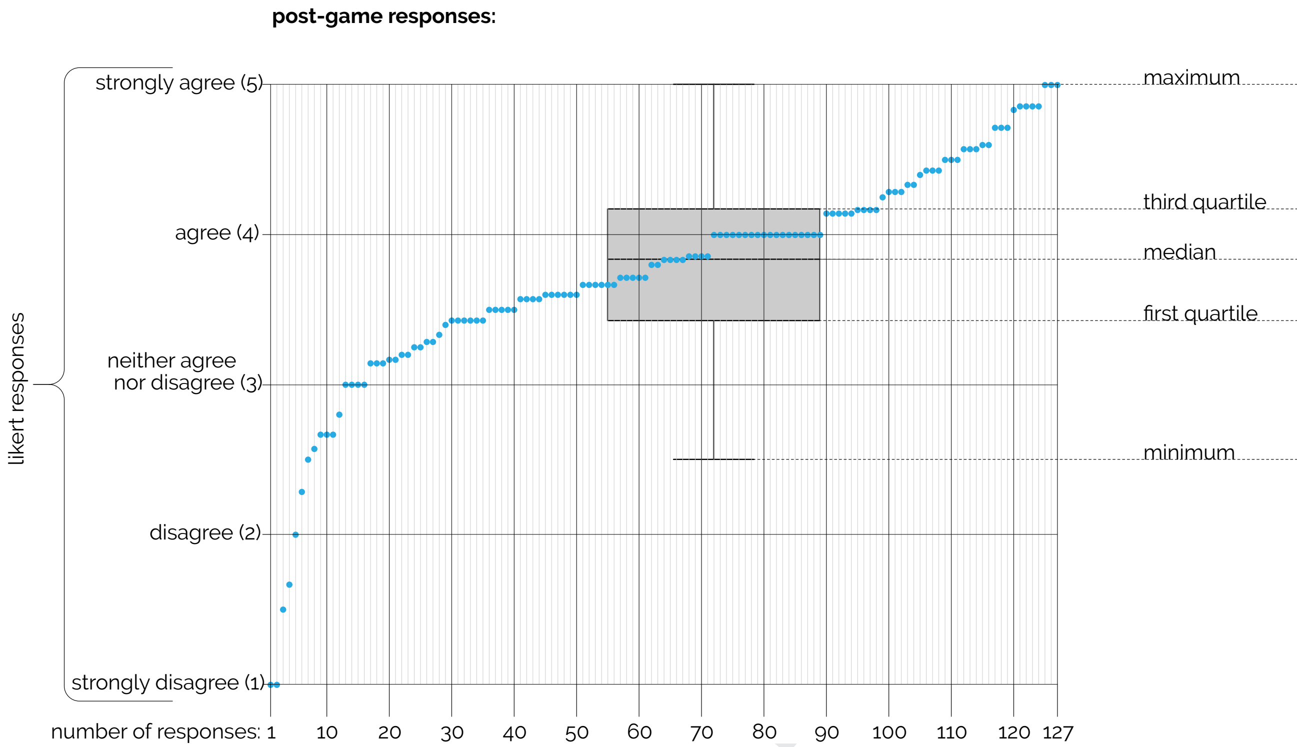


Figure 7.15. Responses to composite of seven questions relevant to Learning and Awareness from the post-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0.

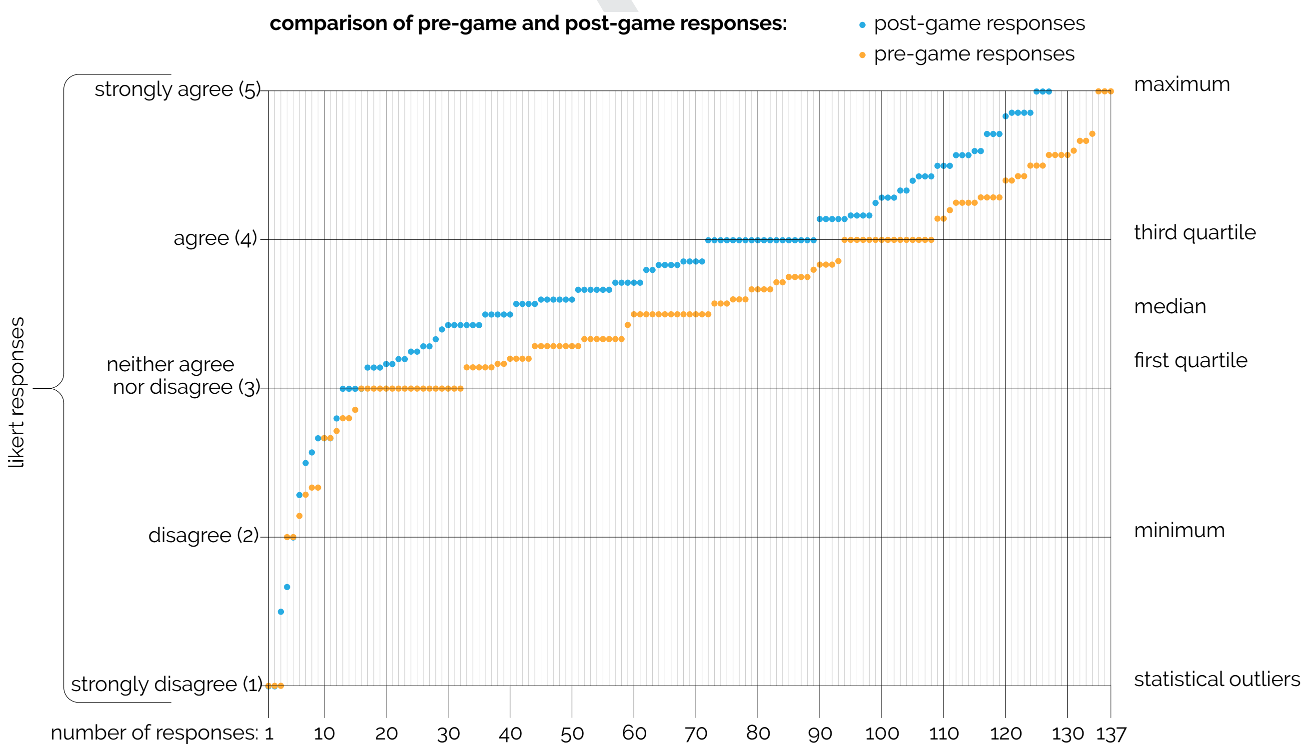


Figure 7.16. Responses to composite of seven questions relevant to Learning and Awareness from the pre-game survey (in orange) and the post-game survey (in blue) given to students at L. Middle School in K-12 Energy Challenge 2.0.

To determine the statistical significance of these observations, a two-sample t-test was conducted assuming equal variances.[1] The t-value was calculated as -2.40. The t-critical value (two-tail) was calculated as 1.96. This suggests that the null hypothesis may be rejected and we conclude that the pre-game and post-game responses differ significantly. The p-value was calculated as 0.017 (<0.05), suggesting that the results are statistically significant.

Thus, with respect to the measurement of student responses to paired questions in K-12 Energy Challenge 2.0, playing an open, pervasive game can lead to Learning and Awareness about energy-savings.

7.3.6 Paired question with objective responses

On both of the surveys given to students at L. Middle School, one question (pre-game survey question Q6 and post-game survey question Q8) had objectively correct and incorrect responses (Table 7.19).

Table 7.19. Paired question relevant to Learning and Awareness from survey given to students at L. Middle School in K-12 Energy Challenge 2.0.

pre-game question #	post-game question #	question text
Q6	Q8	Building occupants can achieve the following percentage of energy savings if they are aware of where and how energy is being wasted. (5%, 10%, 15%, 20% , up to 25%, Don't Know)

The correct responses to this question were "20%" or "up to 25%." Responses from the two surveys were recorded as shown in Figure 7.17 (pre-game) and Figure 7.18 (post-game).

1 Prior to conducting the t-test, an F-test returned a F-critical value of 1.34 and an F-statistic of 1.02. The F-statistic is less than the F-critical value, suggesting that the null hypothesis cannot be rejected and that the variances of V1 and V2 are equal. However, the calculated p-value of 0.463 (>0.05) implies that this result is not statistically significant, and that consequently, the null hypothesis concerning variances cannot be rejected. Thus, a two-sample t-test was conducted assuming equal variances.

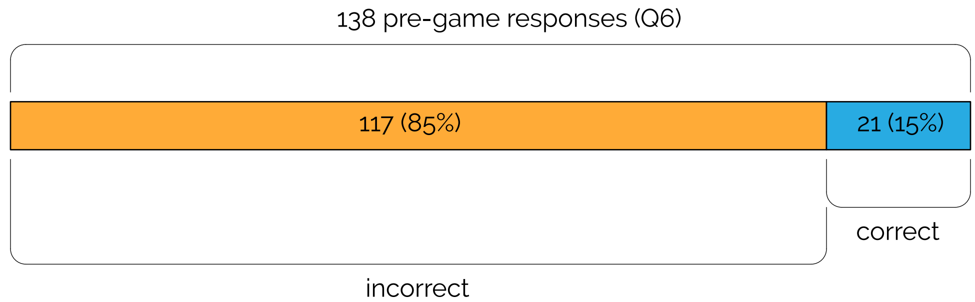


Figure 7.17. Responses to question Q6 from pre-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0.

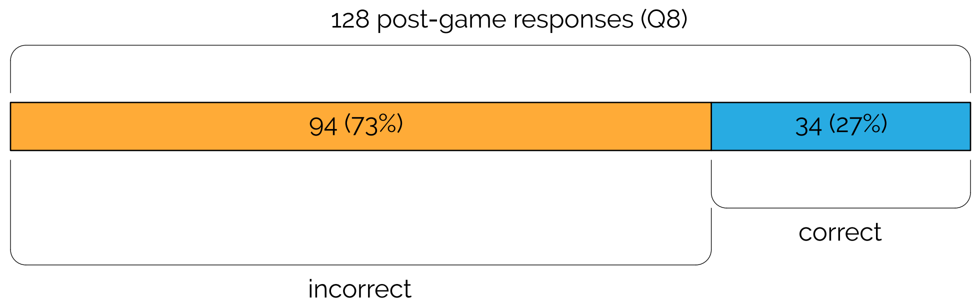


Figure 7.18. Responses to question Q8 from post-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0.

To summarize, students were more likely to provide a correct response to Q6/Q8 following the intervention. To determine the statistical significance of this observation, a two-sample t-test was conducted assuming equal variances.[1] The t-value was calculated as -2.30. The t-critical value (two-tail) was calculated as 1.97. This suggests that the null hypothesis may be rejected, suggesting that the pre-test and post-test responses differ significantly. The p-value was calculated as 0.02 (<0.05), suggesting that the results are statistically significant.

Thus, with respect to the measurement of student responses to Q6/Q8 in K-12 Energy Challenge 2.0, playing an open, pervasive game can lead to Learning and Awareness about energy-savings.

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1 Prior to conducting the t-test, an F-test returned a calculated F-critical value of 1.56 and an F-statistic of 1.26. The F-statistic is less than the F-critical value, suggesting that the null hypothesis cannot be rejected and that the variances of V1 and V2 are equal. However, the calculated p-value of 0.193 (>0.05) implies that this result is not statistically significant, implying that the null hypothesis concerning variances cannot be rejected. Thus, a two-sample t-test was conducted assuming equal variances.

7.3.7 Dissemination of learning & awareness: Implications for spatial expansion about motivation to save energy in a different typology

Specifically with respect to dissemination or spatial expansion (to a typology beyond the K-12 Energy Challenge), measurement was done through a combination of two questions from a post-game survey given to students at L. Middle School (Table 7.20). The two questions were directed to discovering whether participation in the K-12 Energy Challenge could lead to possible spatial expansion of knowledge outside of the school (i. e., specifically to the students' homes).

Table 7.20. Questions relevant to Learning and Awareness, and specifically to dissemination, from the post-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0.

post-game question #	question text
Q24	Participating in the K-12 Energy Challenge helped me become conscious of energy use in my home.
Q25	Participating in the K-12 Energy Challenge motivated me to save energy use in my home.

Question responses used a five-point Likert scale ("Strongly agree," "Agree," "Neutral," "Disagree," "Strongly disagree"). For purposes of analysis, responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). Figure 7.21 illustrates the responses to the two questions, graphically sorted by mean-value response to a composite of both questions. Inspection of Figure 7.21 suggests that the responses show good cross-question reliability. To test this observation, Cronbach's alpha for the two questions (Q24 and Q25) was calculated as .749, indicating a good level of reliability across the questions, i. e., that the responses to the two questions in Table 7.20 are well-correlated.

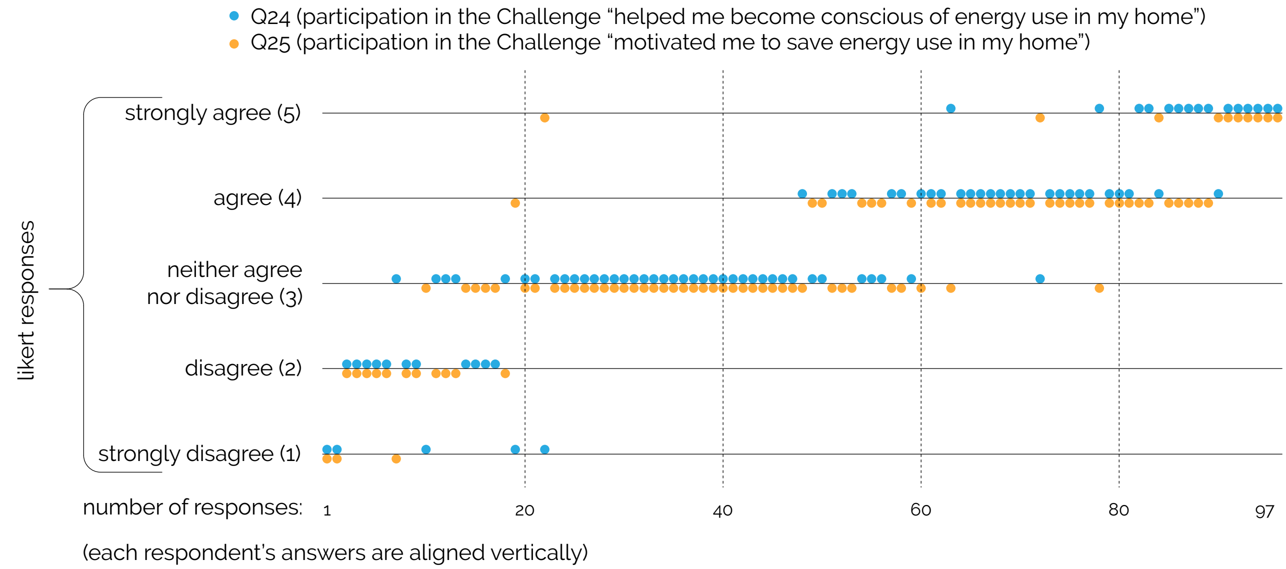

Figure 7.21. Cross-question reliability for two questions relevant to Learning and Awareness, and specifically dissemination and spatial expansion, from the post-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0. Respondents sorted by mean-value response to composite of both questions.

Figure 7.22 illustrates the responses to the two questions, graphically sorted by response. Inspection of Figure 7.22 suggests that the mean response to the three questions is higher than a hypothesized mean response of 3.0.

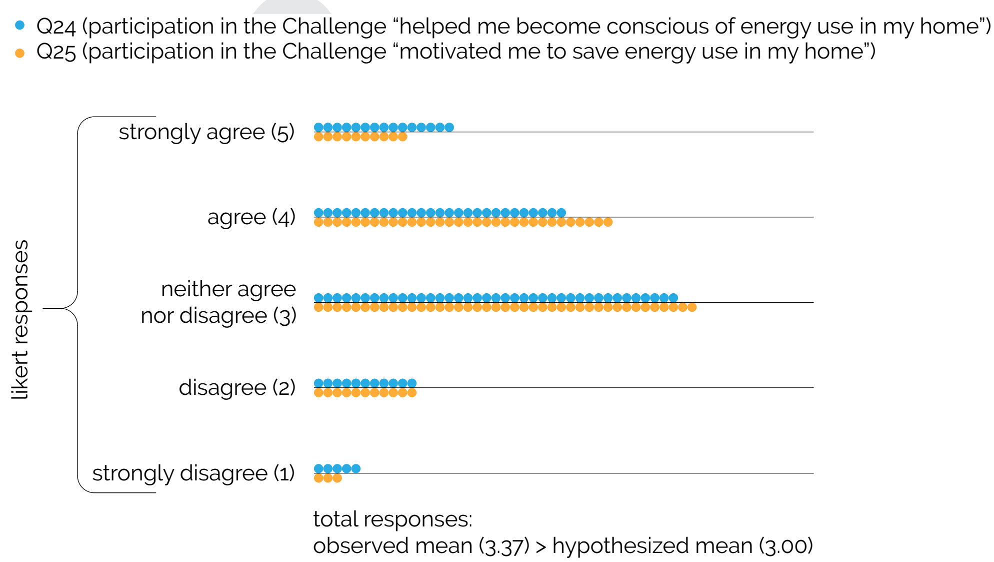

Figure 7.22. Mean-value responses for two questions relevant to Learning and Awareness, and specifically dissemination, from the post-game survey given to students in K-12 Energy Challenge 2.0.

To verify this, the mean of numerical values assigned to responses from all three questions was computed to form a compound variable. Non-responses were omitted from subsequent analysis. Table 7.21 includes the descriptive statistics for this variable. Note that higher values indicate more agreement.

Table 7.21. Descriptive statistics for responses to composite of two questions relevant to Learning and Awareness, and specifically dissemination, from the post-game survey given to students in K-12 Energy Challenge 2.0.

variable	n	range	mean	median	standard deviation
compound of Q24 and Q25	97	1.00 to 5.00	3.37	3.5	0.88

The observed mean (3.37) is greater than the hypothesized mean (3.00). To test the statistical significance of this observation, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (3). For the sample size of 97, the t-critical value was calculated as 1.985, and the t-statistic was calculated as 4.106. The p-value of 0.001 is less than 0.05, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 3 is outside of the 95% confidence interval of [3.189, 3.543], i. e., the observed mean is significantly different from the neutral point of the scale. The difference between the mean level of agreement and the neutral point of the scale is therefore statistically significant.

Thus, with respect to the measurement of post-game questions in the student survey related to awareness, playing an open, pervasive game can lead to a perception of Learning and Awareness about energy-savings in another building typology, a form of spatial expansion. Motivation to save energy in another typology could also be understood as a perception of willingness to engage in energy-saving behavior.

7.4.3 Energy-saving behavior (K-12 Energy Challenge 2.0 / 2017)

Engagement and activities that involved changing energy use behaviors and one-time activities were charted with weekly interviews and emails with teachers and staff involved in the K-12 Energy Challenge (Table 7.xx). In addition, perception of willingness to change behavior was measured and assessed in K-12 Energy Challenge 2.0 using a combination of three questions from two surveys given to students at L. Middle School (Table 7.22). The first survey (pre-game) was completed by (n=138) students before K-12 Energy Challenge 2.0 gameplay and the second survey (post-game) was completed by (n=128) students following completion of the K-12 Energy Challenge 2.0 game.

Table 7.22. Questions relevant to energy-saving behavior from the pre-game and post-game surveys given to students at L. Middle School in K-12 Energy Challenge 2.0.

pre-game question #	post-game question #	question text
Q2	n/a	I turn off lights & TV when I leave the room to save energy.
n/a	Q2	I turn off lights & TV when I leave the room to save energy in school and at home.
Q4	Q4	I unplug all my devices such as chargers, computers, laptops and games when I am not using them.
Q13	n/a	My behavior can make a difference as to how much energy is used in a building.
n/a	Q14	My behavior can change how much energy is used in a building.

Responses used a five-point Likert scale ("Strongly agree," "Agree," "Neutral," "Disagree," and "Strongly disagree"). For purposes of analysis, responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). Students were also given the option to select "don't know", and these responses were excluded from the analyses that follow.

Figure 7.7 illustrates the responses to the three pre-game questions, graphically sorted by respondent. Inspection of Figure 7.7 suggests that the responses show fair cross-question reliability. To test this observation, Cronbach's alpha for the three pre-game questions listed in Table 7.22 was calculated as 0.633, indicating a questionable level of reliability across the questions, i. e., that the responses to the three pre-game questions in Table 7.22 are not well-correlated.

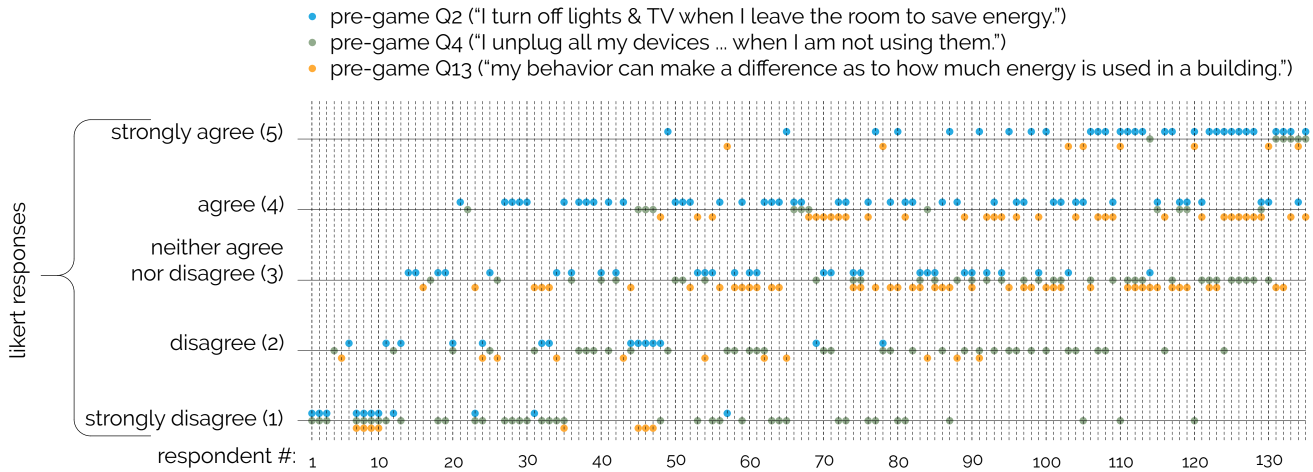

Figure 7.7. Cross-question reliability for three questions relevant to energy-saving behavior from the pre-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0. Respondents sorted by mean-value response to composite of all three questions.

Similarly, Figure 7.8 illustrates the responses to the three post-game questions, graphically sorted by respondent. Inspection of Figure 7.8 suggests that the responses show fair cross-question reliability. To test this observation, Cronbach's alpha for the three post-game questions listed in Table 7.22 was calculated as 0.637, indicating an questionable level of reliability across the questions, i. e., that the responses to the three post-game questions in Table 7.22 are not well-correlated.

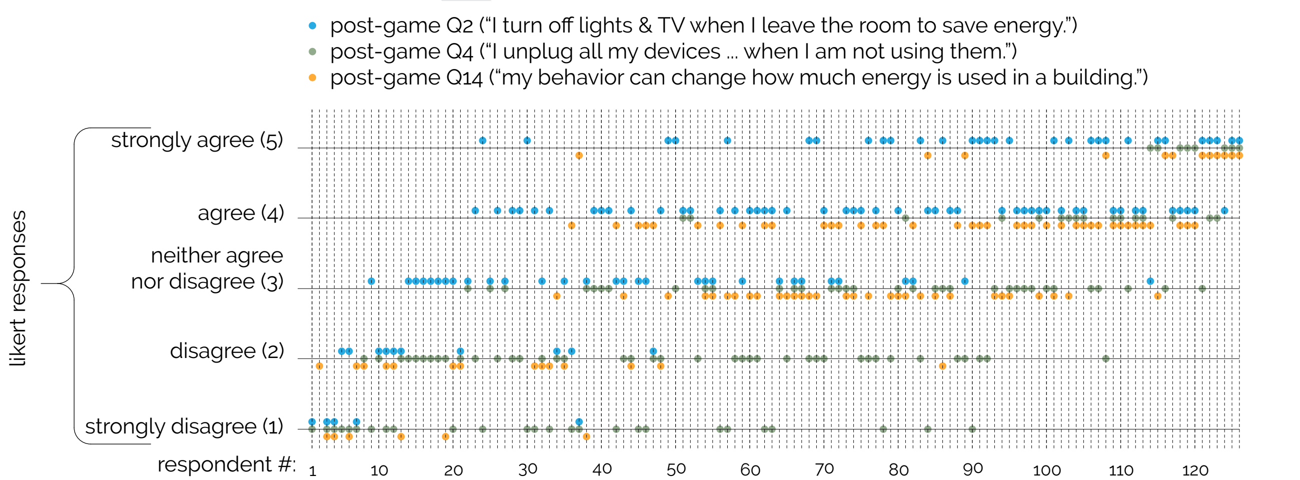

Figure 7.8. Cross-question reliability for three questions relevant to energy-saving behavior from the post-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0. Respondents sorted by mean-value response to composite of all three questions.

Figure 7.9 illustrates the responses to the three pre-game questions, graphically sorted by response. Inspection of Figure 7.9 suggests that the mean response to the four pre-game questions is close to a hypothesized mean response of 3.0.

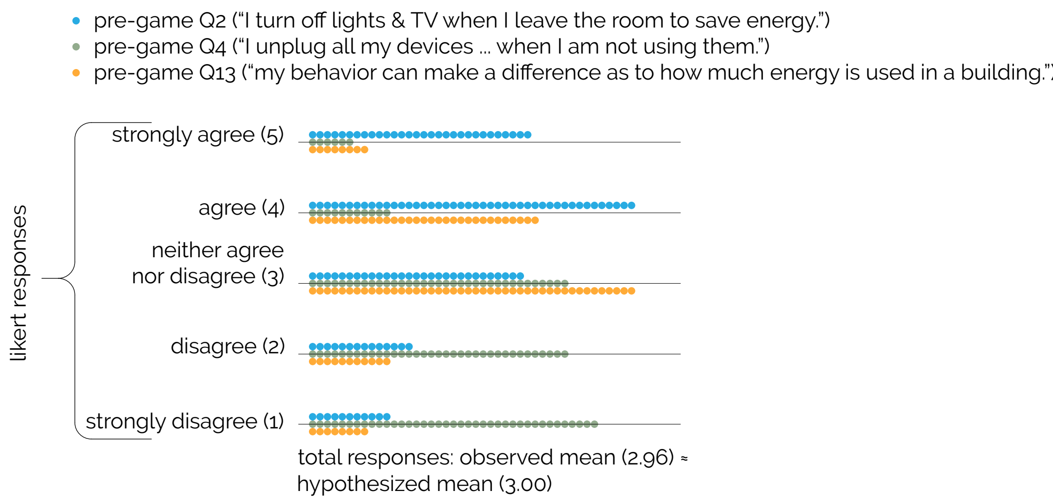

Figure 7.9. Mean-value responses for three questions relevant to Behavior change from the pre-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0.

Similarly, Figure 7.10 illustrates the responses to the three post-game questions, graphically sorted by response. Inspection of Figure 7.10 suggests that the mean response to the four post-game questions is close to a hypothesized mean response of 3.0.

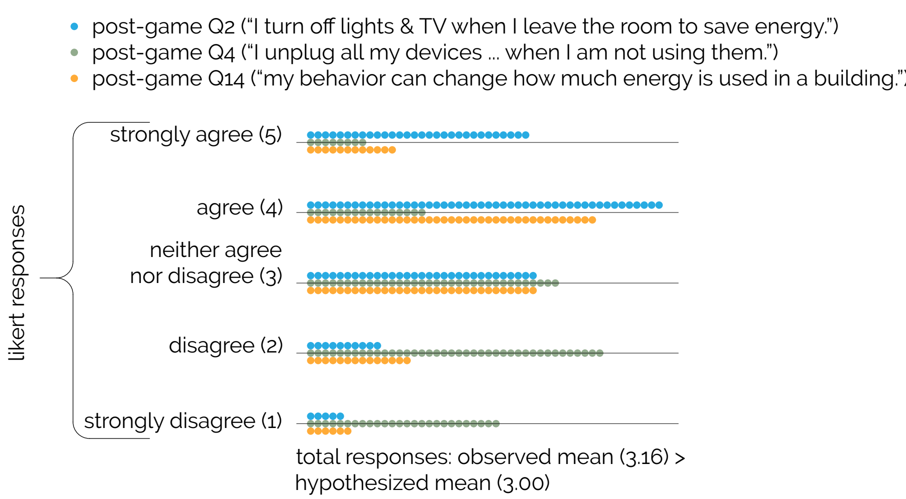

Figure 7.10. Mean-value responses for three questions relevant to energy-saving behavior from the post-game survey given to students at L. Middle School in K-12 Energy Challenge 2.0.

To test these observations, each question set was combined into a compound variable. Compound variable V1 represents the combined effect of pre-test questions (Q2, Q4, and Q13) and compound variable V2 represents the combined effect of post-test questions (Q2, Q4, and Q14). Non-responses were omitted from subsequent analysis. Descriptive statistics for the two compound variables were calculated. Table 7.23 shows the descriptive statistics for the two variables. Note that higher values indicate more agreement.

Table 7.23. Descriptive statistics for composite of three questions relevant to energy-saving behavior from the pre-game and post-game surveys given to students at L. Middle School in K-12 Energy Challenge 2.0.

variable	n	range	mean	median	standard deviation
V1	135	1.00 to 4.67	2.96	3	0.81
V2	126	1.00 to 5.00	3.16	3.33	0.84

Inspection of the descriptive statistics shows that the mean response and median response increased in the post-test responses. To determine the statistical significance of these observations, a two-sample t-test was conducted assuming equal variances.[1] The t-value was calculated as -1.89. The t-critical value (two-tail) was calculated as 1.97. This is insufficient to reject the null hypothesis. However, the p-value was calculated as 0.06 (>0.05), suggesting that the results of the t-test are not statistically significant.

Thus, with respect to the student survey data in K-12 Energy Challenge 2.0, although the descriptive statistics shows that the mean response and median response increased in the post-test responses, the results were not statistically significant.

1 Prior to conducting the t-test, an F-test returned a calculated F-critical value of 1.36 and an F-statistic of 1.08. The F-statistic is less than the F-critical value, suggesting that we cannot reject the null hypothesis that the variances of V1 and V2 are equal. However, the calculated p-value of 0.337 (>0.05) implies that this result is not statistically significant, and that consequently, we cannot reject the null hypothesis concerning variances. Thus, the t-test was conducted assuming equal variances

7.3 Energy Challenge 2.0 take-aways

During K-12 Energy Challenge 2.0, at the request of the Fargo Public Schools District curriculum coordinator, surveys for participating elementary-school children were limited to a three-response scale (i. e., agreement, disagreement and do not know). The participating middle school completed surveys with a 5-point Likert scale. Only the 5-point surveys (i. e., the middle-school responses) were analyzed. L. Middle School (the middle school that participated in the Challenge) showed statistically significant results in Learning and Awareness and Dissemination (the social expansion of learning to homes).

Regarding the willingness to engage in energy-saving behavior, although mean-value responses improved from pre-game to post-game perceptions, the change was not statistically significant. Also, the responses to the behavior-change-related questions were widely distributed across the Likert scale. This may be explained by the activities and engagement reported by the teachers at the middle school. L. F. Elementary focused only on educational and awareness activities in the first three weeks of the competition. Even in the last three weeks of the competition, the school's engagement in energy-saving action items was very low compared to other schools and was still focused on awareness activities (e. g., presentations, announcements and poster-making). One of the positive outcomes of this focus on learning was the perception of spatial expansion that occurred. In response to questions related to understanding of energy waste and the potential for energy savings in homes, the surveys returned statistically significant positive outcomes.

Another positive outcome was that the physical game with its tools such as tags, meters, toolkits, and video introductions returned results in the form of substantive reductions in energy savings in the top three schools engaged in energy-saving behaviors and learning activities. The dashboard that provided stickers for tagging the energy waste and allowed students and teachers to differentiate and record their energy-saving activities in different categories such as lighting, devices, heating and cooling, and miscellaneous provided structure, direction, and room for creativity and flexibility. However, feedback from teachers and staff provided the opportunity to continue improvements to the game and game tools design. Suggestions for improvements included providing more direction to the students and teachers in terms of energy-saving activities, with learning activities at various challenge levels so teachers could determine what was appropriate for their class. Teachers and staff were also interested in having the engagement scoring reflect the number of students, teachers, and staff that participated, and not just the activity and the number of days on which it had an impact. Suggestions for improvement to the physical game tools included providing non-sticker tags so that painted surfaces would not peel, and providing ways to attach or hang the dashboards. The introductory video that provided a preview of how to play the game was appreciated, including the structured timeline and game-play instructions. At the events where efargo researchers introduced the game to the students, the team received questions about what the school would win in terms of a prize. Students were given choices of a tree being planted in their school or winning a FLIR camera. Almost unanimously the students voted for the tree. The winning school, R. Elementary, had a 3”-diameter tree planted in their front yard. In addition, student leaders received Energy Star certificates and all students who participated in the Challenge received a tree sapling donated by the Cass County Soil Conservation office.

The timing of K-12 Energy Challenge 2.0 was a key concern for teachers. Because the Challenge was implemented late in the school year, it competed with several end-of-school-year activities and scheduled events. This impacted not only participation but also the ability to complete surveys and meter readings. For example, surveys and interviews at L. C. Elementary were not implemented due to a lack of time at the end of the school year. A related problem during the first two implementations of the K-12 Energy Challenge was alignments across schools in classroom schedule. Due to various teaching approaches for different grades, teachers were limited in their ability to participate. At L. F. Elementary School, due to prior commitments, teachers were unable to participate as fully as they would have liked to do during 2016 and 2017. Similarly, J. Elementary was able to participate only for one week during Spring 2016 and then did not return in 2017.

7.4 K-12 Energy Challenge 3.0

Several changes were incorporated for testing future potential asynchronous play in K-12 Energy

Challenge 3.0, held in Spring 2018. K-12 Energy Challenge 3.0 introduced the idea of classrooms within schools competing with each other instead of competing against other schools or against students in other schools (i. e., schools could participate based on their specific class schedules and curricular needs), thus providing more flexibility in participation. Calendar coordination would need to occur only between teachers and classrooms in the same school and grades, rather than across schools and across grades in the same school. Given the resources available, the competition was purposefully limited to two schools from which multiple classrooms could participate. This allowed the efargo team to conduct controlled surveys of the same group of students pre- and post-game. (The change in structure followed the example set by L. C. Elementary in K-12 Energy Challenge 1.0, where all of the classrooms from a single grade participated in the Challenge, involving others in the school only during specific event times.)

Although K-12 Energy Challenge 3.0 game play included tagging energy waste in the building, making waste visible, the focus was on earning engagement points by completing activities for a competition between classrooms. As such, plaques and awards were the incentive for the classrooms, rather than a school receiving a tree for achieving the greatest energy savings. Several learning activities, links to other games, and specific action items were provided, grouped by difficulty level, in categories such as lighting, heating and cooling, devices, kick-off activities, and bonus points. Moreover, the point system was tied to the number of people participating. Points were assigned based on the activity's difficulty level (1 point, 5 points or 10 points) and adding the points associated with the range of participant numbers.

Two schools committed to participate for the duration of the game and to conduct pre- and post-game surveys. The schools collectively fielded a total of seven fifth-grade classrooms (three from W. Elementary School and four from L. F. Elementary School), which was manageable within the funding available, In keeping with the spirit of testing an open, voluntary game, the classrooms were decided on a first-come, first-served basis. A total of 134 students, 7 teachers, 2 support staff members, and 2 facility managers participated in the game (Table 7.24).

Table 7.24. Participation in K-12 Energy Challenge 3.0. Spring 2018

	W. Elementary (S Classroom)		W. Elementary (K Classroom)		W. Elementary (C Classroom)		L. F. Elementary (P Classroom)		L. F. Elementary (M Classroom)		L. F. Elementary (C Classroom)		L. F. Elementary (B Classroom)		TOTAL
	W1	W3	W1	W3	W1	W3	W1	W3	W1	W3	W1	W3	W1	W3	
Students	18	18	20	21	19	21	19	20	18	16	21	19	20	19	134
Teachers	1		1		1		1		1		1		1		7
Support Staff	1		0		0		0		1		0		0		2
Community Volunteers	0		0		0		0		0		0		0		0
Facility	0		0		0		0		1		0		0		1

7.5.1 Energy savings (K-12 Energy Challenge 3.0 / Spring 2018)

Because meter readings and any resultant energy savings could not be attributed to specific classrooms within the school, energy savings were reported by school and not by classroom. Following the conjecture that increased engagement would result in energy savings, the competition focused on improving engagement and activity points. Yet, despite its high levels of engagement and activity, of the four implementations of the Challenge, K-12 Energy Challenge 3.0 achieved the least amount of energy savings (Table 7.25).

Table 7.25. Analysis of weekly meter readings (using the Kissock method) from schools participating in K-12 Energy Challenge 3.0.[1]

dates	period	L. F. Elementary School	W. Elementary School	Control*	units
April 7- April 13, 2017	Baseline Week	109.18	141.37		kWh/ HDD + CDD
April 14 - May 4, 2017	Competition period Week 1 - 3	102.07	139.4252		kWh/ HDD + CDD
	increase or decrease	decrease of 6.51%	decrease of 1.39%		

The winning school, L. F. Elementary School, decreased its NEU by 6.51%. W. Elementary School decreased its NEU by 1.39% (Figure 7.xx).

1 See Appendix X.X for a more detailed data analysis.

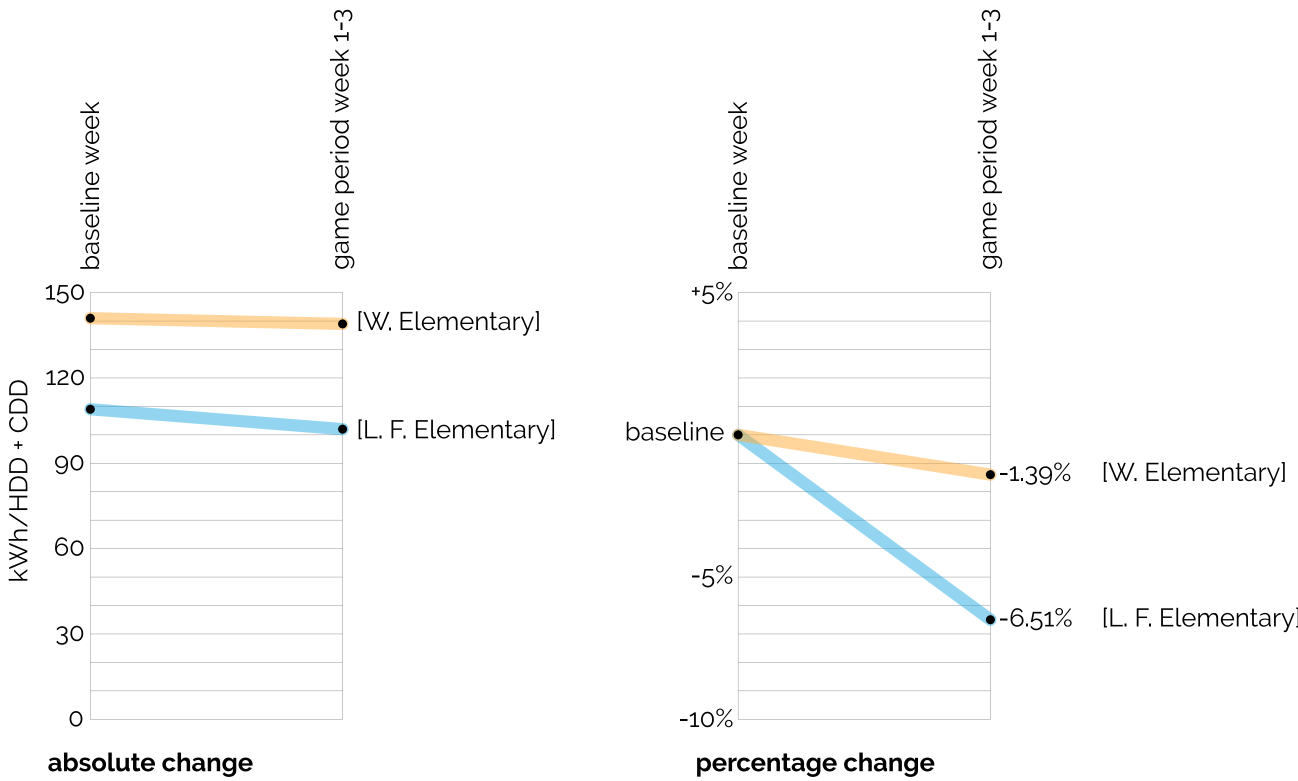

Figure 7. xx. Absolute and percentage change in normalized energy use (NEU), relative to baseline week, for schools participating in K-12 Energy Challenge 3.0.

7.5.2 Engagement in learning activities and action items (K-12 Energy Challenge 3.0 / 2018 spring)

The game was introduced using the same video used in K-12 Energy Challenge 2.0. In K-12 Energy Challenge 3.0, tagging became an introductory learning activity to kick off the game. Three forms of media (VR files, website files, and Energy Cards with several examples of typical energy waste) were provided to students to prompt them to find and tag typical areas of energy waste around the schools in order to learn about energy waste and energy savings. Points were earned on the basis of difficulty of the activity and numbers of students participating, rather than by capturing tags. The more difficult the activity and the greater the student participation, the more points could be earned. Unlike the first and second challenges, where the weekly energy savings and narratives of activity types were included in the weekly reports, the weekly point totals were the focus of the reports in Energy Challenge 3.0 (Table 7.26). Teachers emailed photographs of their weekly scoreboards to the efargo team for consolidation into reports.

Table 7.26. Weekly point totals, K-12 Energy Challenge 3.0.

		WEEK 1							WEEK 2							WEEK 3						
		W. Elementary classrooms			L. F. Elementary classrooms				W. Elementary classrooms			L. F. Elementary classrooms				W. Elementary classrooms			L. F. Elementary classrooms			
		S	K	C	P	M	C	B	S	K	C	P	M	C	B	S	K	C	P	M	C	B
KICK OFF ACTIVITIES																						
1 pt	Appoint a Classroom Leader / VRtagging / Energy Cards tagging/ Online tour for tagging / set goals / expert talks/ Tag the Waste / Take a pledge / Play the home game	1			40	40	10	20			20	20	10		10	1						1
	PARTICIPATION RANGE	1			10	10	10	10			10	10	10		10	1						1
5 pts	Activities originated by classrooms				300	250	55					100	30	75					50	30	125	
	PARTICIPATION RANGE				10	10	10					5	5	5					10	1	5	
10 pts	Poster Contest				200	200	100	100	20	50						140		110				
	PARTICIPATION RANGE				10	10	10	10	1	5						1		10				
TOTALS	TOTALS: PARTICIPATION	1	0	0	30	30	30	20	1	5	10	15	15	5	10	2	0	10	10	1	5	1
	TOTALS: POINTS	1	0	0	540	490	165	120	20	50	20	120	40	75	10	141	0	110	50	30	125	1
LIGHTING																						
1 pt	Energy Saving Actions, Mission Lighting Game	5	13	50	40	40	20	40	40	3	32				30	28	50	50				50
	PARTICIPATION RANGE	1	10	10	10	10	10	10	10	1	10				10	10	10	10				10
5 pts	Lighting Energy Patrol, Light Power Hour, Classroom Design		60	250	300	300		250		15	75	50	300		200			120				75
	PARTICIPATION RANGE		10	10	10	10		10		1	10	5	10		10			10				10
10 pts	Light Bulb Comparison						210	100			100	60		220		20			1000	320	630	
	PARTICIPATION RANGE						10	10			10	5		5		1			10	10	10	
TOTALS	TOTALS: PARTICIPATION	1	20	20	20	20	20	30	10	2	30	10	10	5	20	11	10	20	10	10	10	20
	TOTALS: POINTS	5	73	300	340	340	230	390	40	18	207	110	300	220	230	48	50	170	1000	320	630	125
DEVICES																						
1 pt	Energy Saving Actions, Energy Meter Madness Game	5	1	4		10	20	40	45	2	2		30		30	1		10				50
	PARTICIPATION RANGE	1	1	1		10	10	10	10	1	1		10		10	1		1				10
5 pts	Devices Energy Patrol, Night Unplug, Weekend Unplug, The Day Amy Saved the World (Game)!	50	5		300	350	55	250		5	5	50	50	35	150	50		25		500	150	360
	PARTICIPATION RANGE	1	1		10	10	10	10		1	1	5	10	1	10	5		1		10	10	10
10 pts	Kill-a-Watt Meters			100			100	100				10				250	50		540			
	PARTICIPATION RANGE			10			10	10				1				5	5		10			

		WEEK 1							WEEK 2							WEEK 3						
		W. Elementary classrooms			L. F. Elementary classrooms				W. Elementary classrooms			L. F. Elementary classrooms				W. Elementary classrooms			L. F. Elementary classrooms			
		S	K	C	P	M	C	B	S	K	C	P	M	C	B	S	K	C	P	M	C	B
TOTALS	TOTALS: PARTICIPATION	2	2	11	10	20	30	30	10	2	2	6	20	1	20	11	5	2	10	10	10	20
	TOTALS: POINTS	55	6	104	300	360	175	390	45	7	7	60	80	35	180	301	50	35	540	500	150	410
HEATING / COOLING																						
1 pt	Energy Saving Actions, Conserving Energy Game		1				1	40		3	15	5			30			9		2	20	32
	PARTICIPATION RANGE		1		10		1	10		1	5	5			10			5		1	10	10
5 pts	Shading Energy Patrol, Thermostat settings		10		300	150	50	200		5	55	50		50	150			5	50			160
	Thermostats																					
	PARTICIPATION RANGE		1			10	10	10		1	10	5		5	10			1	5			10
10 pts	Insulation Experiments, Solar cookers						170							10		20			50		100	
	PARTICIPATION RANGE						10							1		1			5		5	
TOTALS	TOTALS: PARTICIPATION	0	2	0	10	10	21	20	0	2	15	10	0	6	20	1	0	6	10	1	15	20
	TOTALS: POINTS	0	11	0	300	150	221	240	0	8	70	55	0	60	180	20	0	14	100	2	120	192

Based on the weekly point totals of activities and numbers of students participating, L. F. Elementary School won the third challenge. The engagement points also aligned with the energy savings where L. F. Elementary School achieved more energy savings than did W. Elementary School. Several awards were given based on the highest number of points earned by a classroom (P Classroom at L. F. Elementary) and the greatest number of points in a particular activity (Lighting, Heating & Cooling, and Devices).

In addition to the engagement activities and resultant energy-savings achieved by the schools, pre- and post-game surveys were analyzed to test the various hypotheses.

7.x Hypothesis 1: Learning, awareness & dissemination of learning about energy-savings (social and spatial expansions) (K-12 Energy Challenge 3.0 / Spring 2018)

In K-12 Energy Challenge 3.0, Learning and Awareness was measured and assessed with respect to three data sources (Table 7.28).

Table 7.28. Data Sources, Learning and Awareness, K-12 Energy Challenge 3.0.

	2018
Learning and Awareness	1. Five paired questions from pre-game and post-game surveys completed by students 2. Eight post-game survey questions completed by students 3. Two post-game survey questions, specifically related to dissemination, completed by students

7.5.4.1 Comparison of pre- and post-game survey questions

Measurement was done by comparing a set of 5 questions from a pre-game survey given to students at L. F. Elementary School and W. Elementary School to a corresponding set of 5 questions (Table 7.29).

Table 7.29. Questions relevant to Learning and Awareness from the pre- and post-game surveys of students at L. F. Elementary School and W. Elementary School, in K-12 Energy Challenge 3.0.

pre-game question #	post-game question #	question text
Q1	Q1	I know where energy is being wasted in my school.
Q4	Q4	I know where energy is being wasted in my home.
Q18	Q18	My actions can change how much energy is used.
Q23	Q23	Energy use in buildings impacts the environment.
Q31	Q31	Letting the sun warm the classroom during winter can help reduce energy use.

Question responses used a five-point Likert scale (“Strongly agree,” “Agree,” “Neutral,” “Disagree,” “Strongly disagree”). For purposes of analysis, responses were assigned numerical values from 1 (for “Strongly disagree”) to 5 (for “Strongly agree”). Cronbach’s alpha for the five pre-game questions listed in Table 7.29 was calculated as 0.757, indicating an acceptable level of reliability across the question; similarly, Cronbach's alpha for the five post-game questions listed in Table 7.29 was calculated as 0.843, indicating a good level of reliability across the questions. This suggests that the responses to the five questions in Table 7.29 are acceptably correlated, with respect to both pre-game and post-game surveys.

Each question set was combined into a compound variable. Compound variable V1 represents the combined effect of pre-game questions (Q1, Q4, Q18, Q23, and Q31) and compound variable V2 represents the combined effect of post-game questions (Q1, Q4, Q18, Q23, and Q31). Table 7.30 includes the descriptive statistics for the two compound variables. Note that higher values indicate more agreement.

Table 7.30. Descriptive statistics for composite of five questions relevant to Learning and Awareness from the pre- and post-game surveys of students at L. F. Elementary School and W. Elementary School, in K-12 Energy Challenge 3.0.

variable	n	range	mean	median	standard deviation
V1	135	1.80 to 5.00	3.86	4	0.57
V2	134	1.00 to 5.00	4.04	4	0.69

Inspection of the descriptive statistics shows that in both V1 and V2, the mean response is higher than a hypothesized mean of 3.0. Further inspection of the descriptive statistics shows that the mean response increased (by 4.66%) while the median response remained unchanged in the post-game responses. The responses to the two variables are summarized in Figure 7.23 (before the game), Figure 7.24 (after the game), and Figure 7.25 (in comparison).

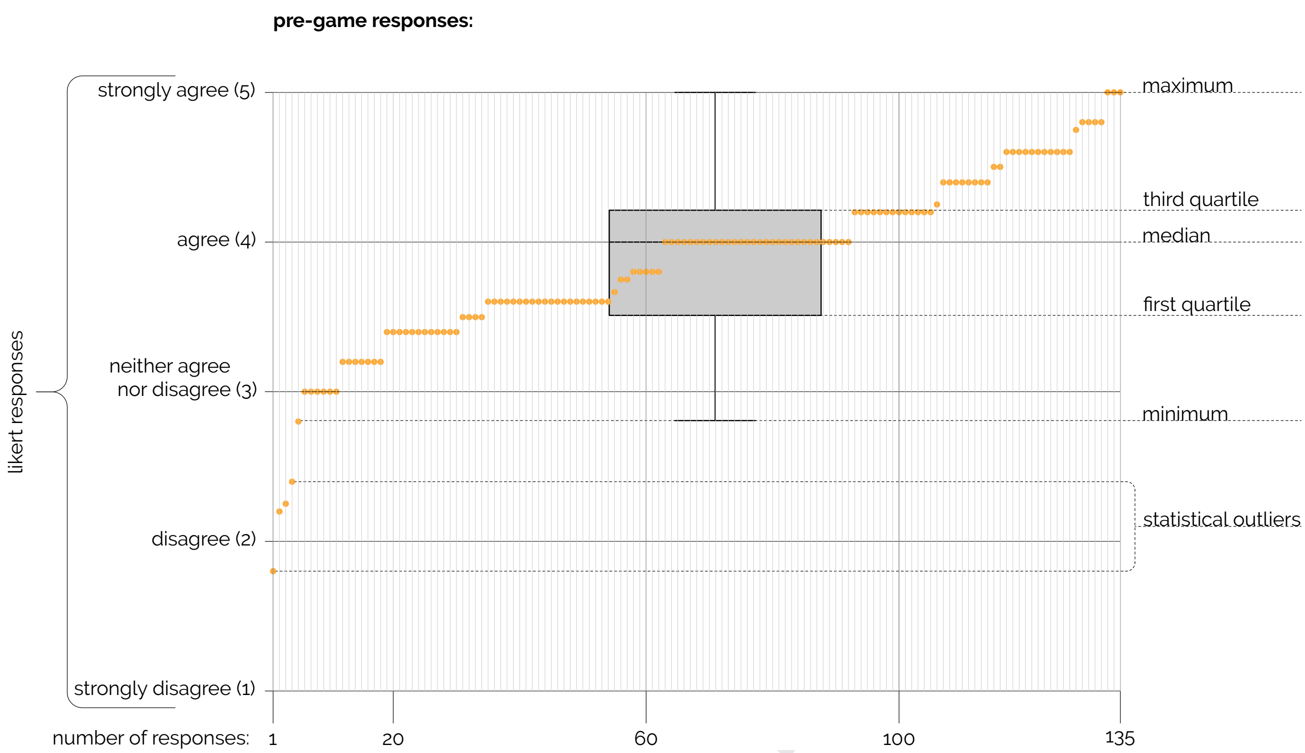

Figure 7.23. Responses to composite of five questions relevant to Learning and Awareness from the pre-game survey given to students in K-12 Energy Challenge 3.0.

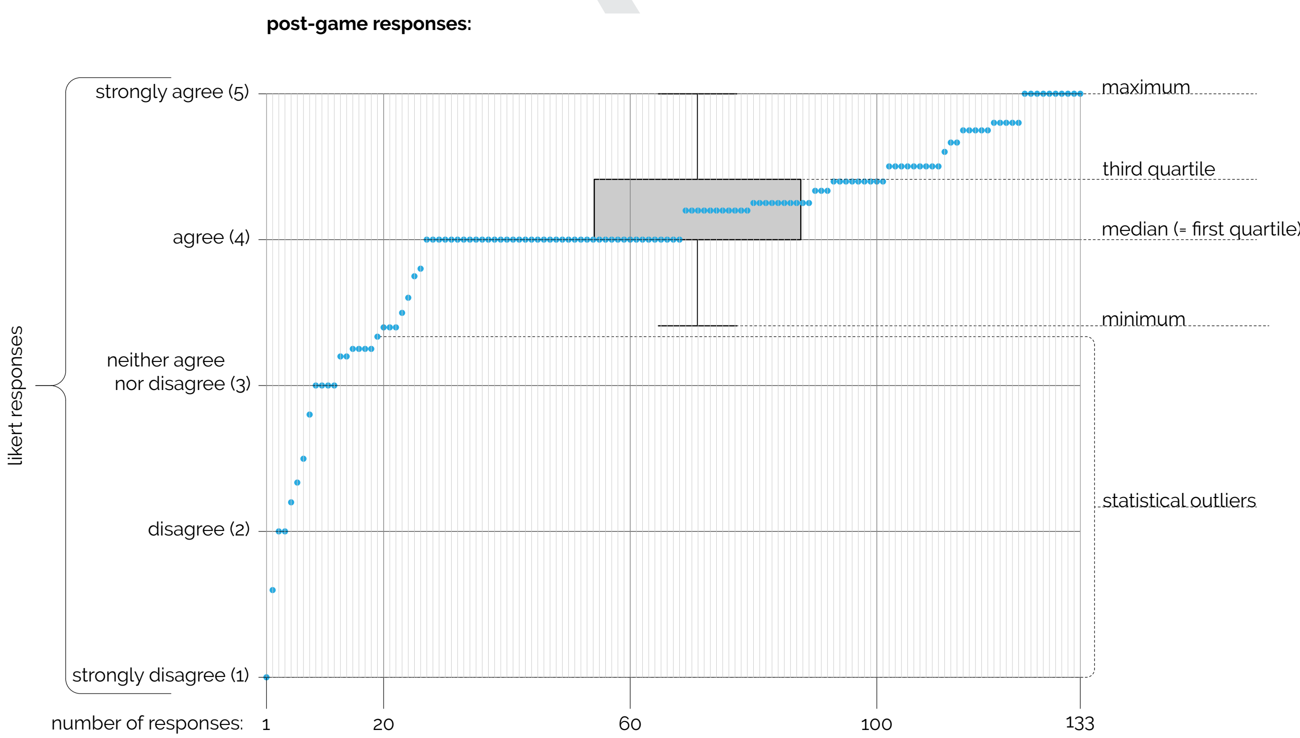

Figure 7.24. Responses to composite of five questions relevant to Learning and Awareness from the post-game survey given to students in K-12 Energy Challenge 3.0.

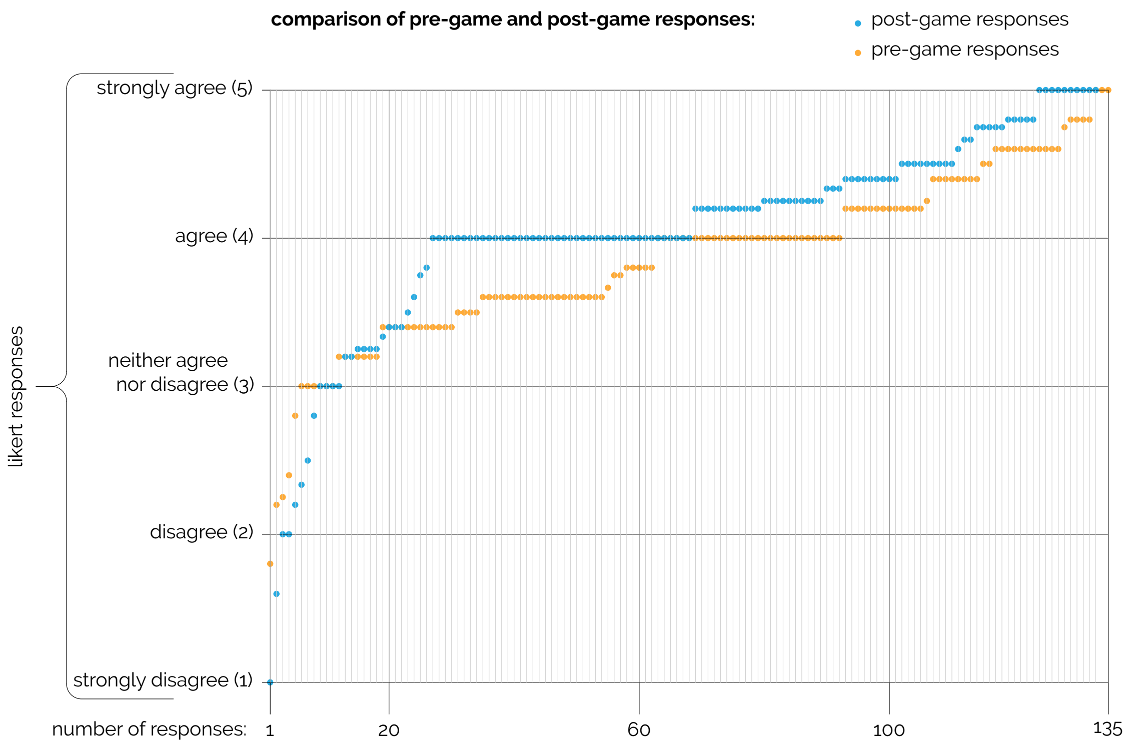

Figure 7.25. Responses to composite of five questions relevant to Learning and Awareness from the pre-game survey (in orange) and the post-game survey (in blue) given to students in K-12 Energy Challenge 3.0.

To determine the statistical significance of these observations, a two-sample t-test was conducted assuming equal variances.[1] The t-value was calculated as 2.59. The t-critical value (two-tail) was calculated as 1.97. Because the absolute value of the t-value exceeds the t-critical value, the null hypothesis may be rejected, and we conclude that the pre-game and post-game responses differ significantly. The p-value was calculated as 0.010 (<0.05), suggesting that the results are statistically significant.

Thus, with respect to the measurement of student responses to paired questions in K-12 Energy Challenge 3.0, playing an open, pervasive game can lead to Learning and Awareness about energy-savings and the results are statistically significant.

7.5.5.1 Post-game student survey

1 Prior to conducting the t-test, an F-test returned a F-critical value of 0.751 and an F-statistic of 0.612. The F-statistic is less than the F-critical value, suggesting that the null hypothesis cannot be rejected and that the variances of V1 and V2 are equal. Moreover, the calculated p-value of 0.002 (>0.05) implies that this result is statistically significant, and that consequently, the null hypothesis concerning variances cannot be rejected. Thus, a two-sample t-test was conducted assuming equal variances.

First, measurement was done using a combination of eight questions from a post-game survey given to students at L. F. Elementary School and W. Elementary School (Table 7.31).

Table 7.31. Questions relevant to Learning and Awareness from the post-game survey of students at L. F. Elementary School and W. Elementary School in K-12 Energy Challenge 3.0.

#	question text
Q1	I know where energy is being wasted in my school.
Q4	I know where energy is being wasted in my home.
Q11	I think I learned a lot about not wasting energy by doing the K-12 Energy Challenge.
Q13	I think I learned a lot about saving energy by doing the K-12 Energy Challenge.
Q14	Making sure that heating vents are not blocked can help reduce energy use.
Q18	My actions can change how much energy is used.
Q23	Energy use in buildings impacts the environment.
Q31	Letting the sun warm the classroom during winter can help reduce energy use.

Question responses used a five-point Likert scale ("Strongly agree," "Agree," "Neutral," "Disagree," "Strongly disagree"). For purposes of analysis, responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). Cronbach's alpha for the eight questions listed in Table 7.31 was calculated as .857, indicating a good level of reliability across the questions, i. e., that the responses to the eight questions in Table 7.31 are well-correlated.

The eight questions were combined into a compound variable. Non-responses were omitted from subsequent analysis. Table 7.32 includes the descriptive statistics for this variable. Note that higher values indicate more agreement.

Table 7.32. Descriptive statistics for questions relevant to Learning and Awareness from the post-game survey of students at L. F. Elementary School and W. Elementary School in K-12 Energy Challenge 3.0.

variable	n	range	mean	median	standard deviation
compound of Q1, Q4, Q11, Q13, Q14, Q18, Q23, and Q31	133	1.00 to 5.00	4.04	4.17	0.65

The observed mean (4.04) is greater than the hypothesized mean (3.00). To test the statistical significance of this observation, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (3). For the sample size of 133, the t-critical value was calculated as 1.978, and the t-statistic was calculated as 18.292. The p-value is less than 0.01, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 3 is outside of the 95% confidence interval of [3.926, 4.15], i. e., the observed mean is significantly different from the neutral point of the scale.

The difference between the mean level of agreement and the neutral point of the scale is therefore statistically significant.

Thus, with respect to the measurement of post-game questions in the student survey, playing an open, pervasive game can lead to Learning and Awareness about energy-savings.

7.5.6.2 Dissemination questions in post-game student survey

Specifically with respect to dissemination, measurement was done through a combination of two questions from a post-game survey given to students at L. F. Elementary School and W. Elementary School (Table 7.33).

Table 7.33. Questions relevant to Learning and Awareness, and specifically to dissemination, from the post-game survey given to students in K-12 Energy Challenge 3.0.

#	question text
Q19	I am excited to talk to my parents about what I learned from the K-12 Energy Challenge.
Q21	I will tell others what I learned from the K-12 Energy Challenge.

Question responses used a five-point Likert scale ("Strongly agree," "Agree," "Neutral," "Disagree," "Strongly disagree"). For purposes of analysis, responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). Cronbach's alpha for the two questions listed in Table 7.33 was calculated as .386, indicating a poor level of reliability across the questions, i. e., that the responses to the two questions in Table 7.33 are not correlated.

The two questions were combined into a compound variable. Non-responses were omitted from subsequent analysis. Table 7.34 includes the descriptive statistics for this variable. Note that higher values indicate more agreement.

Table 7.34. Descriptive statistics for composite of two questions relevant to Learning and Awareness, and specifically to dissemination, from the post-game survey given to students in K-12 Energy Challenge 3.0.

variable	n	range	mean	median	standard deviation
compound of Q19 and Q21	129	1.00 to 5.00	4.03	4	0.68

The observed mean (4.03) is greater than the hypothesized mean (3.00). To test the statistical significance of this observation, a single-sample t-test was conducted comparing the mean level of agreement from respondents to the neutral point of the scale (3). For the sample size of 129, the t-critical value was calculated as 1.979, and the t-statistic was calculated as 13.481. The p-value is less than 0.01, suggesting that the result of the t-test is statistically significant. The hypothesized mean of 3 is outside of the 95% confidence interval of [3.883, 4.187], i. e., the observed mean is significantly different from the neutral point of the scale.

The difference between the mean level of agreement and the neutral point of the scale is therefore statistically significant.

Thus, with respect to the measurement of post-game questions in the student survey, playing an open, pervasive game can lead to Learning and Awareness about energy-savings.

7.1.4 Energy-saving behavior in Energy Challenge 3.0 (2018 spring)

Energy-saving behavior was measured and assessed in K-12 Energy Challenge 3.0 using a combination of seven questions from pre- and post-game surveys given to K-12 students (Table 7.35).

Table 7.35. Questions relevant to energy-saving behavior from the pre-game and post-game surveys given to students in

K-12 Energy Challenge 3.0.

pre-game question #	post-game question #	question text
Q3	Q3	I want to take action to prevent energy waste.
Q6	Q6	I unplug my gaming system when I am not using it.
Q8	Q8	I unplug my laptop or chromebook when I am not using it.
Q10	Q10	I unplug my cellphone once it is fully charged.
Q20	Q20	I want to ask my parents to use less energy at home.
Q28	Q28	In the last two days I have shut the lights off when leaving rooms.
Q29	Q29	I have been shutting the TV off when I am not watching it.

Responses used a five-point Likert scale ("Strongly agree," "Agree," "Neutral," "Disagree," and "Strongly disagree"). For purposes of analysis, responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). Students were also given the option to select "don't know", and these responses were excluded from the analyses that follow. Cronbach's alpha for the seven pre-test questions listed in Table 7.35 was calculated as 0.745, indicating an acceptable level of reliability across the questions; similarly, Cronbach's alpha for the seven post-test questions listed in Table 7.35 was calculated as 0.849, indicating a good level of reliability across the questions. This suggests that the responses to the seven questions in Table 7.35 are acceptably correlated, with respect to both pre-game and post-game surveys.

Each question set was combined into a compound variable. Compound variable V1 represents the combined effect of pre-test questions and compound variable V2 represents the combined effect of post-test questions. Non-responses were omitted from subsequent analysis. Table 7.36 includes the descriptive statistics for the two compound variables. Note that higher values indicate more agreement.

Table 7.36. Descriptive statistics for composite of seven questions relevant to energy-saving behavior from the pre-game and post-game surveys given to students in K-12 Energy Challenge 3.0.

variable	n	range	mean	median	standard deviation
V1	135	1.5 to 5.0	3.63	3.71	0.75
V2	132	1.0 to 5.0	3.78	4	0.87

Inspection of the descriptive statistics shows that the mean response and median response increased in the post-test responses. To determine the statistical significance of these observations, a two-sample t-test was conducted assuming unequal variances.[1] The t-value was calculated as 1.44. The t-critical value (two-tail) was calculated as 1.97. This is insufficient to reject the null hypothesis. However, the p-value was calculated as 0.149 (>0.05), suggesting that the results of the t-test are not statistically significant.

Thus, with respect to the student survey data in K-12 Energy Challenge 3.0, although the mean response improved from pre- to post-game, the results for perception of willingness to engage in energy-saving behavior, were not statistically significant.

7.x K-12 Energy Challenge 3.0 take-aways

Although teachers appreciated the inclusion of participation numbers in the scoring, several clarifications were requested about how to score the activities. The scoreboard was not very clear. In addition, teachers at W. Elementary School had appreciated the ability to create their own activities in the second Challenge, which had been replaced with specific activities in the third Challenge. Teachers found this less flexible, but worked their way around this problem by inserting and reporting activities that did not exist on the scoreboards by writing them in. FOr example, there were no 5-point level activities in the Kick-Off week, teachers included their own activities and designed and wrote-in their interpretations or adjustments to the design as they needed. Teachers appreciated the shorter 3-week duration but found that too many activities were suggested for the duration of the game which included the kick-off activities

1 Prior to conducting the t-test, an F-test returned a calculated F-critical value of 1.33 and an F-statistic of 1.38. The F-statistic is greater than the F-critical value, suggesting that we may reject the null hypothesis that the variances of V1 and V2 are equal. Moreover, the calculated p-value of 0.033 (<0.05) implies that this result is statistically significant. Consequently, we reject the null hypothesis that the variances of the pre-test and post-test responses are equal. Thus, we conducted a two-sample t-test assuming unequal variances.

and bonus activities. Positive feedback was received about the Energy Cards and the online files that educated students about Waste-a-Watt tags and the energy waste they signified. In fact, tagging the waste became one of the highest point-earning activities in the next implementation of the game, while daily energy-saving actions received more attention and participation in the third Challenge, although for a much shorter duration (2 weeks of energy-saving activities).

7.6 K-12 Energy challenge 4.0

Due to the low energy savings achieved in K-12 Energy Challenge 3.0, the game design for K-12 Energy Challenge 4.0 (implemented in Fall 2018), returned to synchronous game play with schools competing for energy-use reductions. However, some aspects of K-12 Energy Challenge 3.0, such as recording engagement with a hierarchical point structure based on amount of participation and level of difficulty, were preserved, albeit clarified. Schools and classrooms were asked to commit to the game for its entire duration so that energy results could be compared and pre- and post-game surveys could be conducted with students who had actually participated in the activities. Multiple classrooms within a school could continue to participate in the game as separate entities.

New structural ideas were also introduced in K-12 Energy Challenge 4.0. Each week included activities that were titled "Daily Habits" and were repetitive. In addition, each week focused on a specific energy waste type and encouraged focused messaging, action, and learning with that energy-saving category such as lighting, heating & cooling, and devices. Week 1 was the kick-off tagging week, where Daily Habits were introduced and energy waste learning and identification activities were included; Week 2 was focused on lighting, Week 3 on Devices, and Week 4 on Heating and Cooling. Activist Fridays were introduced, focusing on spreading the message about reducing energy use and preventing energy waste on Fridays. As in previous implementations, schools were encouraged to involve non-participating classrooms, teachers and students, staff, community volunteers, and especially facilities managers (Table 7.37).

Table 7.37. Participation in K-12 Energy Challenge 4.0. Fall 2018

	W. Elementary (S Classroom)		W. Elementary (K Classroom)		W. Elementary (C Classroom)		C. Elementary (B Classroom)		M. Elementary (J Classroom)		TOTAL
	Week 1	Week 4	Week 1	Week 4	Week 1	Week 4	Week 1	Week 4	Week 1	Week 4	
Students	18	19	19	19	19	19	22	22	15	13	92
Teachers	1		1		1		1		1		5
Support Staff	1		0		0		1		1		3
Community Volunteers	0		0		0		0		0		0
Facility	0		0		0		1		1		3

7.6.1 Energy savings (K-12 Energy Challenge 4.0 / Fall 2018)

The control school, L. C. Elementary, was aware of the game (having been a participant in 2016 and 2017) but did not play the game in 2018. While L. C. Elementary administration and facilities allowed meter readings, the teachers did not allow pre- and post-survey data to be collected. All of the schools achieved energy savings in K-12 Energy Challenge 4.0 (Table 7.38; Figure 7.xx).

Table 7.38. Analysis of weekly meter readings (using Woodcock's method) from schools participating in K-12 Energy Challenge 4.0.[1]

dates	period	C. Elementary School	W. Elementary School	M. Elementary School	L. C. Elementary School*	units
Nov 29 - Oct 5, 2018	Baseline Week	75.03	50.31	27.83	60.87	kWh/ HDD + CDD
Oct 6 - Nov 2, 2018	Game period Week 1 - 4	63.5	43.87	23.44	55.74	kWh/ HDD + CDD
	increase or decrease	decrease of 15.36%	decrease of 12.80%	decrease of 15.75%	decrease of 8.42%	

1 See Appendix x.xxx for a more detailed data analysis.

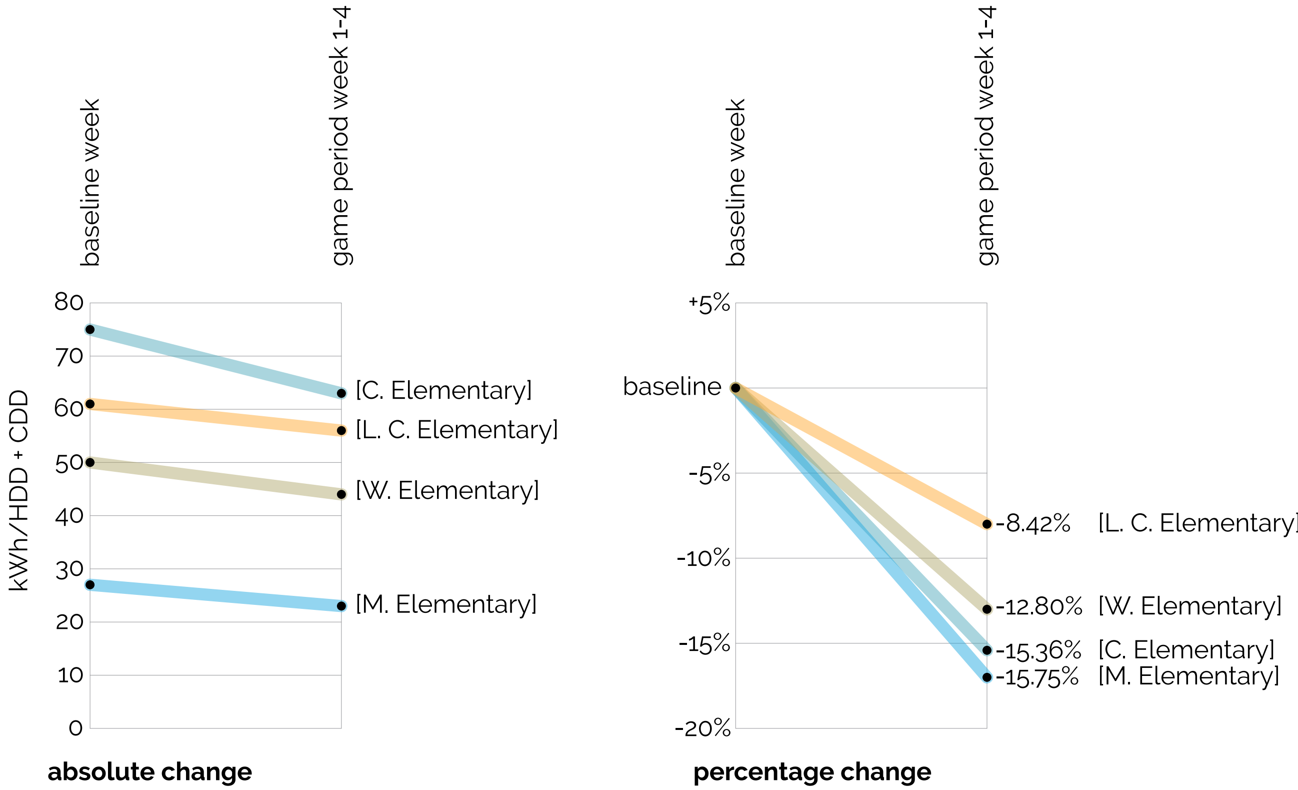

Figure 7.xx

It is unclear what caused L. C. Elementary, the control school, to achieve energy savings. Compared to the actively participating schools, L. C. Elementary had the lowest energy savings. The other schools had comparable energy savings. Different schools also received winning point totals (or the greatest level of engagement) at different times during the Challenge. For example, for the overall greatest point total for lighting, devices, heating and cooling, and kick-off weeks, C. Elementary's fifth-grade B Classroom was the winner. C. Elementary's B Classroom also emerged the consistent winner of Activist Friday throughout the competition. C. Elementary's B Classroom achieved 15.36% in electricity savings compared to baseline week. W. Elementary's K Classroom was the winner of activity point totals for devices in Week 3 and also the point total winner for Week 2 (Lighting) activities. W. Elementary's three classrooms achieved energy use reductions of 12.8% during the competition period. M. Elementary School's J Classroom was the winner for Week 1 activities that included Daily Habits in the areas of lighting, devices, and heating and cooling. As a school, M. Elementary School achieved the greatest energy savings, with a 15.75% reduction in energy use over the competition period (compared to baseline energy use).

Different classrooms in different schools focused their efforts on different areas of the competition and all achieved energy savings. However, it was the winner of the Daily Habits engagement category that ultimately had the greatest reductions in NEU by a slim margin. The Activist Friday winner, C. Elementary School's Classroom B, was also able to earn the most engagement points by creating posters and messaging for the rest of the school beyond the classroom space. They also won the overall point total for engagement in all activities in all weeks like lighting, devices, and heating and cooling. They had the next greatest energy savings by a small margin. Even though three classrooms participated from W. Elementary School and achieved a substantive reduction in NEU, it was lower than the other two schools which had only one classroom each participating in the Challenge. The persistence of daily actions, engagement in all actionable waste types, and the spreading of message to as many numbers of students in the schools, mattered when it came to saving energy.

7.6.2 Engagement in learning and energy-use behavior (K-12 Energy Challenge 4.0 / Fall 2018)

Table 7.39. xxxxxx

		WEEK 1					WEEK 2					WEEK 3					WEEK 4					TOTAL
		W. Elementary Classrooms			M. Elementary J	C.Elementary B	W. Elementary Classrooms			M. Elementary J	C.Elementary B	W. Elementary Classrooms			M. Elementary J	C.Elementary B	W. Elementary Classrooms			M. Elementary J	C.Elementary B	
		S	K	C			S	K	C			S	K	C			S	K	C			
KICK-OFF																						
1 pt	Appoint a classroom leader		1	10	10	10																31
	Take a Pledge		1	10		10																21
	Home Energy-Saving Video	5	1	10																		16
	Set Goals			10				10														20
	Energy Cards										10											10
	PARTICIPATION RANGE	5	1	10	10	10		10			10											56
10 pts	Tag the Waste		100	100	100																	300
	Foot-candle Light Meters								100		100											200
	Kill-a-Watt Meters																					0
	Virtual Reality																				100	100
	Online 360																					0
	PARTICIPATION RANGE		10	10					10		10										10	50
	TOTALS: PARTICIPATION	5	11	20	10	10	0	10	10	0	20	0	0	0	0	0	0	0	0	0	10	106
	TOTALS: POINTS	5	103	140	110	20	0	10	100	0	110	0	0	0	0	0	0	0	0	0	100	698
LIGHTING																						
1 pt	Daily Habit: keep lights off	1	5		30							2	10			10	20					78
	Daily Habit: remind someone to turn off lights		5		30	10						2				10	20					77
	PARTICIPATION RANGE	1	5		10	10						1	10			10						47
5 pts	Lighting Energy Patrol: energy patrol officer																					0
	Lightbulb Video: watch and learn							50	50													100
	Light it Right! Game: online game							50	50		50											150
	Mission Lighting Game: online game								50													50
	Light Blackout Hour: all classroom lights off for an hour								50													50
	PARTICIPATION RANGE							10	10													20

		WEEK 1					WEEK 2					WEEK 3					WEEK 4					
		W. Elementary Classrooms					W. Elementary Classrooms					W. Elementary Classrooms					W. Elementary Classrooms					
		S	K	C	M. Elementary J	C.Elementary B	S	K	C	M. Elementary J	C.Elementary B	S	K	C	M. Elementary J	C.Elementary B	S	K	C	M. Elementary J	C.Elementary B	TOTAL
10 pts	Light Power Day: full day no lights																					0
	Classroom Design: classroom rearrangement																					0
	Light Bulb Comparison: school bulb comparison																					0
	PARTICIPATION RANGE																					0
	TOTALS: PARTICIPATION	1	5	0	10	10	0	10	10	0	0	1	10	0	0	10	0	0	0	0	0	67
	TOTALS: POINTS	1	10	0	60	10	0	100	200	0	50	4	10	0	0	20	40	0	0	0	0	505
DEVICES																						
1 pt	Daily Habit: unplug device	10			20							3					30					63
	Daily Habit: switch off device											3					30					33
	PARTICIPATION RANGE	10			10							1										21
5 pts	Devices Energy Patrol																					0
	School Unplug: unplug outside classroom																					0
	Energy Street, Energy Conservation Game: online game																					0
	Devices Blackout Hour												25									25
	Night Unplug: unplug class devices overnight																					0
	PARTICIPATION RANGE												10									10
10 pts	Vending Machine Unplug																					0
	Phantom Waste: read article												100									100
	Estimating Home Energy: online activity																					0
	PARTICIPATION RANGE												10									10
	TOTALS: PARTICIPATION	10	0	0	10	0	0	0	0	0	0	1	20	0	0	0	0	0	0	0	0	41
	TOTALS: POINTS	10	0	0	20	0	0	0	0	0	0	6	125	0	0	0	60	0	0	0	0	221
HEATING / COOLING																						
1 pt	Daily Habit; winter blind control				10							2					20					32
	Daily Habit: summer blind control	5										2					20					27
	PARTICIPATION RANGE	5			10							1										16

		WEEK 1					WEEK 2					WEEK 3					WEEK 4					
		W. Elementary Classrooms			M. Elementary J	C.Elementary B	W. Elementary Classrooms			M. Elementary J	C.Elementary B	W. Elementary Classrooms			M. Elementary J	C.Elementary B	W. Elementary Classrooms			M. Elementary J	C.Elementary B	TOTAL
		S	K	C			S	K	C			S	K	C			S	K	C			
5 pts	Shading Energy Patrol																					0
	Thermostats: watch online video																	50	50			100
	School Thermostat: discover school performance																					0
	After-hours Thermostat: discover school reset schedule																					0
	Solar Energy Defenders Game: online game																		50			50
	PARTICIPATION RANGE																	10	10			20
10 pts	Energy Source: discover school energy source																					0
	Solar Cookers: hands-on activity																					0
	Insulation experiments: + online video																					0
	PARTICIPATION RANGE																					0
	TOTALS: PARTICIPATION	5	0	0	10	0	0	0	0	0	0	1	0	0	0	0	0	10	10	0	0	36
	TOTALS: POINTS	5	0	0	10	0	0	0	0	0	0	4	0	0	0	0	40	50	100	0	0	209
ACTIVIST FRIDAY																						
5 pts	Poster Contest: hang signs/ posters around school			50	50	50	50	50	50													300
	Home Game: take home Dylan game			50	50	50	50	50	50													300
	Adopt a Hallway: hallway light control			50	50	50	50	50	50													300
	Minimize Lighting: lighting needs re-evaluation																					0
	Cold Lunch Day: eliminate food heating devices																					0
	Spread Your Daily Habits: all energy saving habits in one day															50						50
	PARTICIPATION RANGE			10	10	10		10	10							10						60
10 pts	Reduce Solar Heat Gain: tree shading potential																				100	100
	Classroom Awareness: other class presentation																					0
	PARTICIPATION RANGE																				10	10
	TOTALS: PARTICIPATION	0	0	10	10	10	0	10	10	0	0	0	0	0	0	10	0	0	0	0	10	70
	TOTALS: POINTS	0	0	150	150	150	150	150	150	0	0	0	0	0	0	50	0	0	0	0	100	1,050

Energy-saving behavior was measured and assessed in K-12 Energy Challenge 4.0 using a combination of three questions from pre- and post-game surveys given to students at C. Elementary School, M. Elementary School, and W. Elementary School (Table 7.41). The total number of respondents (n) was 93.

Table 7.41. Questions relevant to energy-saving behavior from the pre-game and post-game surveys given to students in K-12 Energy Challenge 4.0.

#	question text
Q4	I would like for my family to use less energy at home.
Q6	I would like to try new ways to save energy at school.
Q22	I want to take action to prevent energy waste.

Question responses were on a five-point Likert scale ("Strongly agree," "Somewhat agree," "Neither agree nor disagree," "Somewhat disagree," "Strongly disagree"). For purposes of analysis, the responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). Figure 7.26 illustrates the responses to the three pre-game questions, graphically sorted by respondent. Inspection of Figure 7.26 suggests that the responses show fair cross-question reliability. To test this observation, Cronbach's alpha for the three questions (Q4, Q6, and Q22) was calculated as .394 for the pre-test, indicating poor reliability across the questions, i. e., that the responses to the three questions in Table 7.36 are not correlated.

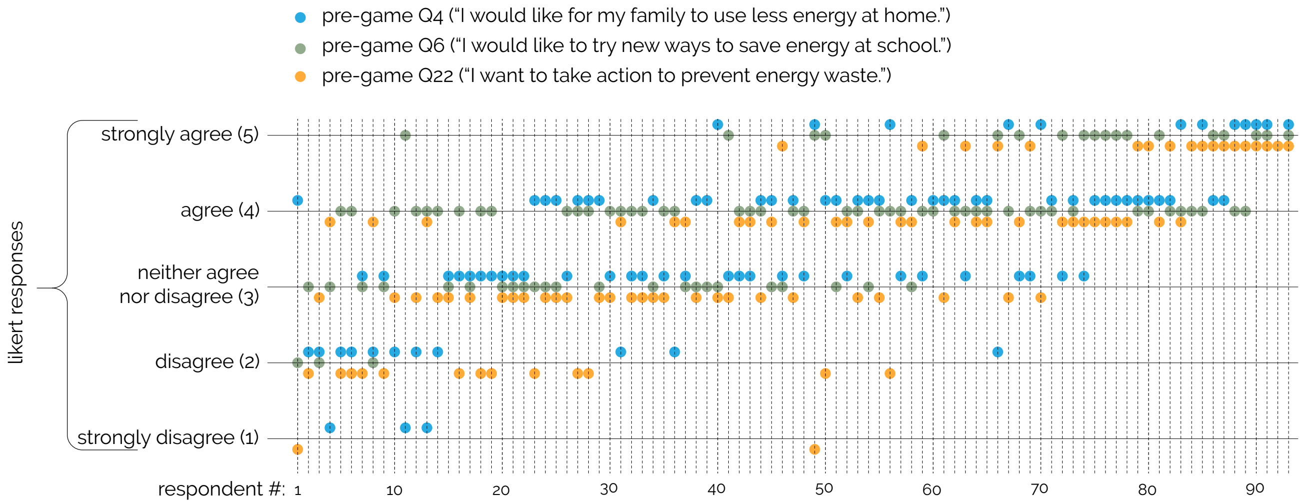

Figure 7.26. Cross-question reliability for three questions relevant to energy-saving behavior from the pre-game survey given to students in K-12 Energy Challenge 4.0.

Similarly, Figure 7.27 illustrates the responses to the three post-game questions, graphically sorted by respondent. Inspection of Figure 7.27 suggests that the responses show fair cross-question reliability. To test this observation, Cronbach's alpha for the three questions (Q4, Q6, and Q22) was calculated as .488 for the post-test, indicating poor reliability across the questions, i. e., that the responses to the three questions in Table 7.36 are not correlated.

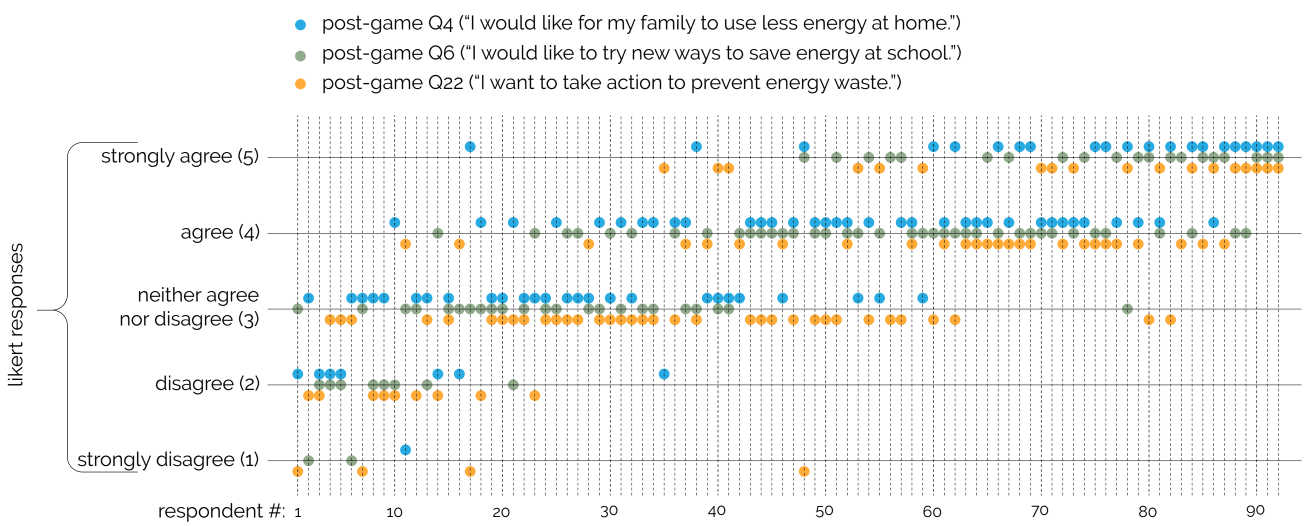

Figure 7.27. Cross-question reliability for three questions relevant to energy-saving behavior from the post-game survey given to students in K-12 Energy Challenge 4.0.

Due to poor cross-question reliability, responses to individual questions were also considered independently. Analysis of responses suggested that the responses to Q4 ("I would like for my family to use less energy at home") could be significant, while others were not. The following discussion summarizes the analysis of the responses to Q04. Figure 7.28 illustrates the responses to Q04, graphically sorted by respondent.

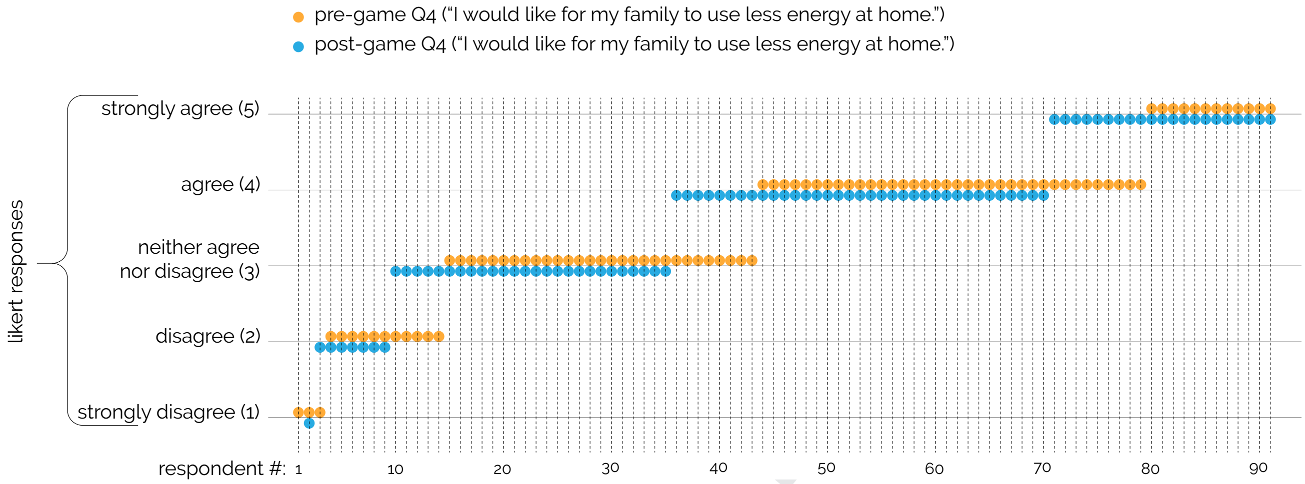

Figure 7.28. Cross-question reliability for question relevant to Behavior Change from the pre-game and post-game surveys given to students in K-12 Energy Challenge 4.0.

Figure 7.29 shows the pre- and post-game responses, graphically sorted by response.

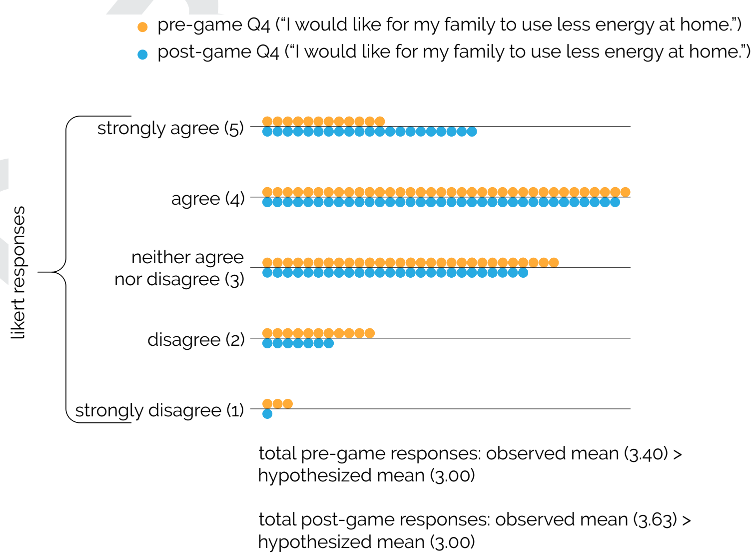

Figure 7.29. Mean-value responses to question relevant to energy-saving behavior from the pre-game and post-game surveys given to students in K-12 Energy Challenge 4.0.

Inspection of Figure 7.29 suggests that the mean response in both pre- and post-test responses is greater than a hypothesized mean of 3.0. This is confirmed through descriptive statistics (Table 7.42).

Table 7.42. Descriptive statistics for responses to question relevant to energy-saving behavior from the pre-game and post-game surveys given to students in K-12 Energy Challenge 4.0.

item	n	range	mean	median	standard deviation
"pre-game Q4 responses"	93	1.00 to 5.00	3.4	4	1.089
post-game Q4 responses	92	1.00 to 5.00	3.63	4	1.134

Inspection of the descriptive statistics shows that the mean response increased (by 6.8%) while the median response remained unchanged in the post-game responses. To determine the statistical significance of these observations, a two-sample t-test was conducted assuming equal variances.[1] The t-value was calculated as -1.44. The t-critical value (two-tail) was calculated as 1.97. This suggests that the null hypothesis may be rejected, supporting the conclusion that the pre-game and post-game responses differ significantly. However, the p-value was calculated as 0.152 (>0.05), suggesting that the results are not statistically significant.

Although the mean response was increased by 6.8% the results were not statistically significant.

WRITE ABOUT ENGAGEMENT AND ACTIVITIES:

xxx vivian's comments???

7.6.3 Learning and Awarness during (K-12 Energy Challenge 4.0 / Fall 2018)

In K-12 Energy Challenge 4.0, Learning and Awareness was measured and assessed with respect to two data sources (Table 7.43).

1 Prior to conducting the t-test, an F-test returned a F-critical value of .0711 and an F-statistic of 0.923. The F-statistic is greater than the F-critical value, suggesting that the null hypothesis may be rejected and that the variances of the pre-test responses and the post-test responses are unequal. However, the calculated p-value of 0.348 (>0.05) implies that this result is not statistically significant, and that consequently, the null hypothesis concerning variances cannot be rejected. Thus, a two-sample t-test was conducted assuming equal variances.

Table 7.43. Data Sources, Learning and Awareness, K-12 Energy Challenge 4.0.

variable	data source
Learning and Awareness	1. 5 pre-game survey questions completed by students at C. Elementary School, M. Elementary School, and W. Elementary School. 2. 5 post-game survey questions completed by students at C. Elementary School, M. Elementary School, and W. Elementary School (Classroom F).

The five questions were worded identically in pre- and post-game surveys (Table 7.44). The total number of survey respondents was 93.

Table 7.44. Questions relevant to Learning and Awareness from the pre-game and post-game surveys given to students in K-12 Energy Challenge 4.0.

#	question text
Q3	I know where energy is being wasted in my school.
Q16	I know where energy is being wasted in my home.
Q24	I (will learn/learned) a lot about saving energy by doing the K-12 Energy Challenge.
Q29	My actions can change how much energy is used.
Q34	I don't have any ideas about how to save energy [reverse coded].

Question responses used a five-point Likert scale ("Strongly agree," "Agree," "Neutral," "Disagree," "Strongly disagree"). For purposes of analysis, responses were assigned numerical values from 1 (for "Strongly disagree") to 5 (for "Strongly agree"). The responses to the five questions are shown in Figure 7.30 (pre-game) and Figure 7.31 (post-game), graphically sorted by the mean-value response to a composite of all five questions. Inspection of Figure 7.30 and Figure 7.31 suggests that the responses show fair, but not high, cross-question reliability. (Non-responses were omitted from subsequent analysis.)

- pre-game Q3 (“I know where energy is being wasted in my school.
- pre-game Q16 (“I know where energy is being wasted in my home.”)
- pre-game Q24 (“I (will learn/learned) a lot about saving energy … ”)
- pre-game Q29 (“My actions can change how much energy is used.”)
- pre-game Q34 (“I don’t have any ideas about how to save energy.”) {reverse coded}

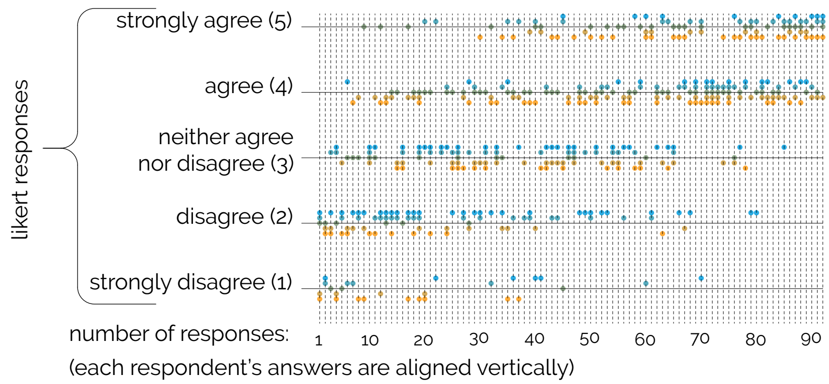

Figure 7.30. Cross-question reliability for five questions relevant to Learning and Awareness from the pre-game survey given to students in K-12 Energy Challenge 4.0. Respondents sorted by mean-value response to composite of all five questions.

- post-game Q3 (“I know where energy is being wasted in my school.
- post-game Q16 (“I know where energy is being wasted in my home.”)
- post-game Q24 (“I (will learn/learned) a lot about saving energy … ”)
- post-game Q29 (“My actions can change how much energy is used.”)
- post-game Q34 (“I don’t have any ideas about how to save energy.”) {reverse coded}

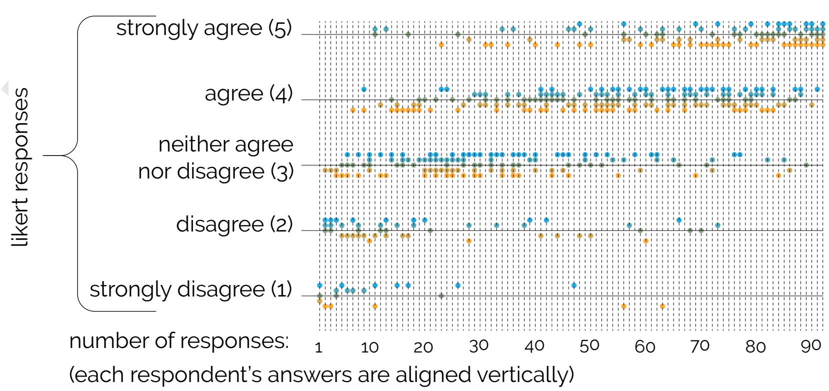

Figure 7.31. Cross-question reliability for five questions relevant to Learning and Awareness from the post-game survey given to students in K-12 Energy Challenge 4.0. Respondents sorted by mean-value response to composite of all five questions.

To test this observation, Cronbach's alpha for the five pre-game questions listed in Table 7.39 was calculated as .456, indicating a poor level of reliability across the questions; similarly, Cronbach's alpha for the five post-game questions listed in Table 7.39 was calculated as .557, indicating a poor level of reliability across the questions. This suggests that the responses to the five questions in Table 7.39 are not correlated, with respect to both pre-game and post-game surveys.

Figure 7.32 illustrates the responses to the five questions, graphically sorted by response. Inspection of Figure 7.32 suggests that the mean response to the five questions is higher than a hypothesized mean response of 3.0.

- Q3 ("I know where energy is being wasted in my school.
- Q16 ("I know where energy is being wasted in my home.")
- Q24 ("I (will learn/learned) a lot about saving energy … ")
- Q29 ("My actions can change how much energy is used.")
- Q34 ("I don't have any ideas about how to save energy.") {reverse coded}

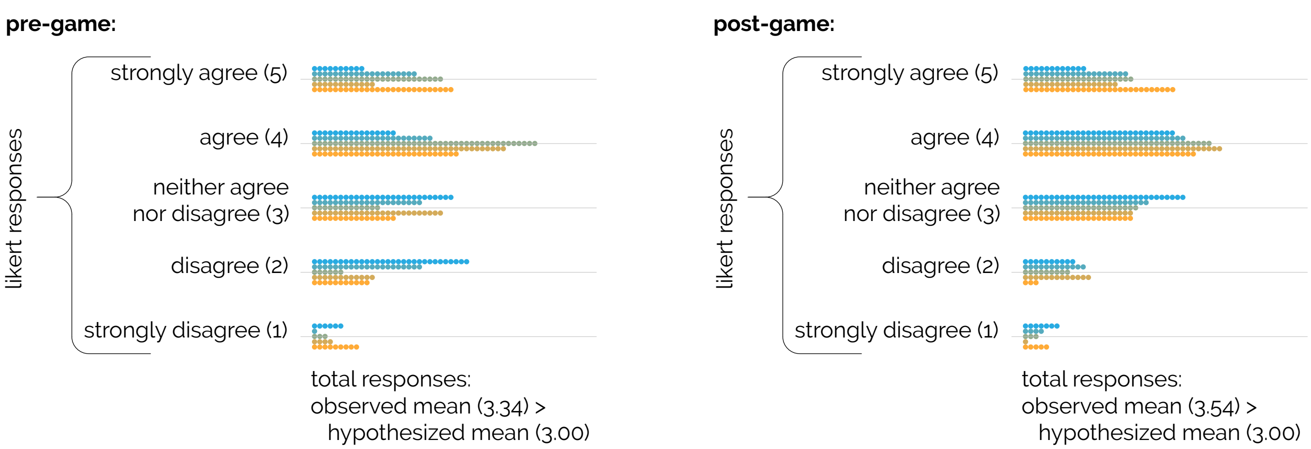

Figure 7.32. Mean-value responses for five questions relevant to Learning and Awareness from the pre-game survey (at left) and the post-game survey (at right) given to students in K-12 Energy Challenge 4.0.

To verify this, each question set was combined into a compound variable. Compound variable V1 represents the combined effect of pre-game questions (Q3, Q16, Q24, Q29, and Q34) and compound variable V2 represents the combined effect of post-game questions (Q3, Q16, Q24, Q29, and Q34). Table 7.45 includes the descriptive statistics for the two compound variables. Note that higher values indicate more agreement.

Table 7.45. Descriptive statistics for responses to composite of five questions relevant to Learning and Awareness from the pre-game survey and the post-game survey given to students in K-12 Energy Challenge 4.0.

variable	n	range	mean	median	standard deviation
V1	92	1.60 to 4.80	3.34	3.4	0.765
V2	92	1.60 to 5.00	3.54	3.6	0.78

Inspection of the descriptive statistics shows that in both V1 and V2, the mean response is higher than a hypothesized mean of 3.0. Further inspection of the descriptive statistics shows that the mean response increased (by 5.99%) and the median response increased (by 5.9%) in the post-game responses. The responses to the two variables are summarized in Figure 7.33 (before the game), Figure 7.34 (after the game), and Figure 7.35 (in comparison).

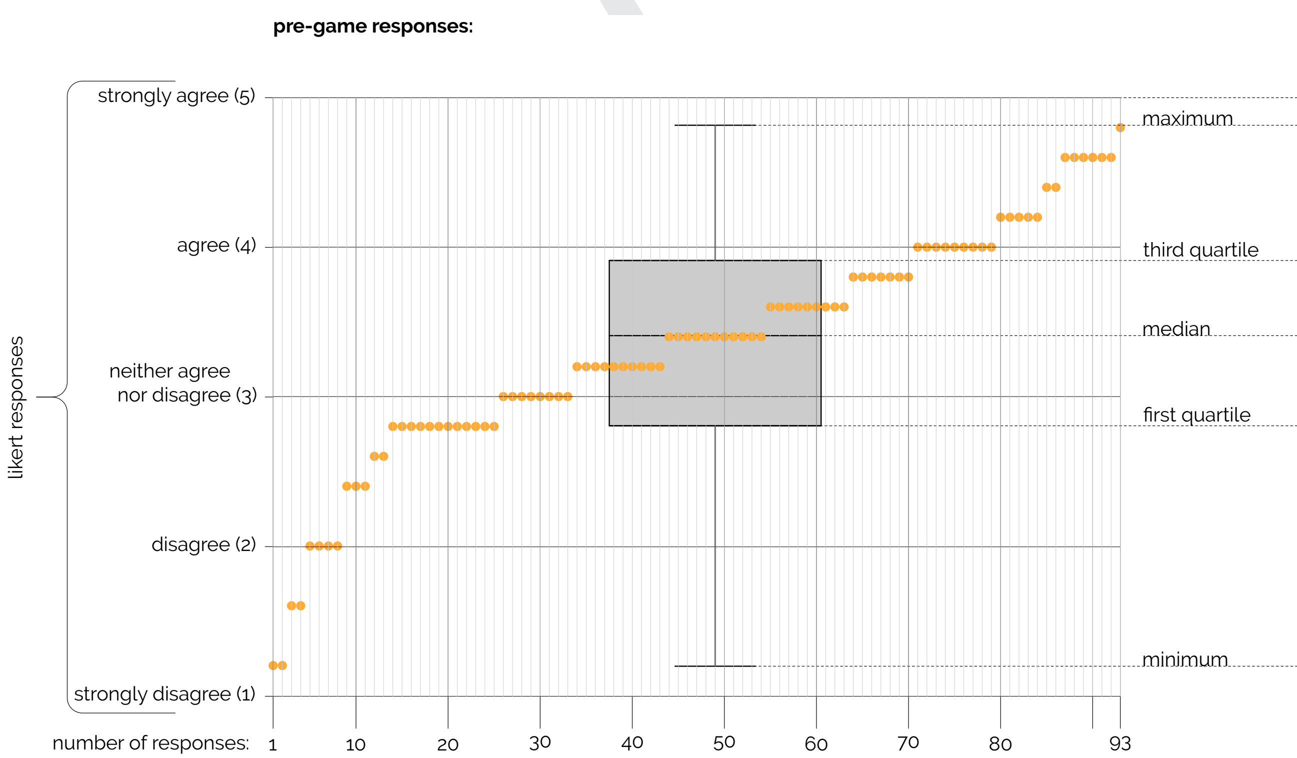

Figure 7.33. Responses to composite of five questions relevant to Learning and Awareness from the pre-game survey

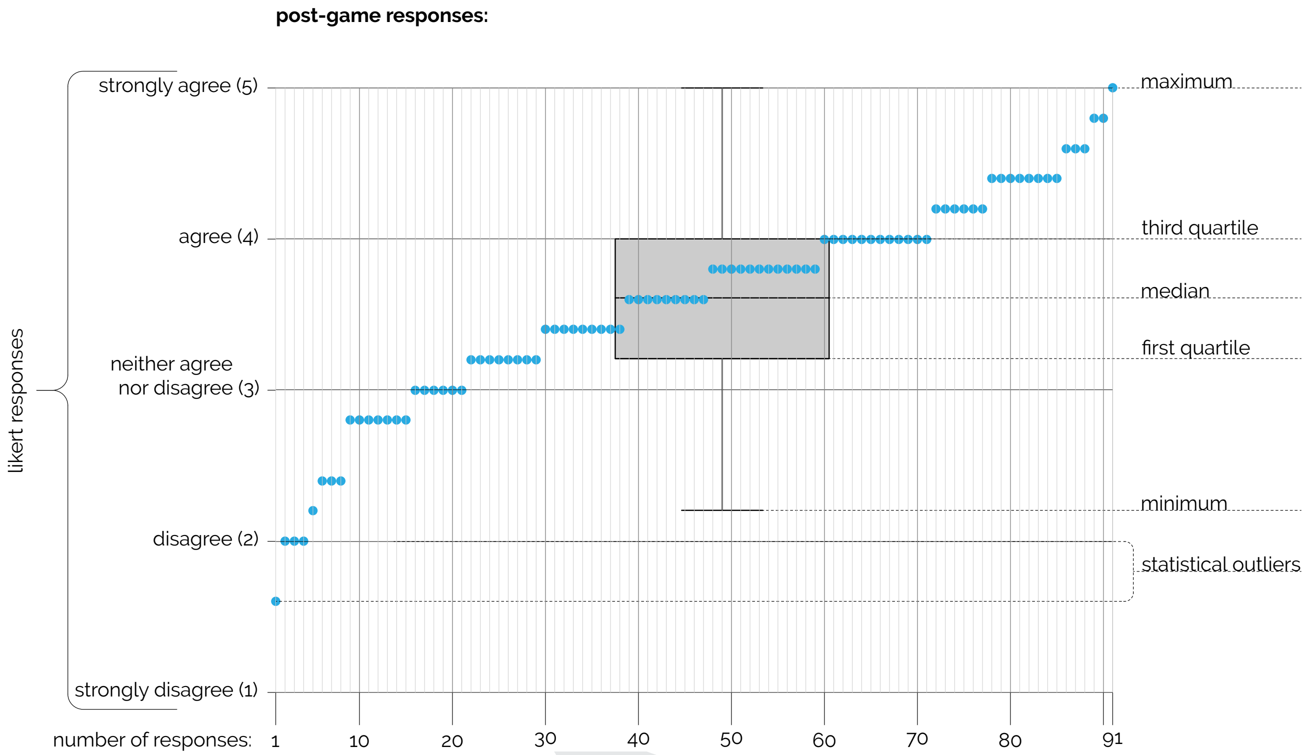

Figure 7.34. Responses to composite of five questions relevant to Learning and Awareness from the post-game survey given to students in K-12 Energy Challenge 4.0.

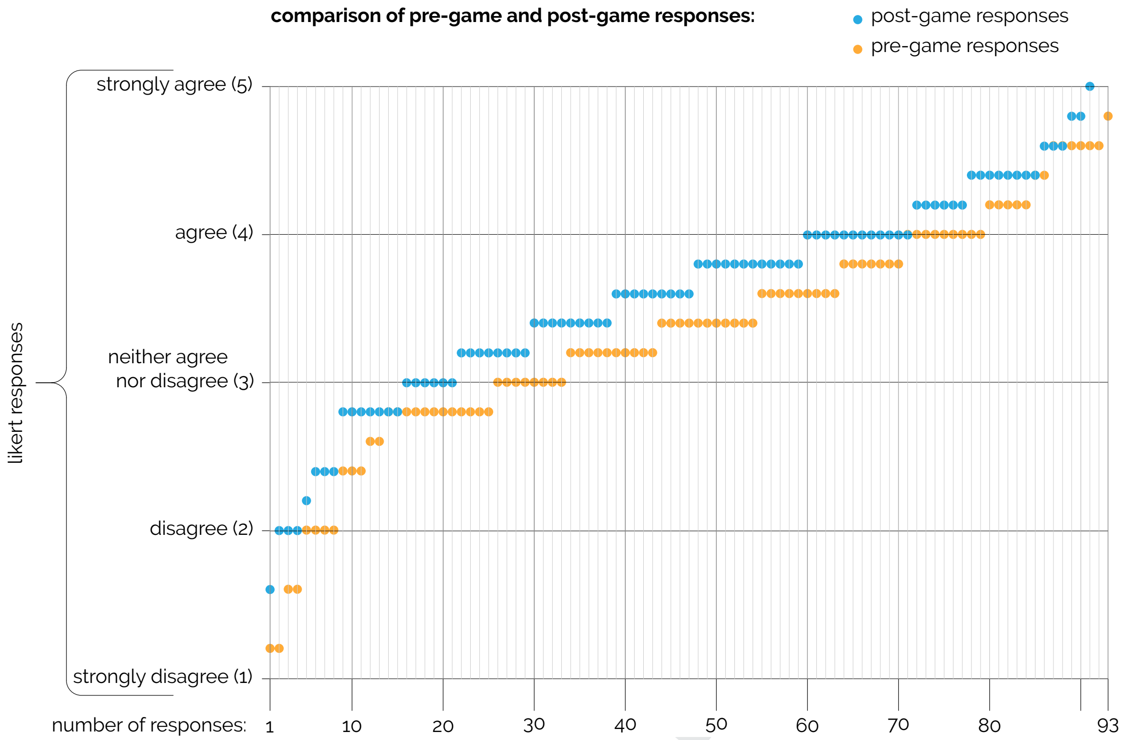

Figure 7.35. Responses to composite of five questions relevant to Learning and Awareness from the pre-game survey (in orange) and the post-game survey (in blue) given to students in K-12 Energy Challenge 4.0.

To determine the statistical significance of these observations, a two-sample t-test was conducted assuming equal variances.[1] The t-value was calculated as -2.27. The t-critical value (two-tail) was calculated as 1.97. This suggests that the null hypothesis may be rejected and we conclude that the pre-game and post-game responses differ significantly. The p-value was calculated as 0.02 (<0.05), suggesting that the results are statistically significant.

Thus, with respect to the measurement of student responses to paired questions in K-12 Energy Challenge 4.0, playing an open, pervasive game can lead to Learning and Awareness about energy-savings.

7.xx Game limitations and potential impact

The first two implementations of the K-12 Energy Challenge saw increased student participation

1 Prior to conducting the t-test, an F-test returned a F-critical value of 1.41 and an F-statistic of 1.23. The F-statistic is less than the F-critical value, suggesting that the null hypothesis cannot be rejected and that the variances of V1 and V2 are equal. However, the calculated p-value of 0.162 (>0.05) implies that this result is not statistically significant, and that consequently, the null hypothesis concerning variances cannot be rejected. Thus, a two-sample t-test was conducted assuming equal variances.

and engagement over the course of gameplay. These were allowed to be open games, where new participants could join any time during the duration of the game play. K-12 Energy Challenge 1.0 began with 182 students at four active schools; by the end of the six-week game period, participation increased to 720 students. K-12 Energy Challenge 2.0 increased from 221 students to 751 students by the end of the game. Post-game interviews with teachers and administrators explained these increases: although most schools started with a core group of students, awareness spread by word of mouth and through game activities. The third and fourth implementations were confined to specific grades and keeping the game open only till the start of the game play. Once the game had started, new participants were not allowed in to the game. This was done to ensure that the pre- and post-game surveys were being answered by students who had participated in the games for the entire duration through the game structure and the participation was not just event-based.

One of the schools exemplifies initial core-group participation: because its eighth-grade science teachers met curricular goals through K-12 Energy Challenge 1.0, only eighth-graders initially participated in the game. At two other schools, only fifth-graders initially participated; they began with a day-long intense learning unit on Energy and the Environment with guest speakers and reviewers as a precursor to actual gameplay. Examples of activities by the core group included switching off hall and bathroom lights, removing alternate light bulbs (reducing ambient light to lower, but safe levels), closing of blinds after school (retaining solar gain), and unplugging vending machines with non-perishable items after school. Students displayed posters relating to energy and environment, and a school started using long-unused vestibule double doors (taking advantage of their original purpose). When an energy-saving activity occurred, students became interested in the “crossing-off” of Waste-a-Watt on the scorecards or game tiles in Energy Challenge 2.0. Student Energy Patrols, announcements, visible game tiles and stickers caught the attention of students and teachers in the schools. However, the large participation numbers occurred in short bursts through planned events and not through consistent energy-use reduction activities. The daily activities were still completed mostly by the core group. While the large engagement numbers might have a positive effect on learning through the game, the teachers guessed that energy-use reduction was impacted through consistent and repetitive activity.

Through the post-game interviews with teachers and staff in the schools it became apparent that the consistent and enthusiastic participation of teachers and leading administrators (such as R. Elementary School's principal) emerged as a game attribute that needed further examination for its correlation to energy-saving and participation outcomes. Through observation, it seemed like those schools who participated actively and consistently were strongly and consistently supported by administrators, teachers, and staff. At the school that won both of the first two implementations of the K-12 Energy Challenge (R. Elementary School), student teams were supported by a principal, teachers and a facilities manager who worked with the students to initiate, develop, and implement energy-use reduction ideas. Also at this school, the K-12 Energy Challenge was led by a group of students drawn from multiple classrooms. Although R. Elementary School initially placed their activity and team in an after-school club activity, the fact that students from multiple classrooms in the school could work with their teachers in playing the game, ensured that spaces throughout the school were part of game space. In the other schools that participated for the full six weeks, only one of the grades and its classrooms participated as part of STEM curricular activity. This school had a particularly enthusiastic school principal who led the game participation.

Elsewhere, although principals endorsed the K-12 Energy Challenge, staff did not participate actively, and outcomes were less good. For example, in one school, students from the participating grade proposed turning off hallway lights when not needed, yet they were opposed by teachers from other grade levels. At another school, non-participating teachers were reluctant to allow students to play the game, to enter their classrooms, or to suggest or make changes. At one school, students playing the game were restricted to the doorways of non-participating classrooms: they could record instances of energy waste but they could not tag or fix them. At other schools, where gameplay was partial, students had ideas and support but lacked implementation time. Although follow-up interviews were not conducted, the engagement scores in W. Elementary School were typically lower than other schools. This may have been due to the restrictions placed on the students from completing activities, or to a lack of motivation in the face of opposition, or to a lack of time dedicated to the game. In future game design, periodic mini-interviews or conversations between gamers and implementers throughout the game could be a key aspect of data collection.

The longer duration (6 weeks) of K-12 Energy Challenge 1.0 and 2.0 allowed students to develop energy-saving habits, e. g., switching off lights or unused devices. However, longer durations also encroached on other school activities and overloaded school teachers. In the first two implementations of the K-12 Energy Challenge, the six weeks of game play generated long-term engagement, growing numbers of interested participants, and an active and empowered group of gamers or community members with time and support to implement their ideas. In the third and fourth implementation, the K-12 Challenge employed 3-week and 4-week game play timelines. Future design implementations or replication and scalability of the K-12 Energy Challenge should continue to refine game timeline concepts through iterative design and implementation processes.

Game rules are significant, in that they must address gamers' heterogeneous needs, allowing them flexibility to voluntarily engage the game based on resources and abilities. Schools and teachers had limited time to participate, but the game design's flexibility allowed different patterns of participation and engagement.

Small-interval data collection and feedback is critical to ongoing engagement and continued gamer activity, as it provides measurable data for documenting savings, directly associating Waste-a-Watt captures with activity completion and energy savings, and increasing gamer interest in competitive gameplay. efargo is currently (2019-2020) engaged in a pilot program to place smart meters enabling small-interval data collection in a small number of Fargo public schools.

When the signs and symbols of game play such as stickers, energy announcements, energy patrols, posters, reduced lighting, etc., pervaded and created game space, teachers reported that other students, teachers and staff became curious due to the visible, audible, and perceptible presence of the game. Some of the curiosity was negative, where complaints were received about low light levels or lights turned off in bathrooms and other spaces. However, some outcomes were positive. Engagement numbers increased with more students expressing an interest in participation and then participating. More importantly, other teachers, staff and facilities staff got involved in some schools as well, having the potential for social and spatial expansions. On surveys, students reported taking their learning home and telling their parents about the game, creating a potential for social, spatial, and temporal expansions. Greater engagement can potentially translate to greater learning and energy-savings in the future. However, the game implementations thus far, do not fully track these expansions for impact beyond the school buildings' energy performance.

The K-12 Challenge experienced obstructions and limitations in the game play and data collection process. Primary amongst them was the time constraints on the teachers with heavy curricular loads. Of all the schools that participated, only one school chose to implement the game as an after-school activity. Most of the other teachers were interested in finding out whether the game incorporated enough material so as to help meet curricular goals. Secondly, data collection activities were very restricted. Since minors were involved, permissions were not only needed from the IRB but also from the administrators of K-12 schools. This included sending notification and consent forms to parents for surveys, participation, and documentation. For Energy Challenge 1.0, by the time the IRB and Public schools gave partial approval to the data collection, only a post-game teachers survey was allowed. While the students' game-activity results could be seen in the weekly reports of weekly energy-use, there were no surveys or engagement point tracking. In Energy Challenge 2.0, while permission to survey students was obtained, the teachers only wanted to follow a 3-point Likert scale in the elementary schools. The middle-school teachers were not as concerned about the eighth-grade students' ability to complete a 5-point Likert-scale survey, and so this format was used for the middle school survey. During Energy Challenge 3.0 and 4.0, after some level of trust had been built between the IRB, K-12 administrators, game designers, and gamers, permissions were obtained to complete a 5-point Likert scale pre- and post-game surveys of the 5th graders (3.0) and 4th graders (4.0). In these games, engagement points became another way of creating competitive structures and incentivizing longer-term impact activities and energy-efficient behavior adoption.

Another limitation that is currently (2019-2021) being addressed in the latest grant funding for efargo, is that in the past four years of game implementation (2015-2018), the K-12 Challenge requires direct involvement of efargo personnel in data collection. This has been a considerable barrier in the research effort to test the true effectiveness of the game. Several challenges arose due to the need to conduct manual meter-reading and recording. Human errors in meter readings (e. g., not recording readings consistently, transcribing incorrect information or overlooked meters among multiple meters) happened in all four game implementations. While the research assistants could certainly have benefited from additional training, there were occasions when facility managers were unaware of the specific purposes of every meter, leading to a failure to collect all relevant meter data. If a meter-reading day happened to coincide with a school holiday, the consequent adjustment in the meter recording cycle negatively impacted the frequency of data collection and normalization. Classroom, teacher, or student event conflicts also precluded meter readings in some cases. The game required facility managers to invest personnel effort to read meters, which wasn't part of the original game plan. This involved training, both to enable personnel to identify the correct meter types, and to develop knowledge to convert meter readings (with known equipment multipliers) for each meter type. Finally, some meters were located in restricted areas (whether fenced, locked, or indoor), requiring the supervision and cooperation of staff.

While participation from facilities personnel was difficult, cooperation from utilities was inconsistent. Unclear and inconsistent instruction from one utility concerning their equipment prevented accurate data collection. The causes for this inconsistency or reluctance to cooperate was not studied in this dissertation, but could form the basis of a future study examining the partnerships required to keep the game fully functional. Lastly, human error was frequently involved in manual transcription of data every week from meter readings to comparative energy dashboards. Producing the weekly report was a substantive time burden for efargo, but at the same time it provided sufficiently frequent data release for successful reminders to engage in energy-saving behaviors.

8.0 Games & The Georgetown Prize

Summary

This chapter describes the City of Fargo's performance in the national competition, the Georgetown University Energy Prize (GUEP), which was the background opportunity to conduct this research. In addition, this chapter examines the rankings of the cities that implemented games as part of their GUEP effort. Rankings of the cities were based on the Overall Energy Score (OES) of the cities, as defined by the GUEP up to the Finalist round.[1]

8.1 Introduction

Participation in the Georgetown University Energy Prize (GUEP) provided an opportunity to test the effectiveness of Serious Pervasive Energy Games (SPEG). The participation effort for the cIty of Fargo, led by this author, included several game-based activities, of which the research and design of open serious pervasive energy games was the major effort. Two games were designed and implemented, one for residential owners and renters and the other for K-12 schools. The K-12 game was iterated four times. Both games were openly available to anyone choosing to play voluntarily in the city of Fargo, North Dakota. The implementation of the games allowed for the following to occur: (a) implementation, testing and data collection from the games; (b) critiquing the K-12 schools game through an iterative implementation process; (c) winning the Georgetown University Energy Prize; (d) proposing the attributes for a future pervasive game.

8.2 Georgetown University Energy Prize: Energy-use data collection

The city of Fargo won the Georgetown University Energy Prize. The final evaluation of the Prize accounted for energy-use reduction, but also considered whether innovative, sustainable, replicable, and scalable approaches were developed that had potential for wider application

1 Portions of this chapter make reference to Srivastava & Nelson (2017). Portions of this chapter also depend on an end-of-semi-finals performance data analysis reported by the GUEP team (Appendix X-#), an end-of-competition report compiled by Georgetown University on the finalist cities (Appendix X-#). In addition, the Georgetown University Competition Handbook was a major source for the GUEP process and methodology of ranking (Appendix X-#).

(Srivastava & Nelson, 2017). While games were central to Fargo's efforts, other GUEP-competing cities included games as part of their activities. An analysis of the energy data collection for the citywide performance during the GUEP competition was structured by the GUEP team and implemented by all participating cities as a fundamental requirement of participation (Table 8.1). Georgetown University periodically published the normalized data. Based on this data, the following includes the energy savings accomplished by the city of Fargo and also an overview of the outcomes and performance of other cities that implemented games during the GUEP competition.

Table 8.1. Energy-use data collection (boldface check marks indicate year game was played)

intervention	utility data or utility bills			
	Baseline reference		Competition period	
	2013	2014	2015	2016
GUEP Participating Cities	✓	✓	☑	☑
GUEP City of Fargo	✓	✓	✓	☑

Each community submitted quarterly reports of their energy consumption to the GUEP administration team. These reports included monthly, aggregated electric and natural gas energy consumption data for residential and municipal sectors, provided by local utilities, plus the total number of residential bills issued for electric and natural gas service. Communities also submitted baseline energy reports for 2013 and 2014, which were compared to the quarterly reports submitted throughout the competition period to assess overall savings and related rankings. Competition data was normalized for weather, population, and to account for the "source energy" required to produce the energy in the "full-fuel-cycle" by the GUEP team. Weather normalization and source-energy conversion was conducted with the U.S. Environmental Protection Agency's Energy Star Portfolio Manager.[1]

8.3 Fargo's GUEP performance

According to the energy data analysis of the GUEP team, in two years, Fargo reduced overall energy consumption by over 172,361 MMBTUs. Estimated CO_2e saved was 49,719 metric tons,

1 See Chapter 3.

and the overall energy consumption reduced on average per-household was over 8 MMBTUs. Other performance measures reported by the utilities (Xcel Energy and Cass County Electric Cooperative) and analyzed by the GUEP team are as follows:

a) The total weather-normalized site electricity use based on grid purchase was reduced by 3.06% or 18,420,249 kWh over the competition period compared to the baseline years average (Table 8.3).

Table 8.3. Total weather-normalized site electricity use based on grid purchase.

Year Ending	Electricity Use - Grid Purchase (kWh)	Weather Normalized Site Electricity (kWh)		
12/31/13	598,228,257	572,677,489		
12/31/14	647,414,219	633,080,697	602,879,093	BASELINE
12/31/15	591,912,022	610,684,402	1.29%	(% increase on baseline)
12/31/16	576,653,535	576,653,535	-4.35%	(% reduction on baseline)
TOTAL REDUCTIONS		18,420,249	-3.06%	(% reduction on baseline)

b) The total weather-normalized site gas use based on gas purchase was reduced by 6.45% or 1,403,573 therms over the competition period compared to the baseline years average (Table 8.4).

Table 8.4. Total weather-normalized site gas use based on gas purchase.

Year Ending	Natural Gas Use (therms)	Weather Normalized Site Natural Gas Use (therms)		
12/31/13	22,882,425	21,455,205		
12/31/14	23,304,107	22,073,399	21,764,302	BASELINE
12/31/15	19,166,456	21,397,988	-1.68%	% reduction on baseline)
12/31/16	17,732,308	20,727,043	-4.77%	% reduction on baseline)
TOTAL REDUCTIONS		1,403,573	-6.45%	% reduction on baseline)

c) The total weather-normalized site energy use based on electricity and gas purchase reported by utilities was reduced by 4.80% or 203,207,120 kBtu over the competition period compared to the baseline years average (Table 8.5).

Table 8.5. total weather-normalized site energy use based on electricity and gas purchase.

Year Ending	Electricity Use - Grid Purchase (kBtu)	Natural Gas Use (kBtu)	Site Energy Use (kBtu)	Weather Normalized Site Energy Use (kBtu)		
12/31/13	2,041,155,061	2,288,242,482	4,329,397,543	4,099,496,322		
12/31/14	2,208,977,583	2,330,410,670	4,539,388,253	4,367,411,481	4,233,453,902	BASELINE
12/31/15	2,019,604,066	1,916,645,580	3,936,249,645	4,223,454,274	-0.24%	(% reduction on baseline)
12/31/16	1,967,542,100	1,773,230,800	3,740,772,900	4,040,246,409	-4.56%	(% reduction on baseline)
TOTAL REDUCTIONS				203,207,120	-4.80%	(% reduction on baseline)

d) The total weather-normalized source energy use based on electricity and gas purchase reported by utilities was reduced by 3.94% or 344,723,765 kBtu over the competition period compared to the baseline years average (Table 8.6).

Table 8.6. Total weather-normalized source energy use based on electricity and gas purchase.

Year Ending	Source Energy Use (kBtu)	Weather Normalized Source Energy Use (kBtu)		
12/31/13	8,811,881,498	8,388,280,623		
12/31/14	9,383,120,814	9,100,331,703	8,744,306,163	BASELINE
12/31/15	8,354,034,625	8,789,466,843	0.52%	(% increase on baseline)
12/31/16	8,039,974,534	8,354,421,718	-4.46%	(% reduction on baseline)
TOTAL REDUCTIONS		344,723,765	-3.94%	(percentage reduction on baseline)

e) The total estimated average reduction in greenhouse gas emissions was 49,719 metric Tons CO2e or 9.42% average during competition years compared to baseline years average

(Table 8.7).

Table 8.7. Total estimated average reduction in greenhouse gas emissions.

Year Ending	Direct GHG Emissions (Metric Tons CO2e)	Indirect GHG Emissions (Metric Tons CO2e)	Total GHG Emissions (Metric Tons CO2e)		
12/31/13	121,540	388,898	510,437		
12/31/14	123,779	420,873	544,652	527,545	BASELINE
12/31/15	101,802	384,792	486,594	-7.76%	(percentage reduction on baseline)
12/31/16	94,185	374,873	469,057	-11.09%	(percentage reduction on baseline)
TOTAL REDUCTIONS			49,719	-9.42%	(percentage reduction on baseline)

Overall, Fargo had several reductions in electricity and gas usage in the residential and municipal sectors for the competition period (2015-2016), as compared to the baseline period (2012-3014). The total normalized overall energy use was reduced by 4.8%; normalized site electricity use was reduced by 3.06%; normalized site natural gas use was reduced by 6.45%; normalized source energy use was reduced by 3.94%; and total CO2 emissions were reduced by 9.42%. Also noteworthy is that reductions in 2016 were greater than reductions in 2015. Though it cannot be directly correlated, this may be attributable to efargo's efforts creating community learning and awareness about energy waste and energy savings, inculcating a willingness to change behavior and make investments to achieve energy savings.

Table 8.8. Summary of CIty of Fargo performance measures for the GUEP

Energy Use (weather normalized)	% change in 2015 (GUEP Year 1)	% change in 2016 (GUEP Year 2)
Site Energy Use	-0.24%	-4.56%
Source Energy Use	0.52%	-4.46%
Site Gas Usage	-1.68%	-4.77%
Site Electricity Usage	1.29%	-4.35%
CO2e	-7.76%	-11.09%

8.4 GUEP performance of other participating cities

Of the 50 cities in the semi-finals of the Georgetown University Energy Prize, six cities were known, on the basis of publicly available information, to play games in support of their competition entry (Fargo, ND; Fort Collins, CO; Walla Walla, WA; Madison, WI; Sunnyvale, CA; and Athens County, OH). Because the activity reports of participating cities were not publicly accessible (other than brief summaries of the top ten finalists), extensive keyword searches of online public sources, including published articles and community websites, were the primary data source in order to identify the cities that included game play in their energy-saving strategies. Information was available for 48 of the 50 cities and for five of the six game-playing cities (Table 8.8).The Overall Energy Score (OES) and rankings of these cities were available from the GUEP team. Interviews were conducted with leaders from the communities working on the GUEP to gather details of game design and participation.

Table 8.8. Games played by cities.

Game, City	"GUEP Semi-final rank (Published in 2015)"	GUEP Final rank (Published in 2016)	Overall Energy Score (OES)	# of Gamers	Data collection
efargo community game, Fargo ND	4	1	-6.8472	~300 people	Surveys were conducted and gamers were asked to share energy bills. 122 people completed at least one of the surveys, 56 completed both pre- and post-surveys. 26 people gave waivers for energy results of which 17 utility bills were recovered by the utility.
K-12 Energy Challenge, Fargo ND	4	1	-6.8472	1832 people (of which 1697 are students)	Pre- and post-surveys were completed by approximately half of the students who participated. Weekly meter recordings were taken by game organizers.
Lose-a-Watt (customized Joule Bug app), Fort Collins CO	5	2	-6.0757	~700 people	Estimated by Joule Bug based on points collected rather than actual reductions.
Power Play (energy bingo), Walla Walla WA	2	5	-9.1141	100 out of 600 middle schoolers.	Did not track energy results and unable to track participation in the social media format. Tracked participation in the middle schools.

Green Madison Online sustainability game (Cool Choices), Madison WI	15	n/a	-3.3478	45-50 businesses, 800-850 people	Tracked participation, estimated energy savings behind "Cool choices" total about $245,000, estimated 849,086 kWh saved.
I Green Sunnyvale, (customized Joule Bug app), Sunnyvale CA	18	n/a	-3.1261	~800+ people	Estimated according to recorded actions in the app were savings of 478,000 CO2 lbs.
The Card Game, Athens County OH	33	n/a	-0.6581	No response	No response.

Games were available to their communities most often in digital formats as web interfaces or apps. Four of the cities (Sunnyvale, Fort Collins, Madison, and Fargo) had digital apps. Sunnyvale and Fort Collins used customized versions of the same base app (Joule Bug); Madison used the Cool Choices app, and Fargo researched, designed and implemented its own games. Two of the cities included physical games: the Walla Walla Power Play, an energy bingo game, and the Fargo K-12 Energy Challenge, implemented in schools. Fargo was the only city that implemented both physical and digital games.

In Fort Collins, Environmental Planner Katie Bigner partnered with JouleBug to create the Lose-a-Watt app in order to change behavior and improve engagement in energy efficiency. Lose-a-Watt was launched in January 2015 as a community-wide challenge in which approximately 700 people participated during a period of 10 days. Several monthly challenges were launched where various groups participated (e. g., 120 students and teachers at various schools, 120 active people as part of a neighborhood challenge). The organizers received positive feedback from the gamers. The app was marketed through various efforts such as flyers, social media, canvassing at the farmer's market and local events, and Earth Day at schools. Approximately 700 people played the Lose-a-Watt app, and for a total of 3,000 actions taken, the estimated savings were 569 lbs of CO2, 1M gallons of water, and 38 lb of waste.

Sunnyvale's app, I Green Sunnyvale (developed in partnership with Joulebug), made sustainability fun and engaging, with competitive structures between members of the community. The idea to have a game came from local high school students. The results were not measured or tracked and the only feedback was anecdotal. However, the organizers believed that the games would impact energy use behavior due to regular notifications and the ability to see what peers were doing. Approximately 800+ people played the game. The reported savings from the app were 478,000 lbs of CO_2, 723,000 gallons of water, and 26,000 lbs of waste.

Based in Madison, WI, Cool Choices is a nonprofit that works with games to inspire behavior change in order to cause greenhouse gas emission reduction. The Cool Choices game was implemented for eight weeks. Approximately 850 people signed up and 800 people played the game, most of them through team-based participation from their place of work. The gamers made 41,374 “Cool Choices” during game play (Cool Choices included adopting energy-saving behaviors). While pre-game motivations typically were the attraction of the Prize, post-game reflections were that the fun aspect was the motivating factor. An estimated (not measured) $245,186 was saved from previously completed and new actions. An estimated 2,639,372 lbs of CO_2 were avoided, 849,086 kWh were saved, 2,541,894 gallons of water were saved, and 1,482 sustainable ideas were generated.

In Walla Walla, Power Play was designed to be a reusable platform throughout the competition. Essentially a Bingo game containing energy-saving actions, the completed cards could be submitted for a monthly drawing for energy-saving kits. Approximately 11,000-12,000 Bingo cards were distributed through outreach events. The game was marketed through social media, in-person outreach, mailing lists, a newsletter from the local Chamber of Commerce, and utility company outreach. Middle schoolers were also offered the game. The approximate participation ratio was 1 in 6 in the schools. No surveys or outcomes were tracked, though the incentives were available from July 2015-December 2016. The organizers designed the game themselves and believed that the game and its related marketing created awareness because they received positive feedback.

In spite of repeated efforts, the author was unable to reach the designers or organizers of the Card Game in Athens County, OH. The Fargo games (the K-12 Energy Challenge and the efargo game) are described elsewhere in this dissertation.

8.5 Gaming cities' interviews

The planners and leaders of GUEP efforts in the cities playing games were interviewed (Appendix 8.B) to learn about motivations, challenges and results due to game play. Interviewees stated that they believed games would increase levels of engagement in the community, cause behavior change, and be fun for their communities. However, the reasons why they believed games would be fun, engaging, and cause behavior shift were varied. One interviewee thought that the competitive structure of games between friends, neighbors, and co-workers would allow an increase in engagement, whereas another city planner decided to use games to allow cooperative structures or strong social networks to inform increased engagement. Yet another city planner said that game structures would inspire or motivate engagement because of the ability for people to participate in various new activities and "try different things" due to the activity-based game structure. All of the cities responded positively that the energy game led to learning and awareness about energy savings. 36% of survey respondents in Fort Collins reported increased awareness from efforts in the game. Walla Walla did not conduct surveys, but in response to the question "Did participation lead to increased awareness of energy use," the organizers responded with an enthusiastic "Yes!" and "definitely" and "received positive feedback."

8.6 Gaming cities OES outcomes

The OES was used as the "figure of merit" according to the GUEP guidelines. Negative OES values are considered better because they indicate energy savings. Most GUEP semi-finalist cities achieved some level of energy savings as reflected in the OES (Figure 8.1). In the semi-finals, all gaming cities reported energy savings after normalizations and weatherization. Among gaming cities in the semifinalist cohort, OES ranged from -9.1141 (i. e., 9.1141% savings) in Walla Walla, WA, to -0.6581 (i. e., 0.6581% increase in energy use) in Athens County, OH.

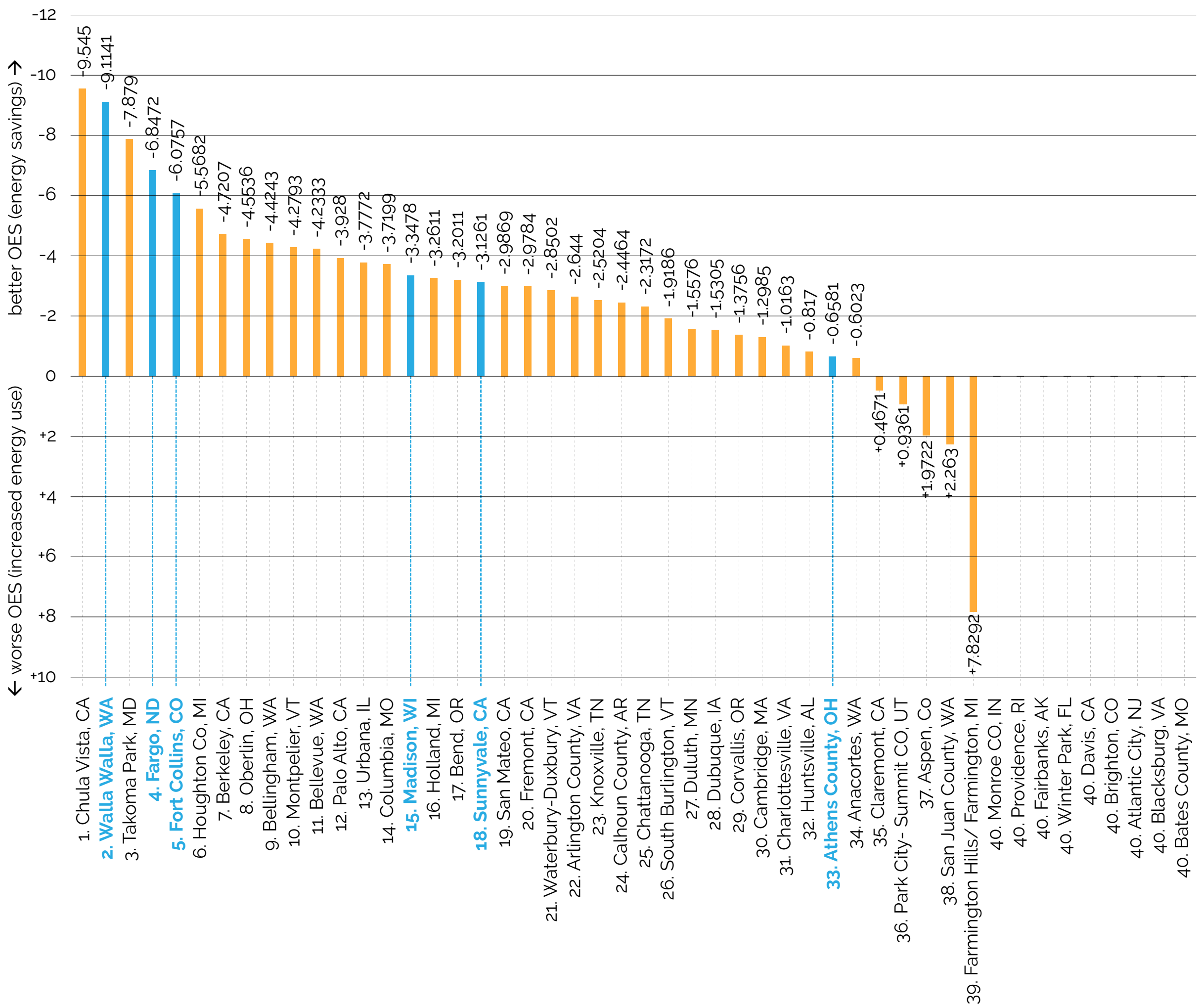

Figure 8.1. Ranking and Overall Energy Score (OES) of semi-finalist cities. (Gaming cities highlighted in blue.)

Based on the OES and the cities that chose to continue to participate in the competition, 10 finalists were announced from the 50 semi-finalist cities (48 reported here due to data availability) at the end of the two-year competition period. The list of ten finalist cities in order of their OES included three cities that played games, ranging from -9.1141 in Walla Walla WA, to -6.8472 in Fargo ND, to -6.0757 in Fort Collins CO (Figure 8.2).

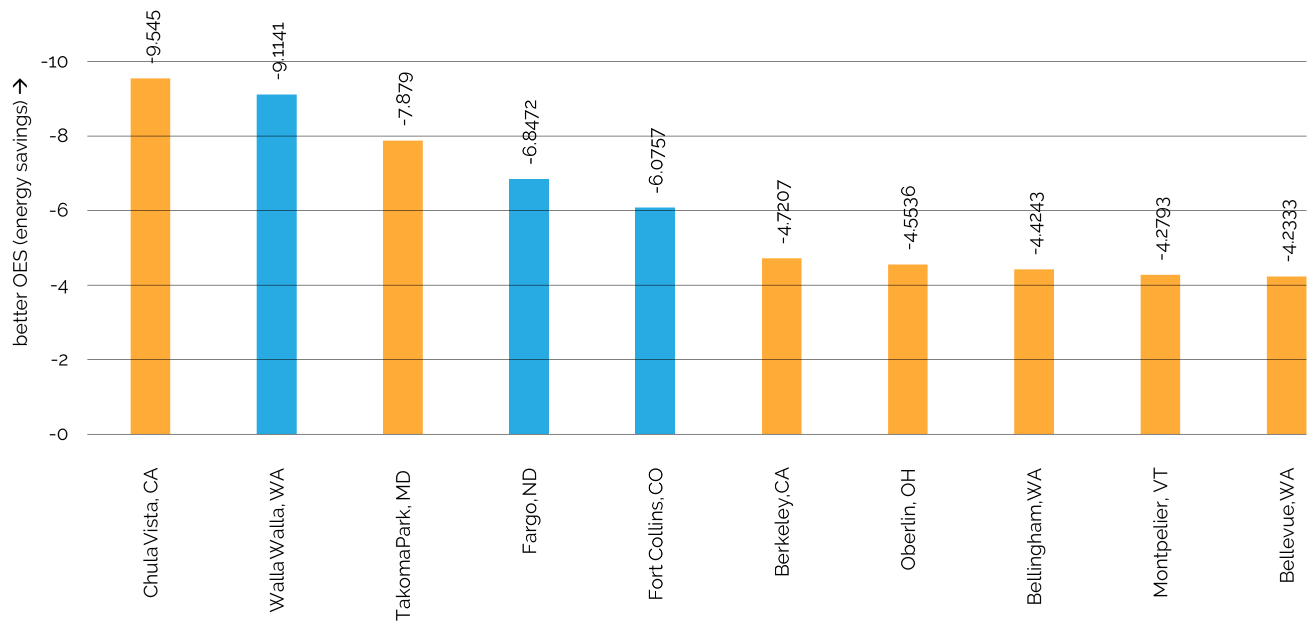

Figure 8.2. Ranking and Overall Energy Score (OES) of Finalist cities. (Gaming cities highlighted.)

The ten finalists were asked to submit final reports based on the plans, initiatives, performance measures, impacts, data collections, and partnerships that were implemented during Stage 3 (semi-finals). A panel of judges reviewed these reports.

In addition to performance (which, with 25 points, was the heaviest-rated category), several other factors were considered by the judge panel including innovation (15 points), the potential for replication (15 points), likely future performance (10 points), equitable access for community and stakeholders (10 points), education (10 points), and overall quality and success (15 points). The final scores based on the evaluation criteria were not announced by the GUEP team. However, based on the evaluation of the above listed categories, the winners of the competition in the Final Stage were as shown in Table 8.9.

Table 8.9. Final Competition Winners. (Gaming cities highlighted.)

Ranking	Community	OES
1	Fargo, ND	-6.8472
2	Fort Collins, CO	-6.0757
3	Bellingham, WA	-4.4243
4	Chula Vista, CA	-9.545
5	Walla Walla, WA	-9.1141

8.7 Conclusions

Based on the semi-final and final results, most of the cities that played games as part of their strategies occupy rankings in the best performing cities. Five of the six cities that played games were ranked in the top 20 performing cities in terms of the OES at Stage 3 of the semi-finals (Walla Walla, WA; Fargo, ND; Fort Collins, OH; Madison, WI; and Sunnyvale, CA). Three of the ten finalist cities designed and/or implemented games in order to cause behavior shifts and energy savings (Walla Walla, WA; Fargo, ND; and Fort Collins, CO). Finally, three out of the five top-ranked cities, including the winning city (Fargo), played games as part of their energy-savings action plan. The winning city, Fargo, depended heavily on the design and implementation of games in multiple venues such as residences, schools, and community events. Although it cannot be conclusively stated that the playing of games directly caused the substantive energy use reductions shown in the GUEP results, it is nevertheless noteworthy that of the one winner and four honorable mentions announced, three of the cities that played games were named to this list. The first two ranks were taken by cities that played games, namely, Fargo, ND and Fort Collins, CO.

ACKNOWLEDGEMENTS

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9.0 Conclusions & Future games

Summary

This chapter summarizes the conclusions from previous chapters and analysis done for this dissertation. It outlines limitations experienced and discusses the potential for future game frameworks.

"The problems that the world faces today require the kinds of thinking that gaming literacy engenders. How does the price of gas in California affect the politics of the Middle East affect the Amazon ecosystem? These problems force us to understand how the parts of a system fit together to create a complex whole with emergent effects. They require playful, innovative, transdisciplinary thinking in which systems can be analyzed, redesigned, and transformed into something new."

Eric Zimmerman, Manifesto for a Ludic Century (20-22),
The Gameful World, Steffen P. Walz, Sebastian Deterding

9.1 Introduction

This dissertation addresses the substantive energy use and carbon emissions of existing building stock in order to seek solutions that mitigate buildings' impacts on climate change through playing serious pervasive energy games. This dissertation contends that games provide a potential answer for bridging the energy efficiency gap and reducing energy use because of their ability to accommodate a heterogeneous target audience through game design, allowing people to play the game based on their own needs, interests, motivations, goals and resources. Based on an extensive literature search conducted intermittently over a period of three years, 129 energy games were identified. Of these 28 serious energy games (SEGs) included data collection. In order to address the informational, behavioral and financial barriers identified as the broad causes of the energy-efficiency gap, the 28 games were further examined for energy savings related learning and awareness outcomes, willingness to engage in energy-saving behavior and make energy-saving investments and most importantly, achievement of energy savings.

Of the 28 SEGs, 13 of games with data collection were Serious Pervasive Energy games. Of note in this literature review was the ability of Serious Pervasive Energy games (SPEGs) to achieve substantive energy savings (Chapter 2). Three SPEGs reported statistically significant energy savings ranging from 8% on the low end to 38% on the high end. Other SPEGs reported statistically untested energy savings in the range of 12.1% - 35.3% (Table2.5). By contrast the rest of the 15 SEGs reported either lower energy savings or statistically untested energy savings (Table 2.6). Two of the SEGs reported statistically significant energy savings from 2-4%. Two SEGs reported savings from 3%-30% but were not tested for significance (Chapter 2). In general, for two measures (investments and energy savings), the

SPEGs show better results. For learning and behavior, both SEGs and SPEGs show comparable results. From the literature review, it is clear that the SPEGs are helping gamers learn or acquire knowledge about energy conservation, are causing behavior change towards more efficiency, and are resulting in energy savings. In other words, these games are overcoming the energy efficiency gap. However, of all the 129 Serious Energy Games that exist, only 14 are Serious Pervasive Energy games and only 5 are open implementations. Of those open implementations (not controlled experiments) only 3 had data collections. Open implementations of games have the potential for large scale impact. Iterative open implementations of Serious Pervasive Energy games were studied for potential larger scale impacts with in-game data collection strategies. This research proves that playing Serious Pervasive Energy Games (SPEGs) can lead to awareness and learning about energy-savings; may engender willingness to engage in energy-saving behavior; may engender willingness to make energy saving investments; and lead to energy-savings in homes and schools.

9.2 The Games We Played

The national Georgetown University Energy Prize (GUEP), led by this author for City of Fargo, included partnership between the University, City, Utilities and Public Schools, provided this author the opportunity to test open implementation of Serious Pervasive Energy games. City of Fargo's participation in the GUEP was based on several game-based activities, of which the research, design and implementation of two serious pervasive energy games, form the core of this research. The author of this dissertation led the research and design efforts for the games which included several team members and was supported by various grants (see Acknowledgements). One of the games was for residential owners and renters (efargo game) and the other for K-12 schools (K-12 Energy Challenge), which was iterated four times. These games were open and available to City of Fargo, North Dakota gamers. The implementation of the games allowed for the following to occur (a) data collection from the games (b) an iterative implementation process; (c) winning the Georgetown University Energy Prize; (d) proposing the attributes for a future pervasive game. One iteration of the efargo game (residential) and the K-12 Energy Challenge (elementary, middle and high schools) were implemented in 2016 (Table 3.3). Three more iterations of the K-12 Energy Challenge were implemented in 2017 and 2018 for the purposes of this research and to continue the momentum gained from and the work done for GUEP. The City of Fargo participation in the GUEP and the overall effort to reduce energy use in the City was titled efargo. The first game for homeowners and renters was eponymously named the efargo game. The second game was designed for schools and was called the K-12 Challenge (Chapters 4 and 6). efargo and Waste-a-Watt (the game villain that signified energy waste and positioned the community as super-heroines and -heroes) became known in the community due to various newspaper, TV and radio articles and features and other earned media around this effort.

Ultimately, the purpose of the games was to achieve energy-savings. In order to do this, the games needed to address the informational, financial and behavior barriers that create the energy-efficiency gap. As such, the gamers needed to become aware of energy waste and learn about how to reduce or eliminate energy waste, be willing to engage in energy-saving behaviors and be willing to make the investments of resources (time, money and skills) in order to achieve the energy-use reductions (Chapters 5, 7 and 8) are summarized here.

9.3 LEARNING, ENERGY-SAVING BEHAVIOR & INVESTMENTS AND ENERGY SAVINGS

The hypotheses that this dissertation tested and proved the following hypotheses that playing a serious pervasive energy game (a) leads to learning and awareness about energy waste and energy savings; (b) may engender a willingness to engage in energy-saving behavior; (c) may engender a willingness to make energy-saving investments; (d) leads to energy-savings. Various data collection efforts such as energy use before, during and after game play (Table 3.4), engagement in game activities such as energy-saving behaviors that resulted in game points (Figure 5.1, 5.2, Tables 5.4, 5.6), and pre- and post-game surveys (Table 3.5, 3.6, 3.7, Figure 5.11), allowed an examination of the hypotheses.

9.3.1 SPEGs and energy savings

All the games implemented in the City of Fargo resulted in energy savings (Table 9.1) ranging from 6.51% to 16.23% decrease in energy use (Figure 9.1, Table 9.1). Various normalization protocols where appropriate were applied such as Portfolio Manager, E-Tracker and the ENEROC comparative method were used to normalize the energy data and results (Chapter 7). City of Fargo's participation in the GUEP also resulted in energy saving and carbon emission reductions. Other participating cities that included games in their GUEP work, also achieved energy savings (Figures 8.1 and 8.2). **During the efargo game,** based on normalized energy saving results from the efargo gamers (residential) that allowed access (Table 5.3), this analysis concludes that the average gamer started to have reductions in electricity use during game play (0.23% average) and that the greatest reductions in electricity use were evident in the eight months after game play (**12% average**

energy savings). During the K-12 Energy Challenge, the winning schools achieved energy savings ranging from 6.51% - 16.23% in the various iterations.

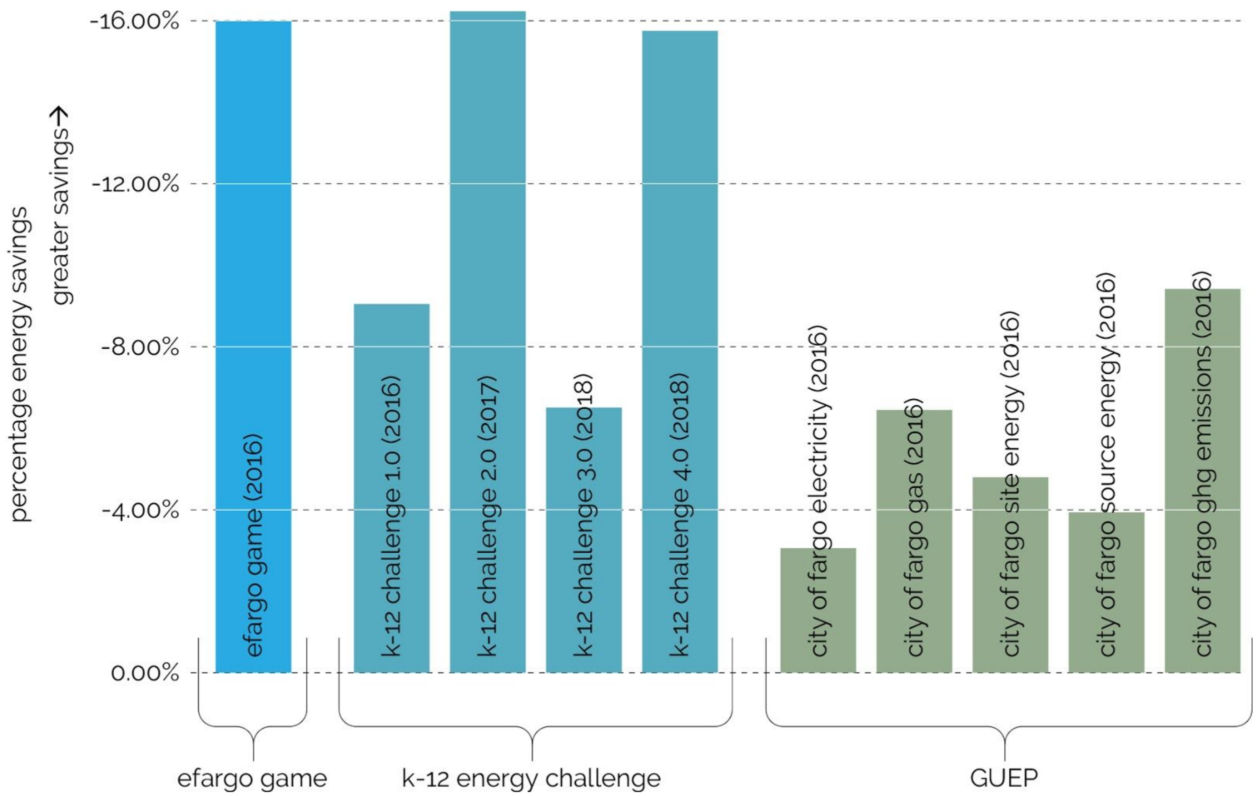


Figure 9.1. Energy Savings in efargo game, K-12 Energy Challenge (4 versions) and GUEP

During the K-12 Energy Challenge 1.0, the control school's (B.F. Elementary) normalized energy use (NEU) *increased* by 15.7%, representing a *decrease* in energy performance. By comparison, the four participating schools increased their NEU by an average of 3.52%. As summarized in Table 7.5, R. Elementary School's NEU *decreased* by 9.05%, while the remaining three schools increased their NEU: L. C. Elementary School by 3.13%; J. Elementary School by 9.41%; and L. Middle School by 10.6%. All fully and partially participating schools performed better than the control school.

Table 9.1. Analysis: Summary of Normalized Data Sources and Results for energy savings

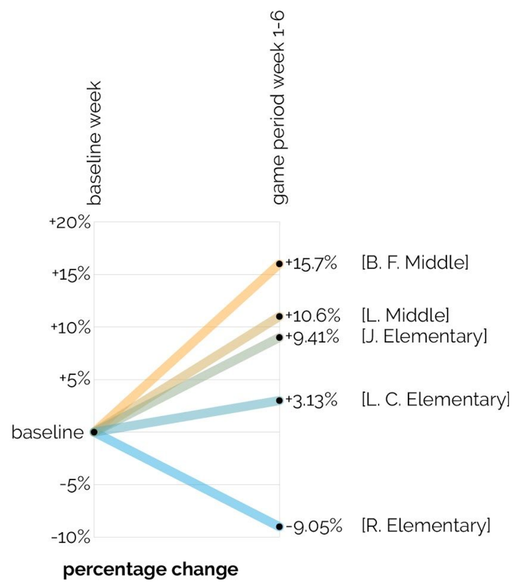
data source	Basis for Determination	Changes in Energy Use	Implications for Hypothesis 4
efargo game (2016)	comparison of predicted with actual energy use	In the period following gameplay, tracked user data indicated an average **12% decrease in energy use**	positive support, not statistically significant
k-12 Energy efargo challenge	normalized K-12 schools energy-use data (Spring 2016)	All fully and partially participating schools performed better than the control school, with the best-performing school achieving **9.05% decrease in energy use** in the competition period	positive support**
	normalized K-12 schools energy-use data (Spring 2017)	All fully and partially participating schools performed better than the control school, with the best-performing school achieving **16.23% decrease in energy use** in the competition period	positive support**
	normalized K-12 schools energy-use data (Spring 2018)	The best-performing school achieved a **6.51% decrease in energy use** in the competition period.	positive support**
	normalized K-12 schools energy-use data (Fall 2018)	All fully and partially participating schools performed better than the control school, with the best-performing school achieving **15.75% decrease in energy use** in the competition period	positive support**
Georgetown University Energy Prize (2015-2016)	normalized energy-use data from the City of Fargo	*Citywide* reductions reported in electricity use (**3.06% decrease**), gas use (**6.45% decrease**), site energy use (**4.80% decrease**), source energy use (**3.94% decrease**), and greenhouse gas emissions (**9.42% decrease**).	positive support*
	normalized energy-use data from participating cities	Of the five top-scoring GUEP cities, three cities played games	positive support*

* Difficult to prove direct causation from game to results
** Not tested for statistical significance

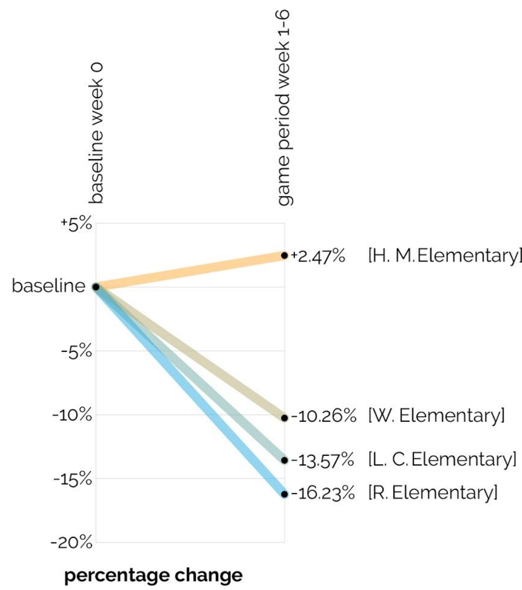
During the K-12 Energy Challenge 2.0, the winning school, R. Elementary School (the same school that won K-12 Energy Challenge 1.0), *reduced* its NEU by 16.23%. The two next-best performing schools, L. C. Elementary School and W. Elementary School, *reduced* their NEU by 13.57% and 10.26% respectively. H. M. Elementary School's NEU increased by 2.47% (Figure 7.6). The L. Middle School's meter readings were only available in the final four weeks of the six week game play. Comparing all the schools with a baseline in the second week of game play (disadvantageous to the other participating schools since they had already started energy-saving activities), schools' relative performance did not change. The three actively game-playing schools (R. Elementary School, L. C. Elementary School, and W. Elementary School) continued to achieve reductions in the same relative positions, while H. M. Elementary School (only teachers completed energy-saving activities in the first three weeks) and L. Middle School increased their energy use (most of the activities were focussed on education such as designing a green school, rather than tagging energy waste and fixing it). A comparative increase in H. M. Elementary School's energy use percentage (from 2.47%, calculated relative to Baseline Week 0, to 18.29% calculated relative to Baseline Week 2) likely results from the teachers completing one-day concentrated energy-saving activities within the first two weeks of the game period. Energy-saving activities did not persist beyond the initial action. The NEU increases for L. Middle School and H. M. Elementary School were very similar to each other, 18.29% and 19.55%, indicating that the weather had a large impact in energy use in that time period, making the other schools' energy reductions during the same time more notable. Also, noteworthy is that both the R. Elementary School and L.C. ELementary schools who were participating in the Challenge for the second time in 2017, had greater energy savings the second time they participated.

During the K-12 Energy Challenge 3.0, the winning school, L. F. Elementary School, decreased its NEU by 6.51%. W. Elementary School decreased its NEU by 1.39%. There were only two participating schools and consistent energy use data collection for control schools was not completed in Spring 2018. During this year, focus on engagement and not energy savings was tested in order to be able to have asynchronous implementation of the Energy Challenge so that teachers could implement the game when they could fit it into their curricular plans and not have to make adjustments for a synchronous implementation. The concept that classrooms might play against each other within a school and the competition would be for engagement (activity points), and not for greatest energy-savings between schools (like the other Challenges) yielded the worst energy-saving results of all the four games. The fact that the game duration for energy-saving activities (2 weeks as opposed to 4-6 weeks) also had an impact on the reductions not being as good as other years. Although the teachers appreciated the potential for asynchronous play and the shorter duration of adjusting normative class activities, this design yielded the lowest energy saving reductions.

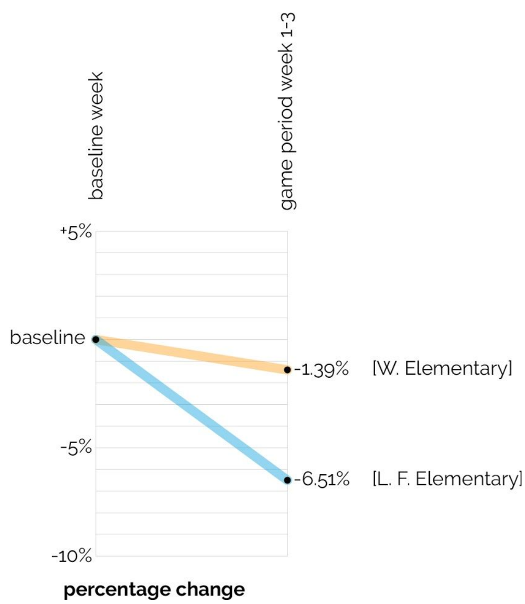
During the K-12 Energy Challenge 4.0, the game design for K-12 Energy Challenge 4.0 (implemented in Fall 2018), returned to synchronous game play with schools competing for energy-use reductions. The game play period was increased to 4 weeks with learning activities in the first week and energy-saving activities in the subsequent three weeks. The control school, L. C. Elementary, was aware of the game (having been a participant in 2016 and 2017) but did not play the game in 2018. All of the schools achieved energy savings in K-12 Energy Challenge 4.0. M. ELementary school (15.75%) and C. Elementary school (15.36%) had the greatest energy savings only separated by the fraction of a percentage point. W. Elementary's three classrooms achieved energy use reductions of 12.8% during the competition period.



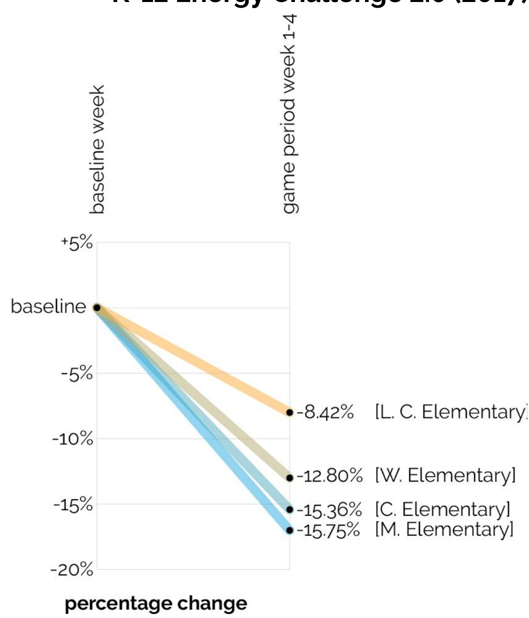
K-12 Energy Challenge 1.0 (2016)



K-12 Energy Challenge 2.0 (2017)



K-12 Energy Challenge 3.0 (Spring 2018)



K-12 Energy Challenge 4.0 (Fall 2018)

Figure 9.1 Normalized Electricity Use percentage (-ve percentages indicate electricity use reductions)

9.3.2 SPEGs and Learning

Through inferential statistical analysis, it was **confirmed** that *playing a serious pervasive game can lead to **awareness and learning about energy-savings*** (Hypothesis 1), based on data from the efargo game and four iterations of the K-12 Energy Challenge, both open serious pervasive energy games. Each of the data sources are discussed in turn (Table 9.2). All instances of the games showed **positive improvements ranging from 4.66% - 40.33%** increase in mean responses in the positive direction from hypothesized neutral to post-game mean or from pre-game to post-game mean response. The one test for objectively correct response that tested knowledge gain, the response was an **80% improvement**. This could be a testing method that can be deployed more often in the future provided it is incorporated into the game play.

Table 9.2. Analysis of questions in surveys of various games that tested gamers' perception of learning and awareness about energy savings).

	data source	**cronbach's alpha (α)**	**data**	**test for significance**	**p**	**implication for hypothesis**	**% change**
k-12 challenge 1.0	five questions from the post-game survey completed by teachers, measuring the teachers' experience.	α = 0.886	2.00 (hypothesized neutral response) 2.61 (post-game)	t-test	0.001	confirmed; statistically significant	**30.50%**
k-12 challenge 1.0	six questions from the post-game survey completed by teachers, measuring the teachers' perception of student experience.	α = 0.893	2.00 (hypothesized neutral response) 2.57 (post-game)	t-test	0.004	confirmed; statistically significant	**28.50%**
k-12 challenge 2.0	seven paired questions from the survey given to students at L. Middle School (pre-game and post-game)	α = 0.898 (pre-game) α = 0.823 (post-game)	3.54 (pre-game) 3.75 (post-game)	t-test	0.017	confirmed; statistically significant	**5.93%**
k-12 challenge 2.0	a single question (about percentage of energy savings) with objectively correct responses was asked of students at L. Middle School (pre-game and post-game)	n/a	15% of respondents answered correctly pre-game 27% of respondents answered correctly post-game	t-test	0.02	confirmed; statistically significant	**80.00%**
k-12 challenge 2.0	responses to two additional questions from the post-game survey given to	α = 0.749	3.00 (hypothesized neutral response)	t-test	0.001	confirmed; statistically significant	**12.33%**

	students at L. Middle School		3.37 (post-game)				
k-12 challenge 3.0	Five paired questions from pre-game and post-game surveys completed by students	α = 0.757 (pre-game) α = 0.843 (post-game)	3.86 (pre-game) 4.04 (post-game)	t-test	0.01	confirmed; statistically significant	**4.66%**
k-12 challenge 3.0	Eight post-game survey questions completed by students	α = 0.857	3.00 (hypothesized neutral response) 4.04 (post-game)	t-test	< 0.01	confirmed; statistically significant	**34.67%**
k-12 challenge 3.0	Two post-game survey questions, specifically related to dissemination, completed by students	α = 0.386	3.00 (hypothesized neutral response) 4.03 (post-game)	t-test	< 0.01	confirmed; statistically significant	**34.33%**
k-12 challenge 4.0	5 paired survey questions completed by students at C. Elementary School, M. Elementary School, and W. Elementary School.	α = 0.456 (pre-game) α = 0.557 (post-game)	3.34 (pre-game) 3.54 (post-game)	t-test	0.02	confirmed; statistically significant	**5.99%**
efargo game	three questions from a post-game survey given to efargo gamers	α = 0.919	3.00 (hypothesized neutral response) 4.21 (post-game)	t-test	< 0.01	confirmed; statistically significant	**40.33%**

The efargo game and the K-12 Challenges provided gamers with the structure, incentive, opportunity and interest in engaging in activities that helped them become aware of energy waste and learn about how to achieve energy savings. The efargo game incorporated educational components in various tokens and action areas.[1] Every week a new token allowed gamers to learn about and achieve energy savings in particular topic areas such as lighting, devices,controls etc. Tokens 2 through 6 and 7 incorporated information and a quiz at the introductory level (Level 10) of every token. 428 learning activities were completed throughout the game for various Tokens (Table 5.4). Token 9 was a celebration event that incorporated learning activities like workshops, exhibit, activities etc. through which 178

[1] See Chapter 4; 4.7 Game Tools.

activities were reported completed. The K-12 Challenge also incorporated several educational activities (Tables 7.5, 7.15, 7.26, 7.39), such as designing a sustainable school, methods to save energy in the school, working with local architects and consultants to research energy-saving measures, arranging for experts to provide educational talks or workshops, making educational posters and announcements about energy waste and savings, using meters to study light levels and greatest energy using devices in the school, using energy cards, online or VR files to tag and understand the energy waste in the school building, using FLIR cameras to understand infiltration and leakage, playing the home energy game to understand energy usage in the students' homes. Most importantly, all the energy-saving activities within the game such as energy patrols, thermostat setbacks, blackout days, unplug-hour etc were heuristic learning activities similar to project-based learning.

9.3.3 SPEGs & Willingness to Engage in energy-saving behavior and make energy-saving investments

Although, all instances of the games returned **positive improvements ranging from 4.13% - 27.67%** increase in mean responses in the positive direction when comparing hypothesized neutral mean to post-game mean or comparing from pre-game mean to post-game mean, descriptive and inferential statistical analysis of survey questions returned **mixed results for the p-values** for the hypotheses that *playing an open or targeted serious pervasive game can **engender willingness to engage in energy-saving behavior*** (Hypothesis 2). One result was based on efargo game responses was statistically significant (p=0.001) and four results based on teacher and student responses were not statistically significant given the standard used (p =< 0.05). Two of the behavior related means have p values of .06 (6%) and .092 (9.2%) (Energy Challenge 1 and 2). And two of the behavior related means have p values in the 0.15 (15%) range (Energy Challenge 3 and 4). These results were based on survey data from the efargo game and four iterations of the K-12 Energy Challenge, both open serious pervasive energy games (Table 9.3).

Table 9.3. Summary of Data Sources and Results, Hypothesis 2.

	data source	**cronbach's alpha (α)**	**data**	**test for significance**	**p**	**% change**	**comments**
Efargo game	post-game survey given to gamers	α = 0.881	3.00 (hypothesized neutral response); 3.83 (post-game)	t-test	**0.001**	**27.67%**	Statistically significant
k-12 challenge 1.0	post-game survey given to teachers	n/a	2.00 (hypothesized neutral response); 2.29 (post-game)	t-test	**0.092**	**14.50%**	Positive support
k-12 challenge 2.0	pre-game and post-game surveys given to students	α = 0.633 (pre-game) α = 0.637 (post-game)	2.96 (pre-game); 3.16 (post-game)	t-test	**0.06**	**6.76%**	Positive support
k-12 challenge 3.0	pre-game and post-game surveys given to students	α = 0.745 (pre-game) α = 0.849 (post-game)	3.63 (pre-game); 3 .78 (post-game)	t-test	**0.149**	**4.13%**	Positive support
k-12 challenge 4.0	pre-game and post-game surveys given to students	n/a	3.4 (pre-game); 3.63 (post-game)	t-test	**0.152**	**6.76%**	Positive support

K-12 students and teachers were not surveyed about making energy-saving investments in the Public Schools. However, efargo gamers, when surveyed about their willingness to make energy-saving investments, increased since playing the efargo game (Hypothesis 3), there was statistically significant positive support for willingness to make energy-saving investments due to game play.

Although the surveys reported mixed results for statistical significance, gamers in the efargo game and the K-12 Challenge demonstrated their willingness to engage in energy-saving behavior and positive support for willingness to make energy-saving investments, by reporting that they had completed several energy-saving actions and made energy-saving investments through the game points that they earned in efargo and the scorecard, email and interview reports that they completed for the K-12 Challenges.

For the efargo game, based on gamers' post-game survey responses, gamers' reported either that they had implemented several no-, low-medium or high-cost action items that involved either shifting behavior repetitively or making energy-saving investments (Tables 5.14, 5.15, Figure 5.11). Greatest numbers of gamers reported having completed no-cost and low-cost action items that required them to engage in energy-saving behaviors and make energy savings investments such as replacing old incandescent bulbs with LED bulbs (42.9% completed; 21.4 planning to complete); washing clothes in cold water (25% completed, 3.6% planning to complete); turning down thermostat by 2 deg F in the winter (21.4% completed; 19.6% planning to complete); using "air dry" on the dishwasher (21.4% completed, 17.9% planning to complete); replacing old holiday lights with LED lighting (21.4% completed; 14.3% planning to complete); unplugging a second or third refrigerator (!9.6%

completed, 1.8% planning to complete); switching off power strips that appliances and devices are plugged into (16.8% completed, 8.9% planning to complete); putting on an extra sweater and slippers instead of turning up the heat (16.1% competed, 3.6% planning to complete) and so on till it got to single digit percentages like 1.8% had completed a full energy assessment of the home during the game and 21.4% were planning to complete the assessment.

Through descriptive and inferential statistics, it was confirmed that *playing an open serious pervasive game can lead to a willingness to make energy saving investments* (Hypothesis 3), based on data from the efargo game (Table 5.10).

In addition to the survey reports of completing action items in the efargo game (Table 5.6), gamers earned points for completing a total 2,375 action items that were linked to energy-saving behaviors, some of which also required investments, to address various areas of energy waste in the residential sector such as Lighting (339 action items); Heating (288 action items); energy use related to water heating/cooling (239 action items); electrical devices (226 action items); controls (197 action items); cooling (217 action items); gamer choices of any of the above (219 action items); and providing feedback to the city regarding community-wide energy issues (180 action items).

During the four K-12 Energy Challenges, gamers completed several action items (or energy-saving behaviors), some that were repetitive such as daily morning and afternoon energy patrols to ensure that unused lighting and devices were turned off or unplugged and some that were one-time action items such as students working with administrators and facility managers to remove every other light bulbs from areas that were over lit. Tables

7.5, 7.15, 7.26 and 7.39 list all the action items completed and points earned by the various schools in the areas of educational activities, lighting, devices, heating and cooling and miscellaneous. Each topic contained action items that needed to be completed daily and action items that could be completed once for longer term impact. For example the Lighting topic contained daily action items such as energy patrols for switching off unused lights in classrooms, hallways, bathrooms, auxiliary areas and classroom or school daily blackout hours. Longer term impact action items included including a weekly full day with no lights except secure areas and low-light areas or changing classroom furniture layouts to take better advantage of daylight or removing several light bulbs in areas that were over lit by using the light meter in the game kit. It was the engagement in these energy-saving behaviors that led to energy savings.

9.3.4 SPEGS and Engagement

For the K-12 Challenges, a study of rankings of school performances based on three criteria was conducted (Table 9.4). The three criteria were rankings based on energy savings in each of the Challenges, rankings based on activity points earned, and lastly rankings based on numbers of people participating (Students, teachers, staff, facilities manager, community members). Based on this analysis it is clear that in most cases, the points activity rankings and energy-saving rankings were aligned with two exceptions. In most cases if the school had a high ranking in activity completion, they also had a high ranking in energy savings. The first exception was L.Middle and H.M. Elementary in Energy Challenge 2.0 and the second exception was W.Elementary and M.Elementary in Energy Challenge 4.0. In Energy CHallenge 2.0, L.Middle and H.M. Elementary had 4th and 5th ranks for activity points respectively and vice versa for energy ranking. At the end of Energy Challenge 4.0, W.Elementary and M.Elementary had 1st and 3rd rank for activity points respectively and vice versa for energy savings. For L.Middle and H.M. Elementary, a possible explanation is that the two activity rankings and energy-saving rankings misalignment was due to the activity points being mainly focussed on educational activities rather than energy-saving activities. For example L.Middle focussed most of their efforts on educational activities such as designing a sustainable school and doing research with consultants and giving presentations about energy savings to consultants and other classrooms. They earned a substantive amount of activity points but these activities did not necessarily translate to energy savings or being empowered to take energy-saving actions.

In addition, participation number rankings were surprisingly not necessarily aligned with the energy-savings (Table 9.4). In other words, having more participants did not necessarily mean that performance would also be better. For example L.Middle had the second largest group of participants but were the lowest (4th in 2016, 5th in 2017) in energy performance for both years of participation. Therefore, types of activities completed in the schools made a difference to the performance. Generally, activities of two types were included in the games. First, learning activities that are about knowledge gain but do not involve action items; second, included action-items that require energy-saving actions or habits (repetitive actions). L.Middle was focussed on learning activities such as designing a green school, making posters, energy announcements and giving presentations in non-participating classrooms.

W. ELementary was aligned in energy performance, activity points and participation rankings in two out of the three years that they participated (third in 2017 and second in

Spring 2018). The third time that they participated (Fall 2018), while their participation numbers and activities were ranked first, their energy performance was ranked third (or lowest). By contrast, M.ELementary was ranked third in activity points but first in energy savings, marginally ahead of C. Elementary. The activities that W.Elementary completed included both daily energy-saving habits in the three classrooms that participated and longer term activities such as educational activities that included meters, posters, learning through other online game resources from the efargo toolkit. They had a balanced approach and yet, in spite of greater numbers of participants and activities, they had the lowest energy savings. The only indication of hurdles they had was that they did not have Facilities staff or administration (Principal, office manager etc) engaged in the game. They also reported facing resistance from non-participating classroom teachers where they were not allowed to step into other classrooms or complete energy patrols in rooms other than their classrooms. This confined their energy-saving activities to the participating classrooms rather than as many areas of the school as possible.

Table 9.4. Rankings of schools based on energy savings, activity points and participation numbers

	k-12 challenge 1.0			**k-12 challenge 2.0**			**k-12 challenge 3.0**			**k-12 challenge 4.0**		
RANKING	**Energy**	**Points (Activities)**	**Participation**	**Energy**	**Points (Activities)**	**Participation**	**Energy**	**Points (Activities)**	**Participation**	**Energy**	**Points (Activities)**	**Participation**
R.Elementary	1	1	2	1	1	1						
L.C. Elementary	2	2	1	2	2	N/A				*4*	*N/A*	*N/A*
J. Elementary	3	3	3									
W. Elementary				3	3	3	2	2	2	3	1	1
H.M. Elementary				4	5	4						
L. Middle	4	4	2	5	4	2						
L.F. Elementary							1	1	1			
C. Elementary										2	2	2
M. Elementary										1	3	3

B.F. Middle	*5*	*N/A*	*N/A*									

Note: Italics indicate a control school that did not participate in game activities that year.

Schools that had consistently been successful at achieving energy-savings such as R.Elementary and M. ELementary consistently reported having enthusiastic support from principals, teachers, librarian, facility managers who helped and assisted students with the goals that they outlined. The schools that had these social expansions, had the best chances of reducing energy in the school even when they did not have the largest number of student participants. Additionally, at R.Elementary, the Energy Challenge was led by a group of students drawn from multiple classrooms. Students were able to come up with ideas for saving energy for the whole school and not just for participating classrooms. For example, they instituted school-wide energy patrols and energy-saving messages and announcements. They reported the school performance to the entire school on the P.A. system and with the help of the Facilities Manager and permission of the Principal, unplugged vending machines over weekends, switched off air handlers when the gym and cafeteria were not in use, removed several light bulbs from around the school and instituted and all lights off policy. All of these actions which were a result of cooperation and partnerships within the various school personnel and multiple classrooms resulted in substantive energy savings.

When the signs and symbols of game play such as stickers, energy announcements, energy patrols, posters, reduced lighting, etc., pervaded and created game space, teachers reported that non-participating students, teachers and staff became curious due to the visible, audible, and perceptible presence of the game. Some of the curiosity was negative (such as at W.Elementary), where complaints were received and students were asked to stay out of non-participating classrooms.. However, some outcomes were positive. Engagement numbers increased with more students expressing an interest in participation and then participating such as at R. ELementary and L.C.ELementary. More importantly, other teachers, staff and facilities staff got involved in some schools as well, having the potential for social and spatial expansions. On surveys, students reported taking their learning home and telling their parents about the game, creating a potential for social, spatial, and temporal expansions. Greater engagement can potentially translate to greater learning and energy-savings in the future. However, the game implementations thus far, do not fully track these expansions.

9.4 Limitations and Barriers

Both the efargo game and the K-12 Challenge experienced obstructions and limitations in the game play and data collection process. Some of the barriers experienced during game implementation were lack of broad game awareness; limitations of manual data collection processes for gamers' perceptions and energy use before, during and after the game; synchronicity of game implementation that was not flexible to gamers' needs; limitations of social and spatial expansions with the games only focussed on two architectural typologies of residential and primary (K-12) education; weighing individual investments and societal benefits; providing intrinsic and extrinsic rewards; and finally, treating the game as a test bed in that being able to respond to gamers' feedback and needs in a timely way (not an annual cycle).

9.4.1 Awareness & Marketing

One of the key barriers experienced was *awareness* of the game. Since the research, design, development, implementation and data collection of the games was fully grant supported, marketing depended upon the good will of partners, invitations and earned media since it was not an allowable activity for the grant funds.. Community members being aware of the game as a freely available and easy-to-use tool is fundamental to the game's success: awareness that a game exists is a first step in gamers joining the game. The word about the game was initially spread through a news conference by the City of Fargo for game announcement and invited presentations around town with audiences ranging from 6 to 80 people. The City of Fargo sponsored a short article in the City newsletter, provided a discounted billboard for a short period of time. One of the Utilities did an article in their newsletter inviting their customers to save energy. Lastly, the efargo effort received attention in some newspaper, radio and TV news reports. New gamers tended to increase around particular events (figure 9.x), though a detailed study of this phenomenon has not been conducted for this dissertation.

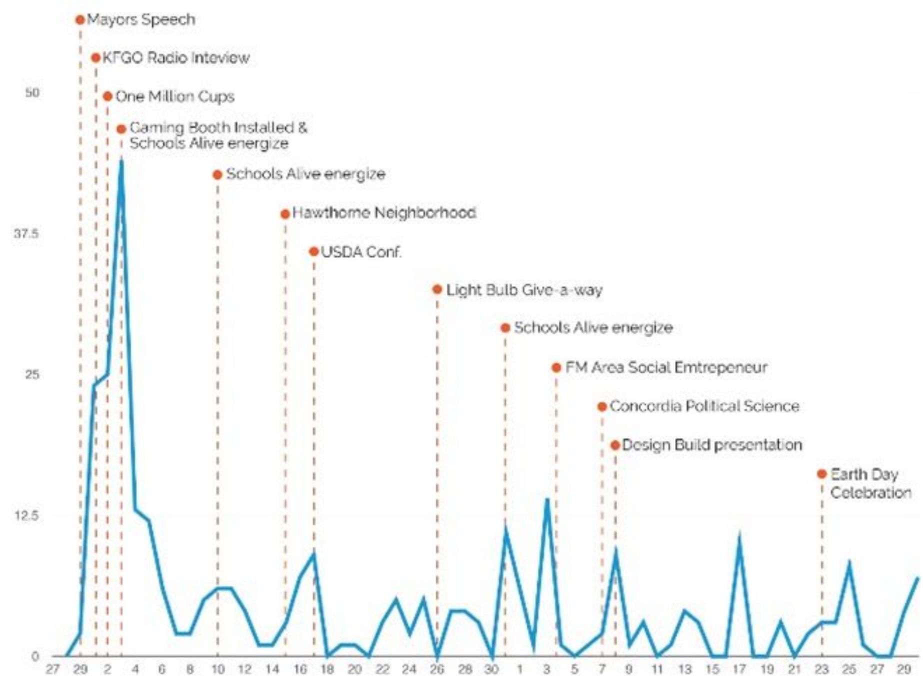


Figure 9.x. Dates gamers signed up for the game and dates of events

While the City of Fargo acted as champion and community liaison for efargo. The outcome of these funding limitations was that the efargo game's availability was communicated primarily social media, small local events, emails and word of mouth.

9.4.2 Gamer Agency & game media

For the gamer to be able to play the game, they have to have the resources necessary to play the game. WHile the efargo game was available for access by any residential owner or renter, they could only utilize the game through digital media. If the game interface is digital, having a device that can access the digital game provides an opportunity to play the game. Games where the target audience or demographic is open, i.e. anyone who has the interest and is aware of the game, may join the game, can result in wide-ranging demographics. Wide-ranging demographics could require multiple modalities of play that can cater to the various demographics for successful game adoption. For example, people lacking access to a digital platform may have been aware that the efargo team had partnered with the Fargo Public Library system to create dedicated stations at the main library where the game could be partially played by any community member. It follows that the target audience and aligned modality or modalities of game play needs to be an important factor of game design. If resources are limited, then there needs to be designed alignment between game modality, target audience (rather than open implementation), and related marketing effort. A technology related access issue for the web-based game was the compatibility with various browsers. The efargo game could only be communicated to community members via an online platform and specific browsers, and the efargo game was coded and tested primarily on Google Chrome due to severe time limitations (following from the GUEP timeline). Gamers reported difficulties with playing the game on Explorer and Mozilla firefox.

9.4.3 Gamer Agency and Time

The time constraint was primarily felt by the teachers who had to squeeze the game into already heavy curricular loads. Of all the schools that participated, only one school chose to implement the game as an after-school activity. Most of the other teachers were interested in finding out whether the game incorporated enough material so as to help meet curricular goals so that they could incorporate it into their class schedules as a replacement for traditional methods of delivering content. Secondly, the teachers were burdened by needing to adjust to the limited time implementation of the game. They asked if they could implement the game when it best fit their annual class curriculum. The K-12 Energy Challenge 3.0 tested this idea of implementing asynchronously so that schools were not competing against each other at the same time, but this wasn't as successful as the other

Challenges. It also tested a shorter duration of game play but the savings and engagement were not as extensive as the other three Challenges.

The longer duration of K-12 Challenge 2.0 allowed students to understand where the energy waste was, to come up with ideas and lobby for changes to be made to the school building and most importantly, develop energy-saving habits, e.g., switching off lights or unused devices by conducting energy patrols. All of these factors generated long-term engagement, growing numbers of interested participants, and an active and empowered group of players or community members with time and support to implement their ideas. Future design iterations or replication and scalability of the K-12 Challenge should account for these elements. Further design work needs to be done to overcome the time or synchronicity barrier. In the efargo game, the game was implemented primarily during March and April in a cold climate zone. WHile the game incorporated didactic ideas about action items that would help reduce energy use during different seasonal cycles, temporal expansions were not as extensive as they could have been.

9.4.4 Data Collection

Data collection activities were restricted and not as granular as needed due to privacy concerns, inadequate infrastructure (manual meters and controls), existing data collection methods and protocols and demographic needs.

Energy Use Data Collection: In the past four years of game implementation (2015-2018), the K-12 Challenge requires direct involvement of efargo personnel in energy use data collection by manually reading meters. This has been a considerable barrier in the research effort to test the true effectiveness of the game. Several challenges arose due to the need to conduct manual meter-reading and recording. Human errors in meter readings (e. g., not recording readings consistently, transcribing incorrect information or overlooked meters among multiple meters) happened in all four game implementations. While the research assistants could certainly have benefited from additional training, there were occasions when facility managers were unaware of the specific purposes of every meter, leading to a failure to collect all relevant meter data. If a meter-reading day happened to coincide with a school holiday, the consequent adjustment in the meter recording cycle negatively impacted the frequency of data collection and normalization. Classroom, teacher, or student event conflicts also precluded meter readings in some cases. The game required facility managers to invest personnel effort to read meters, which wasn't part of the original game plan. This involved training, both to enable personnel to identify the correct meter types, and to develop knowledge to convert meter readings (with known equipment multipliers) for each meter type. Finally, some meters were located in restricted areas (whether fenced, locked, or indoor), requiring the supervision and cooperation of staff. While participation from facilities personnel was difficult, cooperation from utilities was inconsistent. Unclear and inconsistent instruction from one utility concerning their equipment prevented accurate data collection. Lastly, human error was frequently involved in manual transcription of data every week from meter readings to comparative energy dashboards. Producing the weekly report was a substantive time burden for efargo, but at the same time it provided sufficiently frequent data release for successful reminders to engage in energy-saving behaviors.

For the efargo game, in order to study the energy savings accomplished due to game play by homeowners or renters, individual energy use data was needed to study the game's effectiveness. As part of the post-game survey, the gamers were asked to volunteer their energy use data by signing a release form. However the Utilities were unable to associate individual gamers with active utility accounts. This was largely due to mismatches in exact names or addresses, or to owners moving from an address or renters unable to access data for individual units. The utility was only able to match customers to their database if the accounts had the exact spelling of names and addresses, including prefixes, suffixes, numbering system, capitalization and punctuation.

Surveys and interviews: Since minors in K-12 schools were involved, permissions were not only needed from the IRB but also from the administrators of K-12 schools. For Energy Challenge 1.0, by the time each of the participating schools provided approval to the data collection, only post-game surveys and interviews could be conducted. In Energy Challenge 2.0, while permission to survey students was obtained, the teachers only wanted to follow a 3-point Likert scale in the elementary schools. The middle-school teachers were not as concerned about the eighth-grade students' ability to complete a 5-point Likert-scale survey, and so this format was used for the middle school survey. During Energy Challenge 3.0 and 4.0, permissions were obtained to complete a 5-point Likert scale pre- and post-game surveys of the 5th graders (3.0) and 4th graders (4.0). It took time to build trust to conduct the research. For the efargo game, since the game was open to anyone to play, the pre-game data collection was embedded in the game play itself rather than have gamers complete a separate game survey or sign consent forms. In response, NDSU's IRB review resulted in game access being limited to adults (i. e., minors could not access the game). As a result, one of the game's target demographics (ages 13-18) was excluded from the game play. This was a major loss for the efargo effort and the alignment between the data collection for research and the ease of accessing an open game remains a design question for future consideration.

9.4.5 Rewards

While the teachers and administrators were very interested in exploring intrinsic rewards as part of game play such as the game participation, learning and project-based activity, in the interactions that the efargo team has with the students, they were interested in knowing if they could win prizes or if there would be an award for the winner of the competition. Based on these interactions it was apparent that the children considered the rewards fun elements within the game. In order to provide rewards but also address the teachers' concerns, the reward to the students was aligned with the environmental goals of the games. They were offered a choice of game prizes such as certificates, FLIR camera, tree saplings and light bulbs for their school. They overwhelmingly preferred the tree saplings in all the Spring implementations of the game and LED bulbs in the Fall implementation. In addition, to recognize the students who made great efforts in the game, participation certificates and energy star certificates (for students leaders) were awarded.

9.5 Future Game & Future Work

The structure of a game that can successfully address the energy-efficiency gap and all the implicated informational, financial and behavioral barriers would be one which has the potential to be increasingly pervasive, continually setting greater challenges, connecting communities in open structures so that temporal, social and spatial expansions can change and pervade as the gamer needs, but also be societally meaningful in terms of addressing climate change. In other words it would be designed to be a global framework but flexible enough for the gamers to make it personally and locally meaningful in a way that reflects their realities and be able to incorporate changing realities. It would be asynchronous so as to be flexible to the gamers' temporal needs but fully competitive at the same time. It would incorporate any building typology that the gamer would want to include to address gamers' spatial needs and realities, while providing the challenge to be able to continue to create those social and spatial expansions in an ever-changing or growing magic circle. The new game would need to provide information and teach about the impacts of energy waste and energy-saving actions at the personal, local, community, city, national and global scales, and especially to meet curricular goals in the primary education category, but not be boring. The "Tag" function conceptualized by this author in the K-12 Challenge, was a pervasive way for children to learn about complex ideas of energy waste and their power to save energy. It was heuristic learning which was also fun and competitive. Lastly, the game needs to address the barriers of technology, access and generally the barriers to gamer agency by providing a hierarchy of engagement paths such that the game becomes meaningfully flexible for gamers.

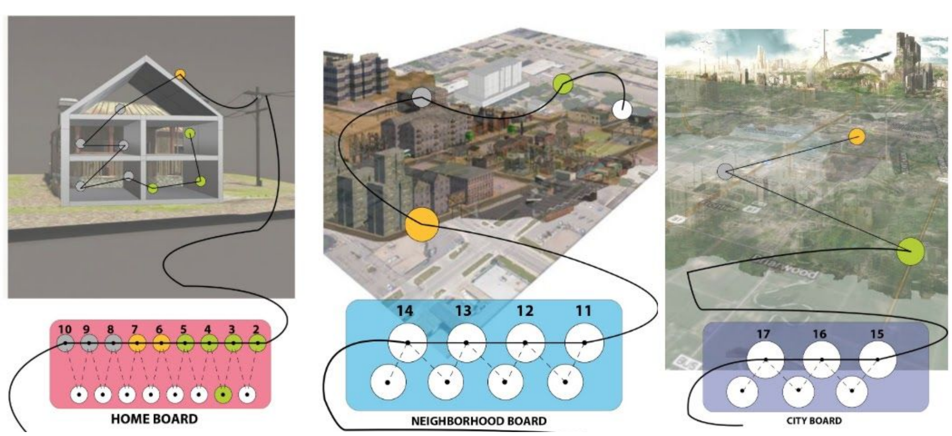


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Figure xx: Concept sketch of nested home, neighborhood, city, cooperative and competitive mission structures within game pilot to fix energy waste

The scale hierarchy that was explored in the efargo game (individual, community and city tokens) and visualized as energy-saving missions (sketch from Chapter 4, repeated here) is now explored as a hierarchical game structure of nested scales that include the personal, local, community, city, national and global scales at which the game can be played. Instead of missions, within this broader framework, the gamer tags energy waste in buildings they own or occupy. Tagging energy waste is essentially completed by creating a digital marker in a physical location with a geographic address. For the gamer it is a click in the app along with a photo and some descriptive information for which they earn points. Therefore a gamer may start with tagging energy waste in their own home. Further, they can tag energy waste in their cities, tagging energy waste in public (libraries, city halls, parks, fire stations, police stations, schools, Universities etc) or municipal space or commercial and privately owned spaces (grocery stores, retail, entertainments, workplaces, industry, manufacturing, schools, universities etc). By tagging their spaces, communities, buildings and cities, gamers create the game that is personally meaningful to them and locally meaningful to the community. Gamers' Tags earn points and also allow the "Capture" phase to occur. Tags can be captured by any gamer to earn more points. Capturing a tag could be done in many ways such as fixing the energy waste, calling attention to the energy waste (organizing the community, calling attention to energy waste, creating activism around energy waste), learning and educating about the energy waste (teaching yourself and others about the energy waste). The framework would allow gamers to organize mini competitions, races and challenges within the game structure. The goal of the game would be to maximize pervasiveness while allowing the game to be personal, local, regional, national and global at the same time.

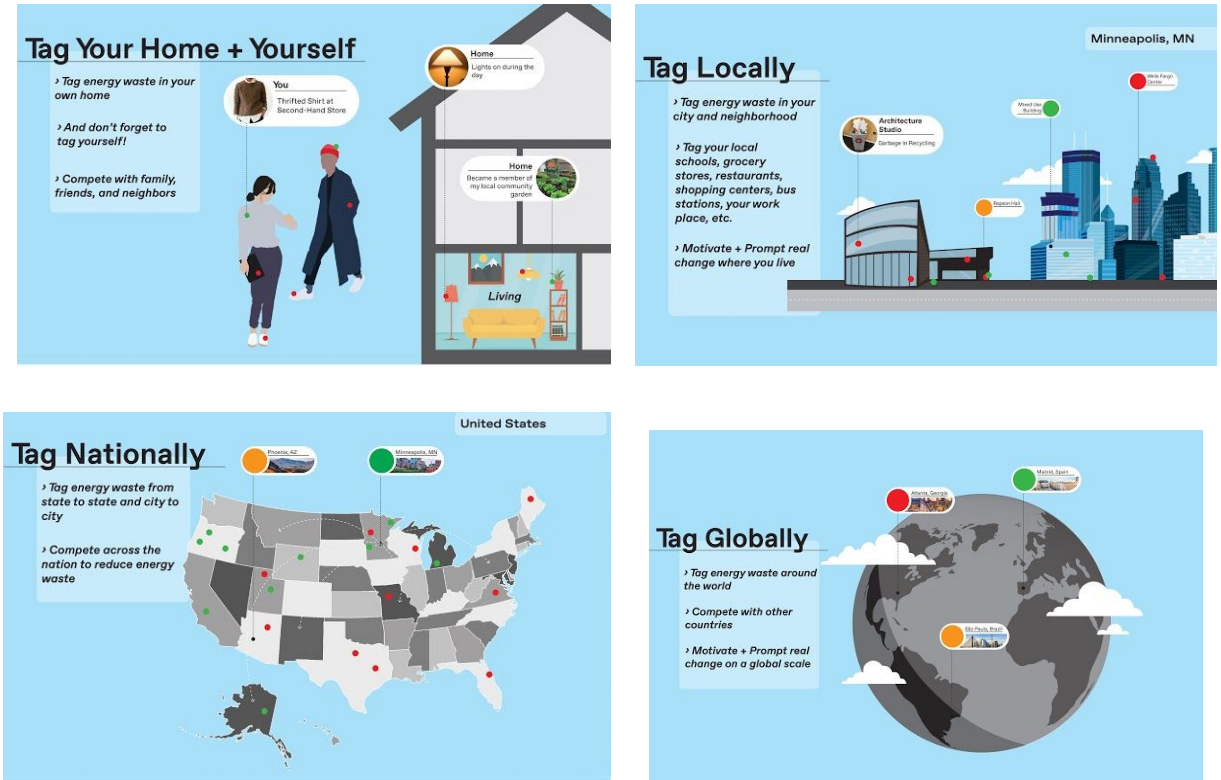

Figure xx: Concept sketch of nested local, neighborhood, city, national and global structures within game pilot to tag energy waste

The design of the game and its data collection strategies within the game play are yet to be designed. However, building on the pervasive tagging of energy waste as a heuristic educational activity in the K-12 Challenge, which has now morphed into tagging across typologies, demographics and geographies in an effort to create a truly local and global framework. While this design work is not part of this dissertation effort and is supported by another granting agency, the conceptual framework is built upon the research conducted in this dissertation from 2016-2018.

9.6 Conclusions

The K-12 Energy Challenge suggests that four elements were necessary and sufficient to save energy: first, social expansions indicated by endorsement of and active participation by stakeholders, in this case administrators, teachers, and especially the facilities staff; second, champions of the game, in this case an engaged core group of players (i. e., the students) who had fun, and who found the energy-saving concepts easy to understand and playful; third, visible, audible and perceptible presence of the game that caused spatial expansions to occur, in this case from participating classrooms to the entire school becoming subject to energy savings which also increased participation and awareness; and finally, a sufficient amount of time for students to learn about energy waste, develop energy-saving solutions, develop the partnerships that would allow them to fix the waste by implementing custom solutions.

A game-based approach inherently advocates and creates the conditions for small scale, local actions accruing for societal and global benefits. There are several questions that emerge from this premise. At an individual level, people who have either time to change behaviors, or skills and resources to make investments in their homes or workplaces accrue both personal benefit while contributing to societal and global benefits. However, there are people who will not be able to participate in the game due to resource limitations or any other personal circumstances that they might have. Any distributed game-based approach needs to consider this constituency and include their benefit in the model. Normally, larger scale actions such as policy changes for larger societal benefits, would include these considerations. Games, especially with their intrinsic and extrinsic reward structures, need to consider that personal and not just societal benefits are inclusive of disenfranchised communities or extenuating circumstances.

Researchers are interested in granular data to understand the reliable impacts of interventions. As such, I have advocated for individual energy data collection in this dissertation. At the same time, I am also concerned about individual protections, especially if such structures may be misused for surveillance, even though the global need is urgent. Creating game design frameworks that protect individuals while creating societal benefits is a requirement for the future game design. Jon E Froelich writes about the need to address scenarios of surveillance and balancing needed societal change with individual actions versus social, societal and regulatory policy shifts. The fear in these scenarios is that the most convenient problems may be addressed rather than the most needed ones. Or that success with the convenient problems may sweep attention away from the inconvenient problems. The following writing is excerpted from a recently published Chapter in the Routledge Companion to Games in Architecture and Urban Planning: Tools for Design, Teaching, and Research, Marta Brković Dodig and Linda N Groat (Srivastava 2019).

"Volume II of the 4 th Climate Assessment report has been recently released (United States Global Change Research Program, 2018). The fact that it was released by a US administration that disavows its basic premise should make all kinds of story-tellers and game designers sit up and take notice. Here is a storyline, already written, of apocalyptical dangers, extremely short length of time, villainous climate change deniers in power and the players that could create large-scale change. Since the early 2000s, SEGs are most often (though not always) targeted towards information transfer. While a laudable goal, games could utilize design structures that could potentially increase engagement, immersion and behavior shift such as compelling narratives related to the zeitgeist, cooperation, competition, coordination, chance, strategy, rewards, skills, role-play etc.

The Serious Energy Game design community, especially those with an expertise in the energy issues of the built environment, can gear up and do what Jane McGonigal said when she related (the most likely apocryphal) story written by Herodotus. The story goes that the Lydians lived through eighteen years of drought and famine by dedicating every other day to playing games, and non-game days to eat and abstain from games. In other words, games can be implemented at large scales to address serious and complex problems. Reading the rankings of the most popular games that surpass the revenues of the most popular movies or TV series in the world today suggests that we need the League of Legends, Fortnites, the Minecrafts, the Grand Theft Autos in terms of the attention and engagement they garner from large numbers of players; considering Serious Games that have solved serious problems suggests that we need the Fold-its and the Long Games for their crowd-sourced, creative problem-solving ability; games that have energized large swaths of communities including non-players calls for the Pokemons and the Tetris of SEGs in terms of games that endure and have broad appeal with a large number of people. In the face of global climate change, we cannot just be fiddling as Rome burns. To adapt the words of Laurel Thatcher Ulrich: timid designs rarely create change. (Ulrich 1976, 20)."

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