MAKAHIKI AND SGSEAM: A SERIOUS GAME ENGINE FOR SUSTAINABILITY AND STAKEHOLDER EXPERIENCE ASSESSMENT METHOD

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Abstract

Sustainability education and conservation have become an international imperative due to the rising cost of energy, increasing scarcity of natural resource and irresponsible environmental practices. Over the past decade, running energy and water challenges has become a focal point for sustainability efforts at both university and industry campuses. For example, there are more than 160 college residence hall energy competitions taking place or being planned for the 2010–2011 academic year in North America [17] to engaging students in sustainability issues. Designers of such challenges typically have three choices for information technology: (a) build their own custom in-house solution (as was done at Oberlin College in 2006 [32]); (b) out-source to a commercial provider (as was done at the University of British Columbia in 2011); or (c) use a minimal tech solution such as a web page and manual posting of data and results (as was done at Harvard in 2012).

None of these choices are ideal: the custom in-house solution requires sophisticated design and implementation skills; out-sourcing can be financially expensive and impedes evolution; and the minimal tech solution does not fully leverage the possibilities of advanced information technology.

To provide a better alternative to these three choices, I have led an effort over the past year to design and implement an open source serious game engine for sustainability called Makahiki. Makahiki implements an extensible framework with a variety of common services for developing sustainability games including authentication; game mechanics such as leaderboards, points, and badges; a variety of built-in games and content focused in sustainability, a responsive user interface, cloud-based deployment, and the ability to customize to the needs of individual organizations.

Makahiki lowers the overhead to those who would build a custom in-house solution by providing pre-built components. It can lower the financial cost to those who would out-source by providing an open source alternative. Finally, it provides an opportunity for those who would choose a minimal tech solution to instead provide more sophisticated information technology.

To provide initial evidence regarding the ability of the Makahiki Framework to support sustainability games in different environments, we ran challenges at three organizations in Fall 2012: The University of Hawaii, Hawaii Pacific Univerisity, and the East-West Center. While these experiences provided anecdotal evidence for the usefulness of Makahiki, we realized that a more rigorous evaluation of the framework would yield better quality insight into its current quality and requirements for future enhancement.

Upon review of the literature, we found little research or experience with formal framework assessment. To address this, I have embarked on research to design an assessment mechanism for serious game frameworks, called Serious Game Stakeholder Experience Assessment Method (SGSEAM). SGSEAM is designed to provide detailed insight into the strengths and weaknesses of a serious game framework through a stakeholder perspective based approach. In my research, I will apply SGSEAM to Makahiki in order to gain better insight into its strengths and weaknesses as a serious game framework.

However, the design of SGSEAM creates another research question: what are the strengths and weaknesses of this assessment method? To answer that question, I propose to apply SGSEAM to another serious game development environment to understand the strengths and weaknesses of SGSEAM.

The anticipated contributions of my research thus includes: the Makahiki framework for serious games for sustainability; the SGSEAM assessment method, the insights into serious game framework design generated through application of SGSEAM to both Makahiki and another serious game framework, and the insights into framework assessment design in general resulting from the above. I believe this research will be of interest to researchers and practitioners across several disciplines: software engineering, game designers, and sustainability researchers.

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Chapter 1

Introduction

1.1 Sustainability Education and Behavior Change

The rising cost, increasing scarcity, and environmental impact of fossil fuels as an energy source makes a transition to cleaner, renewable energy sources an international imperative. One barrier to this transition is the relatively inexpensive cost of current energy, which makes financial incentives less effective. Another barrier is the success that electrical utilities have had in making energy ubiquitous, reliable, and easy to access, thus enabling widespread ignorance in the general population about basic energy principles and trade-offs. In Hawaii, the need for transition is especially acute, as the state leads the US both in the price of energy (over $0.30/kWh) and reliance on fossil fuels as an energy source (over 90% from oil and coal).

Moving away from petroleum is a technological, political, and social paradigm shift, requiring citizens to think differently about energy policies, methods of generation, and their own consumption than they have in the past. Unfortunately, unlike other civic and community issues, energy has been almost completely absent from the educational system. To give a sense for this invisibility, public schools in the United States generally teach about the structure and importance of our political system (via classes like "social studies"), nutrition and health (through "health"), and even sports (through "physical education"). But there is no tradition of teaching "energy" as a core subject area for an educated citizenry, even though energy appears to be one of the most important emergent issues of the 21st century.

On the other hand, changing people's behavior with respect to energy holds significant promise in reducing energy use. Darby's survey of energy consumption research found that identical homes could differ in energy use by a factor of two or more [9]. Data from a military housing community on Oahu show energy usage for similar homes can differ by a factor of 4 [31].

1.2 Collegiate dormitory sustainability competition

Over the past decade, running energy and water challenges have become a focal point for sustain- ability efforts at university and industry campuses, to facilitate and incentivize energy and water reduction. Designers of those competitions have had three choices for information technology: (a) build their own custom in-house solution; (b) out-source to a commercial provider; or (c) use a minimal tech solution such as a web page and manual posting of data and results.

Petersen et al. describe their experiences deploying a real-time feedback system in an Oberlin College dorm energy competition in 2005 that includes 22 dormitories over a 2-week period [32]. Web pages were used to provide feedback to students. They found a 32% reduction in electricity use across all dormitories. However, in a post-competition survey, respondents indicated that some behaviors, such as turning off hallway lights at night and unplugging vending machines were not sustainable outside the competition period. Overall, there has been little analysis on energy usage after competitions finish, or how positive behavior changes could be sustained.

The Building Dashboard [24], developed by Lucid Design Group, is used to support Oberlin's dorm energy competition, as well as the Campus Conservation Nationals, a nationwide electricity and water use reduction competition on college campuses [25]. The Building Dashboard enables viewing, comparing and sharing building energy and water use information on the web in compelling visual interface, but the cost of the system creates the barrier for wider adoptions. In addition, the building dashboard solutions focus on providing energy information as a passive media. There is little interaction between participants and the system.

1.3 Serious games and Gamification

Another emergent issue is the explosive spread of game techniques, not only in its traditional form of entertainment, but across the entire cultural spectrum. Games have been shown with great potential as successful interactive media that provide engaging interfaces in various serious contexts [27, 35]. Priebatsch attempts to build a game layer on top of the world with his location-based service startup [33]. The adoption of game techniques to non-traditional areas such as finance, sales, and education has become such a phenomenon that the Gartner Group included "gamification" [11] on its 2011 Hype List.

Reeves et al. described the design of Power House, an energy game that connects home smart meters to an online multiple player game with the goal to improve home energy behavior [36].

In the game, the real world energy data are transformed into a "more palatable and relevant form of feedback", and players may be incentivized by the in-game rewards to complete more energy-friendly real-world behaviors.

ROI Research and Recyclebank launched the Green Your Home Challenge as a case study of employing gamification techniques online to encourage residential green behavioral changes offline [15]. Working with Google Analytics, the results show a 71% increase in unique visitors and 97% of participants surveyed said that the challenge increased their knowledge about how to help the environment.

1.4 Research Description

The overall research question that will be investigated is: What forms of information technology infrastructure can support effective and efficient development of serious games for sustainability?

In order to address this research question, I started with two development tasks:

- Develop example IT infrastructure for development of serious games for sustainability.
- Develop an assessment method that provides evidence of the strengths and weaknesses of the IT infrastructure for the development of serious games for sustainability.

1.4.1 Makahiki

We developed a innovated serious game framework for sustainability called Makahiki, as an example IT infrastructure for the development of sustainability challenges. Makahiki explores one section of the design space where virtual world game mechanics are employed to affect real world sustainability behaviors. The ultimate goal of the Makahiki project is to learn to not just affect behaviors during the course of the game, but to produce long lasting, sustained change in behaviors and outlooks by participants.

Makahiki has a unique feature set intended to foster more rapid innovation and development. These features include: (1) an open source li- cense and development model which makes the technology available without charge and facilitates collaborative development and improvement; (2) support for an ecosystem of extensible, interre- lated, customizable games and activities; (3) real-time game analytics for research and evaluation; (4) pedagogically organized and extensible

learning activities; (5) a responsive user interface supporting mobile, tablet, and laptop displays; and (6) support for deployment to the cloud as an inexpensive option for hosting the competition.

The Makahiki framework had been successfully used in 2012 by three organizations, namely, University of Hawaii at Manoa, Hawaii Pacific University, EastWest Center of University of Hawaii, to implement individually tailored sustainability challenges focusing on energy and water conservation.

1.4.2 SGSEAM

In order to assess the effectiveness and efficiency of IT infrastructure for serious games for sustainability, I proposed an assessment method called Serious Game Stakeholder Experience Assessment Method (SGSEAM) that address the perspectives from different stakeholders, namely players, game designers, game managers, system admins, developers and researchers. A set of assessment mechanism is described in this proposal to determine the extent to which the system is effective and efficient with respect to these roles.

1.4.3 Evaluation

I will apply the proposed SGSEAM to Makahiki, as well as another serious game framework, to gather evidences of the effectiveness and efficiency of Makahiki and the other framework, and to gain insight into the strenghths and weakness of SGSEAM.

1.5 Outline

The proposal is organized into the following chapters:

- Chapter 2 looks at related research, including serious game, gamification, serious game framework, and framework assessment.
- Chapter 3 describes the design and implemention of the Makahiki system.
- Chapter 4 describes the evaluation framework for the serious games IT infrastructure for sustainability.
- Chapter 5 lists our research questions and explains our plan to evaluate them.
- Chapter 6 concludes the proposal with a list of anticipated contributions and future directions.

- Appendix A contains the questionnaire to be administered to various roles in the evaluation.
- Appendix B contains the google forms to be used in the in-lab evaluation experiments.

Chapter 2

Related Work

This chapter examines related research in this area. The related work on Serious game and and the recent development of gamification is discussed in Section 2.1 and Section 2.2. Section 2.3 looks at the applications of "serious game" in the sustainability context. Finally, Section 2.4 and 2.5 examines the serious game framework and its assessment.

2.1 Serious Game

A Serious game is a complete game designed for a primary purpose other than pure entertainment [**?**]. It includes categories such as educational games and advergames (advertising), political games, and training game (also known as game-learning). Zyda (2005) defines serious game is "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health,etc".

One example is Fold.it, which made the headline [19] by using game play to help solve problems that computers cannot solve very well, in this case, online gamers were able to do what biochemists have been trying to do for a decade: decipher the structure of a protein that is key to the way HIV multiplies.

Serious Alternative Reality Game (ARG) is one type of serious game that blends the real and virtual worlds activities in the serious gaming context. Jane McGonigal designed the award winning serious ARG games "World Without Oil" [13] and "Evoke" [43] with the goal to empower people to come up with creative solutions to our most urgent real-world problems. ARGs have also been used to support learning. Connolly et al. discuss the development of an educational ARG to motivate secondary school students across Europe to learn foreign languages [7]. The results of the pilot run of the game in 2009 indicated that 92% of students felt the game motivated students to learn

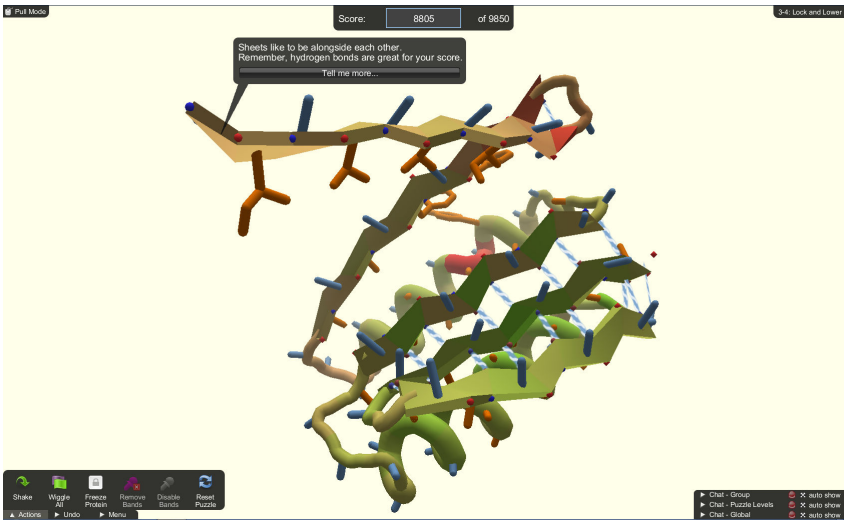


Figure 2.1. Foldit is solving a serious problem

a second language. One of problems the team identified is the limitation of Moodle platform the game is based on.

The report of the ARGOSI project provides insights to the use of ARGs in game based learning and the challenges in the field of higher education [42]. The pilot was run at the University of Bolton with the aim to provide an engaging alternative to traditional methods of introducing students to university life. The overall up-take of the game was fairly low with 173 players and 23 (13%) of whom were active. The project identifies a number of questions surrounding educational ARGs, such as motivation, relationship to curriculum, marketing and timing. The report suggests that a complete ARG model may not be appropriate for wholesale learning, but there is certainly potential in using game elements.

2.2 Gamification

"Gamification", as defined in [11], is "the use of game design elements in non-game contexts". There are many examples of applications that effectively employ game design elements. We will only briefly examine a few here for the purpose of better understanding the gamification concept and how it is utilized across a wide range of everyday life.

Nike+ [30] is a social running game-like application that employs game mechanics to encourage runners - both casual and hardcore - to compete and improve their fitness, with the goal to solve the main problem of most fitness programs: motivation. Nike+ makes it easy for runners to upload their

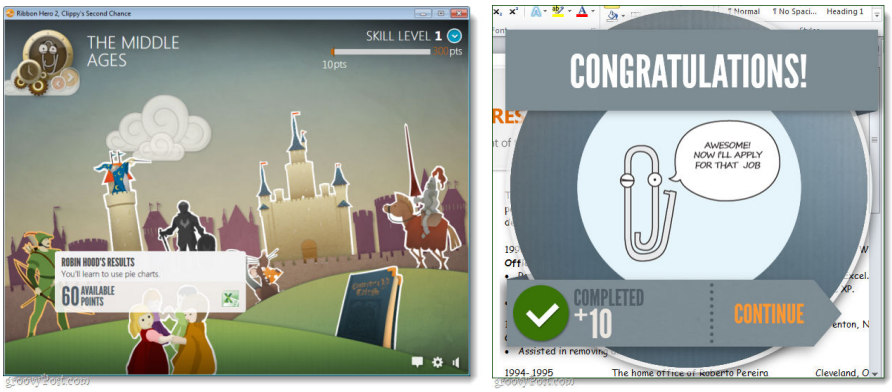
exercise data to its web site, and start challenging themselves and their friends. They can also get supports from their friends through the web site. The game makes running and exercise fun.

Figure 2.2. Nike+ makes fitness run

RibbonHero [37] is a game that helps users discover new Microsoft Office features in a fun and motivating way. The goal is to have users build familiarity and expose them to the Office UI, so that they understand what kind of features are available. According to the creator of the game, Office "has a lot of powerful features that users might not know but can be really useful". The game gives users a chance to learn those features in a fun and engaging way, rather than reading the software manuals or watching the typically dry IT training videos.

The "SmartGauge" dashboard for Ford's hybrid cars, where a digital plant is responding to how energy-efficient the users driving behavior is [18]. The design gives drivers a game like interaction that for them, the game to grow more lush and beautiful leaves, a visual reward, by driving efficiently, desired behavior.

Another example is the "Piano Staircase" created by Volkswagen Sweden and ad agency DDB, installed in a metro station in Stockholm [40]. The design is to make the staircase next to the escalator look and respond like a piano keyboard, so that every step on the stair will generate different piano sounds every time a commuter walked on it. Observation indicates that 66 percent more people chose the staircase over the escalator, a good example of a "Fun Theory" design for persuading and encouraging energy-efficient behavior.



(a) Quest to earn points (b) Competing a task

Figure 2.3. RibbonHero Helps to Learn Office

(a) Efficiency Leaves (b) Piano Stair vs. Escalator

Figure 2.4. Examples of Gameful Design in Every Day Life

Why game? Results of a study published in the May 1998 issue of Nature [21] demonstrated that video game players experienced regular releases of dopamine during game play. Dopamine is a neurotransmitter that signals pleasure rewards for food, sex and addictive drugs, such as cocaine. This and subsequent studies have proven that playing games stimulates pleasure centers in the brain. People are hard-wired to enjoy games.

In the British Museum's department of Greek and Roman antiquities, there is an exhibition section about ancient games. The description of the exhibition states that "We know very little about how most ancient games were played. Their rules were probably too familiar for people to take the trouble of writing them down". A favorite subject of Greek vase-painters was Ajax and Achilles playing a kind of board game called backgammon as illustrated in Figure 2.5. It is noteworthy that both Ajax and Achilles have the full armor on while playing the game. According to Arthur A. Krentz, Plato's "Republic" described the connection between play and education of both adult and children. He points out that, the term "paideia" (in Greek, means education/culture), "paidia" (means play/game/pastime/sport), and "paides" (means children), have the same root. The three terms often show up in the same context. "The central aim of pedagogy (paidagogia) is to encourage learning as a form of play (paidia), which is the most persuasive and effective approach to learning" [22].

Figure 2.5. Ancient Games Shown in British Museum

In modern day, World of Warcraft (WoW) is a massively multiplayer online role-playing game (MMORPG) with 11.1 million subscribers, currently the world's most popular MMORPG. More

than 50 billion hours have been spent in playing the game since the start of this game in 2004. The players created 250,000 articles in the WoW-Wiki, the second largest wiki behind Wikipedia. On average each WoW-player spends from 17 to 21 hours per week playing WoW.

Nick Yee pointed out that the shared experience, the collaborative nature of most activities makes MMORPG unique. "It's the people that are addictive, not the game". "Most importantly, it is the reward of being socialized into a community of gamers and acquiring a reputation within it" [47]. He claimed that "WoW truly is a virtual Skinner box", smoothly increasing reward and difficulty and reinforcing player commitment along the way [46].

In her popular and inspiring TED talk "Gaming can make a better world" [28] and in her book "Reality is Broken" [27], researcher and game designer Jane McGonigal illustrated why good games make us better, and how they can help us change the world. She notes that currently more than 3 billion hours a week is spent in playing video game by our society, for good reasons. She says that the average gamer plays 10,000 hours of games by age 21. That?s about the same number of hours that students spent in high school and middle school. There are 500 million gamers today, playing on all sorts of platforms from the iPhone to the game consoles. Instead of the common conception that gaming is a waste of time, she argues that "playing games is the single most productive thing we can do with our time" and is the solution to the "Broken Reality".

In order to understand why people play games, Richard Bartle identified four player personality types by studying players of the Multi-User Dungeon (MUD) game in 1960s [3]. The four types are based on the 2 underlying axes:

1. Achievers: driven by in-game goals, usually some form of points gathering - whether experience points, levels, or money.

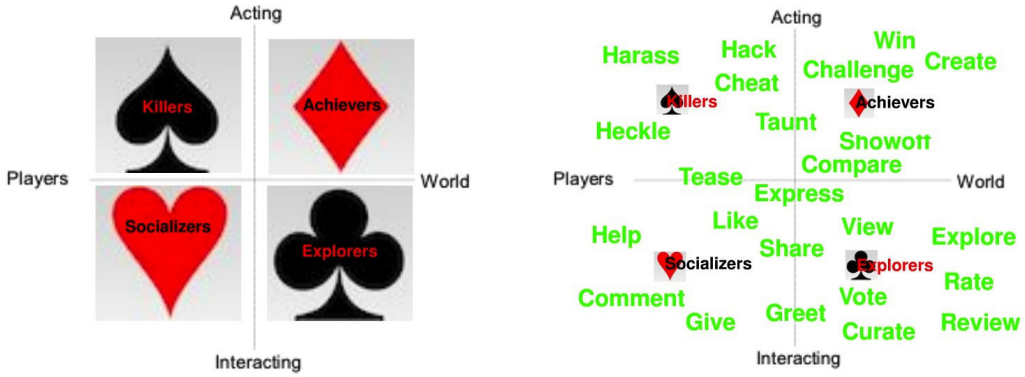
2. Explorers: driven to find out as much as they can about the virtual construct - including mapping its geography and understanding the game mechanics.

3. Socializers: use the virtual construct to converse and role-play with their fellow gamers.

4. Killers: use the virtual construct to cause distress on other players, and gain satisfaction from inflicting anxiety and pain on others.

Bartle's player type model has been the basic for understanding the player motivation. Dan Dixon presented the limitation and misuse of Bartle's model in general games and gamification contexts [12]. Amy Jo Kim applied the model in her gamification approach by overlaying social actions from the game on top of the player types [20], as shown in Figure 2.8.

There are many debates and criticism over whether gamification itself is inherently good or bad. Many considered the current efforts of gamification focus on extrinsic motivators (such as



(a) Bartle's Player Types (1996) (b) Kim's Social Actions (2010)

Figure 2.6. Player Types

points, badges and rewards) instead of intrinsic motivators generated by an individual's internal will or desires.

Designer Stephen Anderson claimed that [1] gamification mistakes extrinsic rewards (rather than intrinsic motivation) for the power of games and hence offers only feedback, not goals & rules.

Figure 2.7. Gamification is about extrinsic rewards (source: Anderson [1])

Jane McGonigal spoke about her concern about current state of gamification in the GDC 2011 talk titled "We don't need no stinking badges: How to reinvent reality without gamification" [29]. She argued that current gamification confuses intrinsic/extrinsic motivation and proposed "Gameful Design" instead of "Gamification". She claimed that "Gameful is player-oriented", which presumed that the loyalty program type gamification is product or service oriented. While the current gami-

fication is about extrinsic reward, with points, badges, and levels, gameful design is about intrinsic reward, with positive emotion, relationships, meaning and accomplishment.

Nicole Lazzaro argued that the use of extrinsic rewards will decrease the motivation to use your products and services once you remove that reward [23]. Vockell resonated that in education psychology, extrinsic motivators may lead to short-range activity increase but reduction in long-range interest in a topic. While intrinsic motivators motivate people best when they are working toward personally meaningful goals [41].

Michael Wu argues that extrinsic rewards can jumpstart intrinsic motivation [44]. He claimed that gamification just has to work long enough for some other processes to take over as the primary driver of value. Subsequently, it becomes a secondary reinforcement system.

As we discussed before, gamification's main driving force is motivation. Serious games also try to solve the motivation problem and influence people's behavior. Deterding illustrates the distinctions between gamification, serious games and other related concepts, As shown in Figure 2.15 [11].

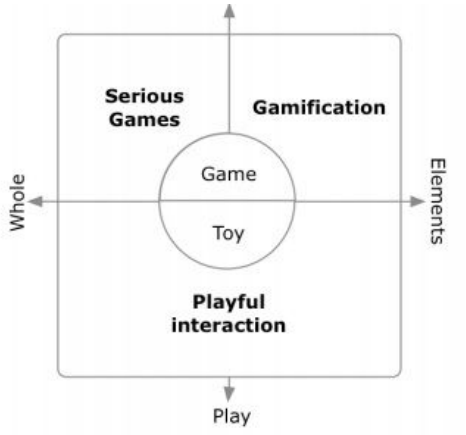


Figure 2.8. Serious Game and Gamification (source: Deterding [11])

According to Deterding, a) Gamification is about game. It is different than playful interaction, playful design. b) Gamification uses game elements. It is not the complete game such as a serious game. c) Gamification applies to non-game context. Similar to serious game, it uses game for other purposed than game's normal expected use for entertainment. d) Gamification focuses on design. It is not game-based technology or practice of wider game ecology.

The difference between Gamification and Serious game is not very clear. Both are trying to solve a problem with game thinking. Some reference serious game such as Foldit as a victorious

example of gamification in science [4]. Sebastian Deterding's definition [11] illustrates that gamification are total different than serious game.

2.3 Serious Games for Sustainability

Energy competitions or challenges have been introduced to college dormitories and residential homes as ways to facilitate and incentivize energy reduction. Petersen et al. describe their experiences deploying a real-time feedback system in an Oberlin College dorm energy competition in 2005 that includes 22 dormitories over a 2-week period [32]. Web pages were used to provide feedback to students. They found a 32% reduction in electricity use across all dormitories. However, in a post-competition survey, respondents indicated that some behaviors, such as turning off hallway lights at night and unplugging vending machines were not sustainable outside the competition period. Overall, there has been little analysis on energy usage after competitions finish, or how positive behavior changes could be sustained.

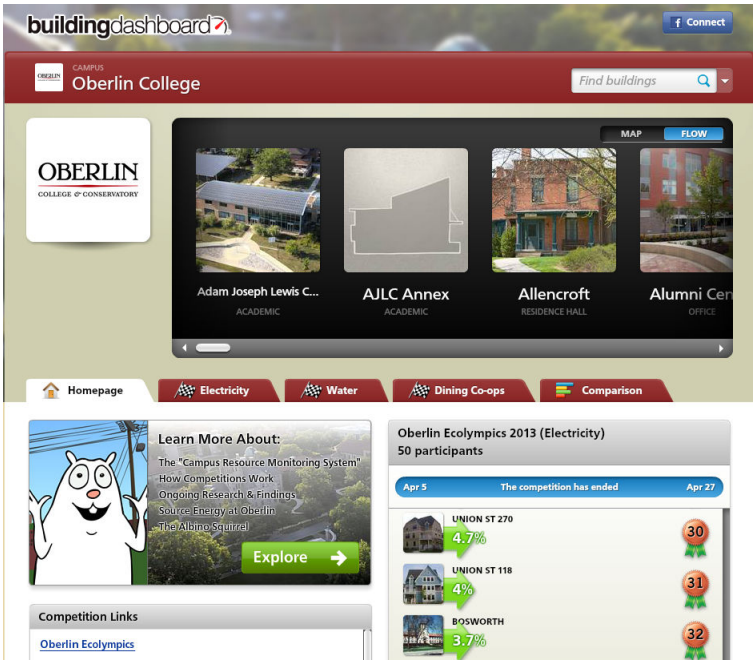


Figure 2.9. Oberlin Energy Competition

Reeves et al. described the design of Power House, an energy game that connects home smart meters to an online multiple player game with the goal to improve home energy behavior [36]. In the game, the real world energy data are transformed into a "more palatable and relevant form

of feedback", and players may be incentivized by the in-game rewards to complete more energy-friendly real-world behaviors.

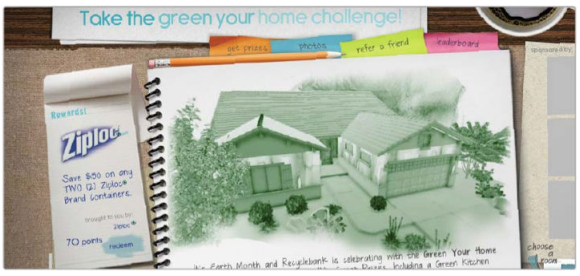
Figure 2.10. Power House (source: Reeves [36])

RecycleBank [34] introduced a series of "Green Challenges" that used gaming techniques online to motivate participants to learn about green living and to take small green actions to live more sustainable lives offline. According to their report [15], 49,000 individuals participated in the "Green Your Home Challenges". Partnered with Google Analytics and ROI research, they found that:

- Gamification can increase awareness of positive environmental actions. 97% of participants surveyed said the game increase their knowledge of environment.
- Games can drive individuals to take positive social and environmental actions. Most participants surveyed indicated they are very or extremely likely to take green actions as a result of participating in the challenge.
- Games are an effective and appealing educational tool. 86% participants agreed online games and contest can be a good way to inform and educate them personally.

2.4 Serious Game Frameworks

Game frameworks (also known as game engines) are "comprised of a collection of different tools, utilities, and interfaces that hide the low-level details of the various tasks that make up a



(a) Green Your Home Challenge

What green actions do you take?	Pre	Post	% +
I turn off the lights	18%	26%	44%
I use CFL/Eco bulbs	28%	38%	36%
I conserve water/energy	34%	45%	32%
I buy local produce	0%	14%	----
I wash clothes in cold water	0%	7%	----

(b) Game Change Behavior

Figure 2.11. RecycleBank - Gaming for Good

game" [38]. One of the benefits of using a serious game framework is that, if correctly designed, it will provide useful and reusable "building blocks" with which to develop a variety of serious games. These building blocks enable the serious game developer to focus more time and thought on content and results instead of on infrastructure.

The examples of game engine includes:

- FPS: Unreal (rendering, physics, AI)
- Mobile: Papaya
- Healthcare: OpenLabyrinth
- Educational storytelling: Fabula

The Building Dashboard [24], developed by Lucid Design Group, is used to support Oberlin's dorm energy competition, as well as the Campus Conservation Nationals, a nationwide electricity and water use reduction competition on college campuses [25]. The Building Dashboard enables viewing, comparing and sharing building energy and water use information on the web in compelling visual interface, but the cost of the system creates the barrier for wider adoptions. In addi-

tion, the building dashboard solutions focus on providing energy information as a passive media. Besides a scoreboard, There is little interaction between participants and the system.

Figure 2.12. Building Dashboard (source: Lucid [24])

The Stanford Energy Services Platform [2] provides services to benefit the creations of energy efficiency program and research. The services include data storage, recommendation system, user registration and participation assignment, surveys and analytics. It had been utilized to support the implementation of several Stanford's energy saving projects. such as Power House, Power Down, Energy Calculator.

Figure 2.13. Stanford Energy Services Platform (source: Stanford [2])

2.5 Serious Game Framework Assessment

One fundamental question in evaluating a serious game is the extent to which the game achieves its "serious" purpose. This is quite different from traditional entertainment games, in which evaluation focuses on usability or playability [39]. In the field of serious games, there is an increasing focus on the methodology of research and evaluation [26]. De Freitas and Oliver describe a four dimensional framework [10] for evaluating an educational game, consisting of: the context, the pedagogy, the representation, and the learner (or player). Harteveld proposes an alternative approach called "Triadic Game Evaluation" [16], consisting of three perspectives: Reality, Meaning, and Play.

The above approaches focus on evaluation of a single game, as opposed to a game *framework*. Game frameworks (also known as game engines) are "comprised of a collection of different tools, utilities, and interfaces that hide the low-level details of the various tasks that make up a game" [38]. One of the benefits of using a serious game framework is that, if correctly designed, it will provide useful and reusable "building blocks" with which to develop a variety of serious games. These building blocks enable the serious game developer to focus more time and thought on content and results instead of on infrastructure. Yet how are we to know if a serious game framework has been "correctly designed"?

Upon review of the literature, we found little prior work concerning formal assessment for the particular needs of serious game frameworks.

Chapter 3

Makahiki System Design

Makahiki, represents research intended to create synergy between the need to create knowledge and engagement regarding energy and the ability of so-called "serious game" techniques and energy feedback to create participation and engagement [11, 9, 14, 32]. In Makahiki, online game mechanics are employed with the goal of affecting real-world energy behaviors [5]. The ultimate goal is to not just affect energy behaviors during the course of the game, but to produce long lasting, sustained change in energy behaviors and outlooks by participants. Figure 3.1 illustrates the architecture of Makahiki.

Makahiki consists of a configurable game engine that can be customized to the needs of different organizations. It includes a library of pre-built game "widgets" that implement a variety of game mechanics. Using the widgets, an organization can create a custom energy challenge in which players can compete individually and/or in teams to earn the most points by reducing their energy consumption as well as by learning about energy concepts in general. The next sections present some of the most important widgets in Makahiki.

3.1 Configurable Game Elements

3.1.1 Smart Grid Game

The Smart Grid Game widget shown in Figure 3.2, is the primary place players go to learn about energy issues and earn points. Actions are organized into a grid of squares (hence the name "Smart Grid") and organized by category columns. The game supports levels so that a large number of actions can be presented in a sequence of smaller grids. Each grid contains four different types of actions: activities, commitments, events, and excursions.

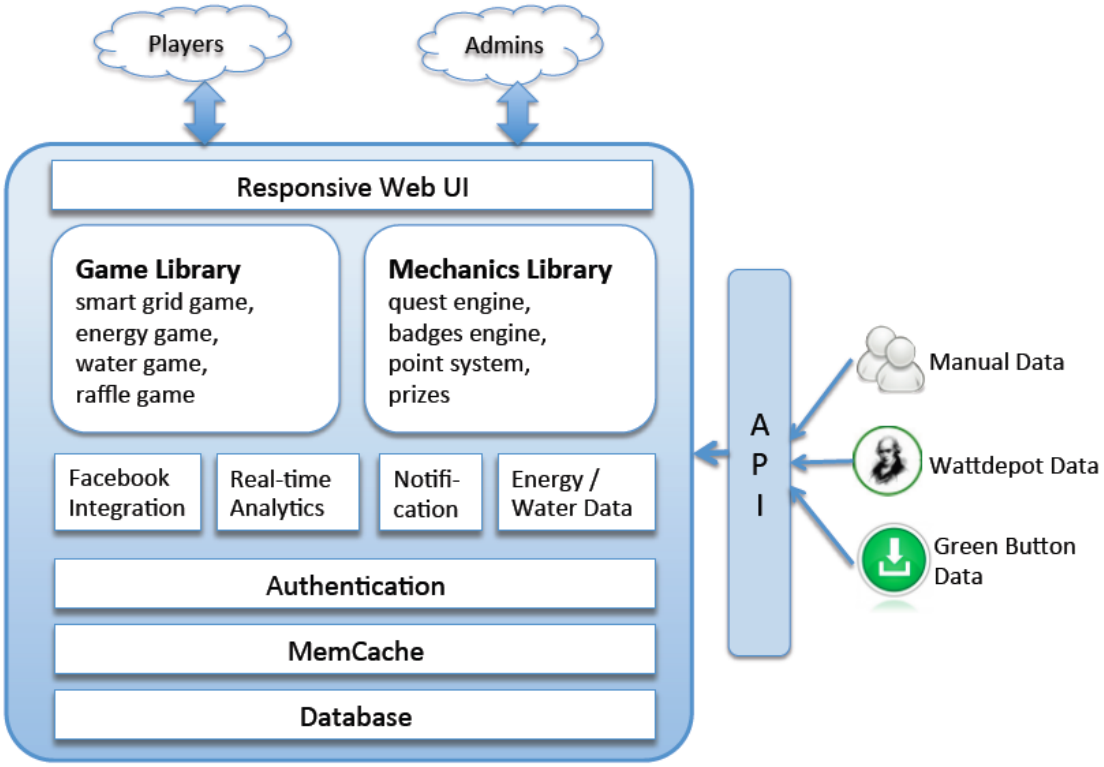


Figure 3.1. Architecture of Makahiki

Figure 3.2. *Smart Grid Game widget*

Activities are the most basic actions available in the Smart Grid. In order to get points for an activity, a player will have to provide a response to the administrators. These responses can be a short textual answer or an uploaded picture. Administrators access a special section of the web application to approve or deny submissions. If a submission is approved, the player will receive points, as well as website notification about the approval. If a submission is rejected, the player will be sent a website notification informing them that their submission was not approved, and a textual description by the administrator of why it was rejected. The player can change and resubmit their response and still earn the full point value for that activity.

Commitments are pledges that the player will do something related to energy or sustainability for a period of five days. Examples include: reducing shower time, taking the stairs, and turning off the lights when leaving a room. Although these commitments are not verifiable, they are public and visible to other players in the same team and worth fewer points than activities. Furthermore,

a player is limited to five active commitments at any given time. After the five day period is up, the player can then declare that they completed the commitment and immediately earn their points. They can then sign up for another commitment, including the one they just completed.

Events and excursions are tied to real world activities. Events are held locally while excursions require transportation. Seating is limited, so players are asked to sign up for events or excursions they wish to attend. Players that do so are provided with a 2 point signup bonus. Players can also set up a reminder that is sent to their email and/or their mobile phone before the event takes place. At the event, an administrator will hand out attendance codes printed on slips of paper that can be entered on the website. These attendance codes are generated by Makahiki and can only be used once. To discourage players from signing up and not attending, a 2 point penalty is applied to players who do not submit an attendance code. If the player submits an attendance code for the event after receiving this penalty, the penalty is reversed.

Not all of the actions and levels in the Smart Grid Game are necessarily available at the start of the game. We provide a set of predicates that can be used to determine if an action or level is locked or unlocked for a player. These predicates include: completed a certain number of actions within a category, completed all actions within a category, completed a certain action, and unlocking of an action or level after a certain date.

These predicates are implemented using a limited subset of Python and can be changed within the administrative interface. Challenge designers can use logical operators to combine any of these functions in order to organize the players' path through the Smart Grid Game.

3.1.2 Power Meter

A fundamental requirement for enabling more active participation by consumers in the smart grid is feedback regarding their energy usage. One of the most simple mechanisms provided by Makahiki for this purpose is the Power Meter widget, illustrated in Figure 3.3.

The Power Meter widget provides basic feedback on energy consumption via a display of the team's power consumption, updated every few seconds. The visualization can normalized using baseline values so that when the needle is pointing straight up, the power consumption is the average for that team during that specific hour of that specific day of the week. Thus, if the needle leans left toward the green side, the team's power consumption at that moment in time is below average, while if the needle leans right toward the red side, the team's power consumption at that moment in time is above average.

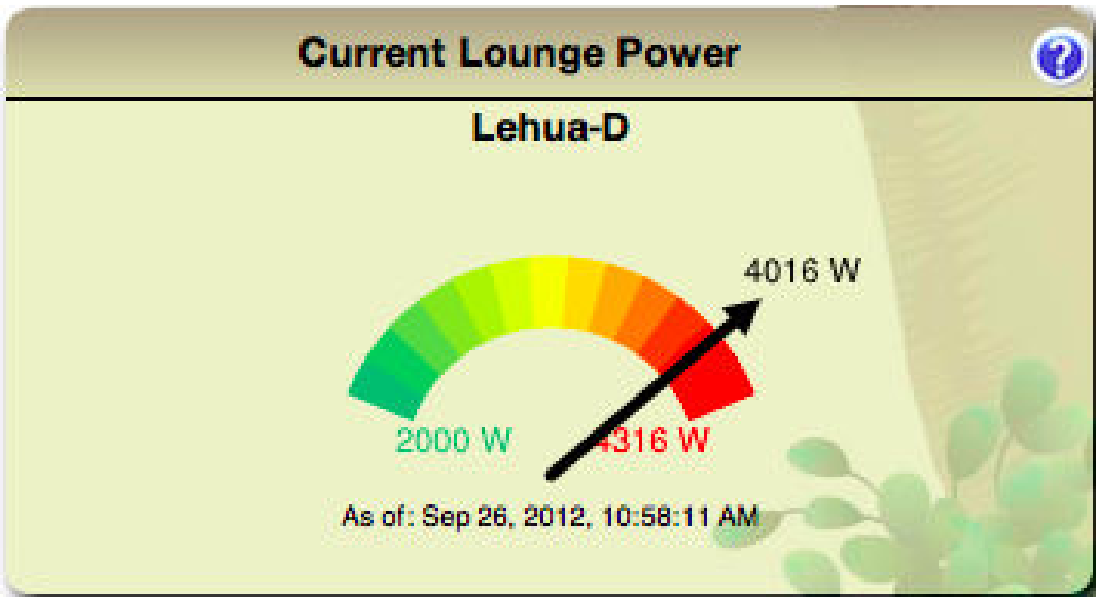


Figure 3.3. *Power Meter widget*

The Power Meter widget obtains its values by querying the WattDepot system for the latest power data consumed by the associated team. The use of WattDepot, rather than directly querying the meter(s), simplifies the widget design significantly. First, the physical meters can vary significantly in the protocol implemented to obtain current power consumption. These protocol variations are handled by the WattDepot sensors, so this widget can simply query the WattDepot server using a single HTTP request that is independent of the physical meter characteristics. Second, the power consumed by a team might be measured by one or multiple meters. Again, the WattDepot source aggregation capability means that this physical difference can be abstracted away by WattDepot, enabling the widget to obtain the aggregate power for the team through a single HTTP request.

The Power Meter widget is a useful, though simple mechanism for energy feedback that uses the WattDepot+Makahiki stack. The next section presents a more sophisticated mechanism called the Daily Energy Goal Game.

3.1.3 Daily Energy Goal Game

The Daily Energy Goal Game widget provides a way for players to earn points by reducing their current energy consumption from a baseline. This baseline can be calculated using historical data or dynamically throughout the competition. Both the baseline data and the current consumption

is typically provided by API calls from Makahiki to an underlying WattDepot server. Figure 3.4 illustrates this widget.

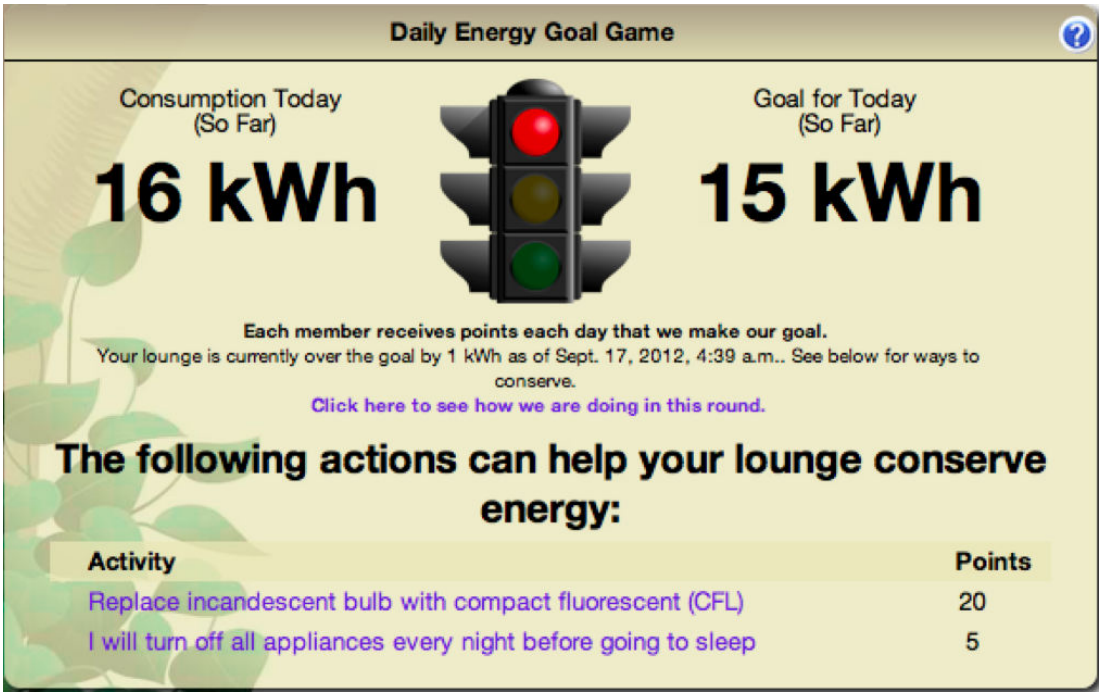


Figure 3.4. *Daily Energy Goal Game widget*

The goal for each team is typically a percent reduction from their baseline usage. When a player goes to the energy page of Makahiki, they can view their team's current progress toward their daily energy goal. Near the end of the day, Makahiki checks the energy data from Wattdepot to see if a floor reached their goal. If the floor did reach their goal, each member of the floor that is participating in the game receives points. The energy goal game provides a link between the energy conservation competition and the point competition.

The Daily Energy Goal display shows both their current progress and their goal so far. We have noticed that our participants use more energy at night rather than during the day. Thus, it is easy to be under their actual energy goal for most of the day and then jump over the goal at the very end. Displaying their progress toward the goal so far provides a pace for players to follow.

3.1.4 Raffle Game

The Raffle Game widget provides a way to incentivize participation from all individuals, even those who are not in the running for a top prize. For every 25 points a player earns, they receive

one virtual raffle ticket. Players can dynamically allocate their tickets to any raffle prizes they are interested in at any time, up to the end of the raffle. Figure 3.5 shows an example of the Raffle Game.

Figure 3.5. *Raffle Game widget*

Each round of the competition has its own set of raffle prizes and any unused raffle tickets carry over to the next round. Raffle tickets are independent from a player's score, and allocating a raffle ticket does not affect their rank. The system provides random selection of the winner of each raffle item at the end of a round.

3.1.5 Social and Referral Bonuses Game Mechanics

The Social and Referral Bonus widgets are the game mechanics that help encourage participation by providing additional points to players who participate in activities with other players, and facilitate the entry of new players into an energy challenge.

The social bonus is an configurable option when an action is created in the Smart Grid Game. Players earn extra points if they perform the action with another player. Examples of actions with a

social bonus include attending an event, recording a song related to energy, or measuring a shower water flow rate. When a player submits a response for an action with a social bonus, the player can provide the email address of the person who jointly completed the action. Once the other player completes the action, the social bonus is awarded. Social bonuses are not bi-directional; if the second player doesn't provide the first player's email address, only the first player will get the social bonus.

Players are led through a setup process when logging into Makahiki for the first time. One of the steps in this process is the referral bonus. If a player was referred by another player in the system, they can use this step to input their email address. Once the new player earns a certain number of points in the competition, both players are awarded a referral bonus of a configurable number of points. Typically, going through the setup process gives you 25 points, so setting a point threshold of 30 points encourages the new player to at least complete one additional action in order to get the referral bonus.

3.1.6 Quest Game Mechanics

One challenge we faced when designing Makahiki was providing adequate help to the player. The game needed to be intuitive, even if a new player is not familiar with energy challenges. Unlike many web applications, such as email, Makahiki players generally do not know in advance what specific actions they wish to accomplish. In an effort to provide a player with guidance through Makahiki after the setup process, we implemented the Quest Engine. Quests are used to guide the player through the various workflows of the site, such as completing a action, signing up for an event, or allocating a raffle ticket. These quests can be created using the administrative interface. Quests use a set of predicates to determine unlock and completion conditions. These predicates include: participating in a action or type of action, completing an action or type of action, having a certain number of points (in a round or overall), completing a certain number of actions in a category or of a given type, being awarded a badge, and adding a picture to their profile.

3.1.7 Badge Game Mechanics

3.2 Real-time Analytics

Makahiki is designed to support energy challenges involving hundreds or thousands of users lasting weeks or months. In these circumstances, effective use of the technology requires the ability

to understand the state of the game, such as: Who is using it? What are they doing? What is the player response to activities, commitments, excursions, and events? Such state information is important for planning purposes, such as assessing the transportation needs for an upcoming excursion by seeing how many players signed up. It can also be used for making in-game changes to game design, such as changing the point values associated with activities to encourage or discourage participation. It can also help identify breakdowns in game play, such as significant numbers of unallocated raffle tickets indicating that users do not understand the nature of that game mechanic.

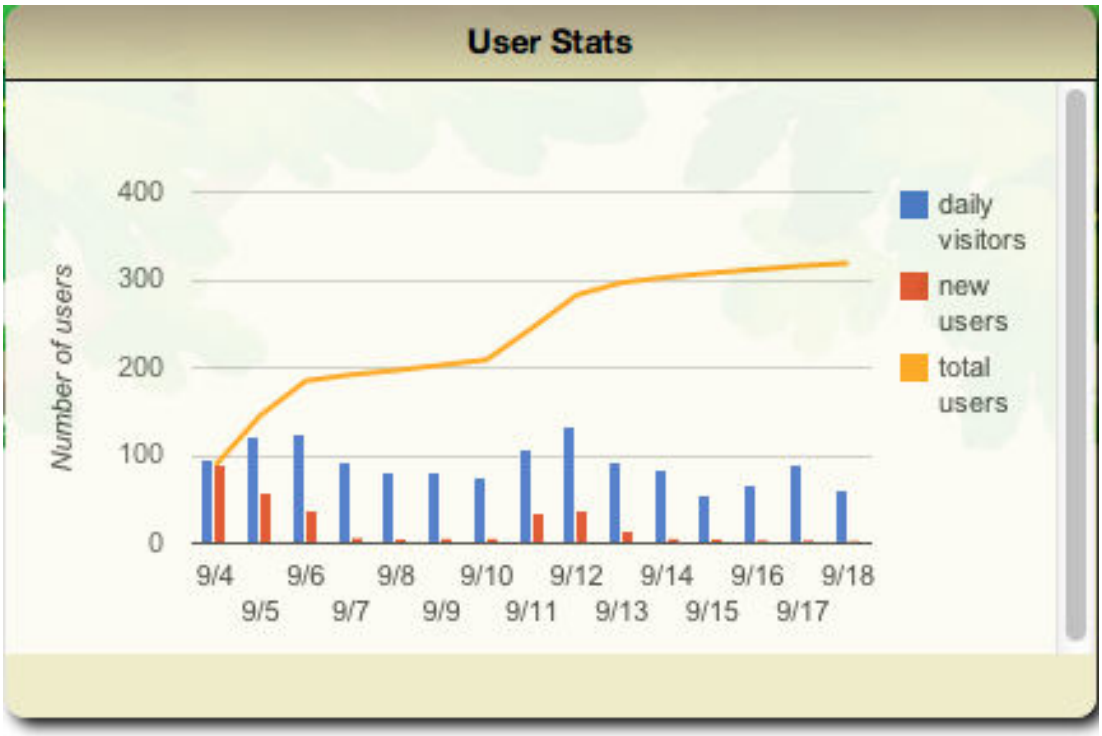
To address these needs and others, Makahiki includes a variety of widgets that work together to provide high level overview of game play state to the administrators of a challenge. Figure 3.6 shows an example of two game analytic widgets.

The top widget, User Stats, shows trends in the total number of players, the total number of new users, and the total number of players visiting the site each day. The bottom widget provides information on the ability of teams to achieve their daily energy goal each day and over time.

3.3 Configurable resource

3.4 Mobile support

3.5 Cloud deployment support



Energy Goal Status

Team	09/16	09/15	09/14	09/13	09/12	09/11	09/10
Lehua-A	-16 87	-2 87	-5 86	-9 87	-8 85	-5 88	-3 87
Lehua-B	-14 101	-7 100	-14 100	-11 101	-12 100	-9 104	-13 99
Lehua-C	-9 91	-2 85	-4 90	-5 92	-4 92	-2 94	-9 92
Lehua-D	-1 94	0 91	-1 92	0 95	2 98	2 97	2 99
Lehua-E	-14 82	-6 77	-4 85	-12 88	-6 91	-4 92	-13 86
Ilima-A	-14 87	-6 89	-5 87	-13 85	-8 87	-13 86	-15 83

Figure 3.6. Game analytic widgets: User Stats and Energy Goal Status

Chapter 4

SGSEAM Design

This chapter describes the design of my proposed Serious Game Stakeholder Experience Assessment Method (SGSEAM). It starts with the overview of SGSEAM, followed by the discussion of assessment methodology, and the details of the proposed assessment method.

4.1 Overview of SGSEAM

The goal of SGSEAM is to identify (a) major strengths of a serious game framework, which aids the community by indicating features of the framework to emulated, and (b) major shortcomings of the framework, which aids the community by indicating features to avoid and the developers of the framework by indicating the areas to improve on.

The approach that SGSEAM uses is to assess the experiences of various important stakeholders when they interact with the serious game framework. In the full life cycle of a serious game framework there are a great variety of potential stakeholders, including:

- *Players*: those who participate in the game produced by the framework.
- *System admins*: those who install and maintain the technological game infrastructure.
- *Game designers*: those who design the content and game mechanics.
- *Game managers*: those who manage the game during the period of game play.
- *Developers*: those who extend, enhance and debug the game framework.
- *Researchers*: those who are conducting research using the game framework.

- *Spectators*: those who do not participate in the game play but are interested in the game and the results of game play.
- *Community partners*: those who partner with the game organizers to help run the game (such as coordinating real-world events as part of the game, providing support for energy data collection, etc)
- *Funding organizations*: the organizations who provide funding for the game or game framework.

The scope of SGSEAM is to assess serious game frameworks as software infrastructure. While the overall success of a serious game depends on the individual success of all of these stakeholders, SGSEAM does not address the spectator, community partner, researchers, and funding organization stakeholders. These are important stakeholders but outside the scope of our assessment. In the context of a serious game framework, SGSEAM focuses on players, system admins, game designers, developers and researchers.

The following sections describe the methodology used in SGSEAM, followed by the detailed description of assessment methods for each identified stakeholder.

4.2 Assessment Methodology

Creswell [8] categorizes research methods into three approaches: quantitative, qualitative, and mixed methods, according to what knowledge claims are being made and how knowledge is acquired. Quantitative method reflects a post-positivist paradigm where hypotheses are specified *a priori* and tested by experimental design. Qualitative method reflects a constructivist or participatory paradigm where knowledge would be acquired by observation and open-ended design. SGSEAM employs the mixed methods approach which based on pragmatic knowledge claims and assumption that collecting diverse types of data provides better understanding of the research problem: assessing the strengths and shortcomings of a serious game framework.

In SGSEAM, the concurrent triangulation strategy [8] of the mixed method approach is used. Data collection and analysis involves both quantitative information (instrument and analytical data recorded by the system such as website logs, interaction database, etc), as well as qualitative information (interviews and questionnaire responses).

4.3 Stakeholder Experience Assessment

SGSEAM follows closely with the ”Goal-Question-Metric” (GQM) approach [6] in software engineering research. GQM defines a software measurement model on three levels: a goal of the measurement, a set of questions to assess the goal, and a set of metrics associated with each question.

In SGSEAM, the assessment goals are the experiences of the identified stakeholders. For each stakeholder, a set of questions is used to assess the strengths and shortcomings from the stakeholder's perspective. For each question, a set of alternative assessment approaches is proposed.

Figure 4.1 provides an overview of the assessment method:

Stakeholder (Goal)	Assessment question	Assessment approaches
Players	To what extent does the system affect players? To what extent does the system engage players?	experimental study, interviews, engagement metrics
System admins	How easy is it to install and maintain the system?	experimental study, interviews
Game designer	How easy is it to design a game?	experimental study, system logs, interviews
Game managers	How easy is it to manage a game?	experimental study, system logs, interviews
Developers	How easy is it to enhancing the system?	experimental study interviews

Figure 4.1. Overview of SGSEAM

There are usually multiple assessment approaches for a specific question. Different assessment approaches will have different levels of rigor. In experimental design terms, rigor refers to external and internal validity. The details of the individual assessment approach for each stakeholder are descried in the following sections. The assessment approaches for a question can be additive. The more approaches applied, the higher confidence of the assessment.

4.3.1 Player Assessment

The goal of player assessment is to determine the effectiveness of the game framework from player's perspective. It is essential that a game produced by a serious game framework could achieve

its intended ”serious” purpose. The intended purposes of serious games are always subject specific. For example, the desired effect of a serious game for energy education and conservation is to increases players' energy literacy and reduces their energy consumption during (and, hopefully, after) the game. A serious game for language learning would have a very different desired effect.

Users of SGSEAM could use domain-specific questions to assess the desired effects of their serious game. For illustration purpose, the following two questions are used to assess a serious game for sustainability: (a) To what extent does the game increase player's literacy in sustainability? (b) To what extent does the game produce positive player behavior change in sustainability?

One approach to assess the question of the effect of literacy changes is a quasi-experimental study. A set of literacy survey questionnaires are presented to a random selection of the players before the game (pre-test). After the game ends, the same survey (post-test) is presented to the players who responded the pre-test survey. These two set of survey response data are compared to understand if the game has had an impact on literacy. The extent of players' sustainability literacy change will indicate the degree of educational effectiveness of the serious game for sustainability.

A pre-experimental study could be used to assess the question of the effect of sustainability behavior changes. The resource (energy and/or water) consumption data during and after the game are recorded (post-test). They are compared to the resource consumption baseline established before the game (pre-test).

Another approach for effectiveness assessment is to interview players about their self-reported behavior change. The combination of resource consumption changes and self-reported behavior changes can be combined to assess the degree of behavior effectiveness of the serious game for sustainability.

In addition to the domain-specific goals of serious games, SGSEAM assesses a common aspect of serious games, player engagement, to address the question of ”To what extent does the game engage players?”

Player engagement is an important measure for understanding the effectiveness of a serious game. By investigating the degree of engagement, we can determine to what extent individuals are participating in the game, as well as to what extent the community population is participating in the game.

Engagement has a subtle relationship to the overall effectiveness of a serious game. It is possible for the game to be played by only a subset of the target population, but have an impact on those not playing by virtue of their contacts with players. Gaining better insight into this effect is an area of active study for us.

To obtain engagement data, SGSEAM analyzes the following measures based upon system log data provided by the framework.

- participation rate
- number of players per day
- play time of a player per day
- submissions of all player per day
- social interaction of all player per day
- website errors per day

The participation rate measures the percentage of users who used the game based on the total eligible players. In the serious game context, it indicates the level of involvement or awareness of the serious matters. The number of players and play time per day measure how frequently the players interact with the game. The submissions per day measures the rate of serious game specific activities (online or real world) that players completed, while the social interaction per day measures the rate of social interactions happened in the game between the players. At last, the website errors per day measures the rate of errors encountered by the players while using the game website. In general, with the opposite of website error measurement, the higher value these measurements are, the higher engagement level the game has.

4.3.2 System Admin Assessment

System administrators are responsible for installing and maintaining the software infrastructure for the game. Their tasks include the framework and dependency installation, maintain the database, backups, and so forth.

One approach to assess the question of how easy it is to install and maintain the system is to use an experimental study. A group of system admins is asked to install the system, record the time spent and problem encountered as they complete each step. The qualitative data (i.e., the descriptive problems reported by the participants of the study) will need to be categorized and coded. The assessor will triangulate the reported time data and the problem categories to identify the area of strength (less time spent) and weakness (problems and difficulties).

Another approach is a post-hoc interview. The system admin(s) are asked about their experience after the installation. The interview includes the following questions:

- How much time did you require to install the system and the dependencies?
- How much time did you require to maintain the system?
- What problems did you encounter?
- Did you find it difficult to admin the system? What was difficult?

After the interview data is acquired, the assessor will perform qualitative data analysis, which involves transcribing (if the interview data is in audio format), categorizing and coding the description of reported problems or difficulties.

The level of confidence of the above two assessment approaches varies. The experimental study approach is more rigor because of the generality achieved from the larger population of participants under study. The data collected during the step by step experimental study is more accurate than the one collected in the post-hoc interview.

4.3.3 Game Designer Assessment

A game designer uses the serious game framework to design and create a serious game. A serious game framework always provides certain tools or interfaces to game designers with the hope that these will simplify the design of a game. Such tools might involve configuring global settings for the game, such as how long will the game run, who are the players, and how to design individual game elements.

SGSEAM assesses the game designer stakeholder by addressing the following two questions: (a) How much time is required to design an instance of a serious game using the framework? and (b) How many, and how problematic are the errors that designers encounter during the design process?

There are also three approaches for game designer assessment. One is a experimental study, where a goup of participants is asked to use the system to perform a same set of design tasks. The time spent and problems encountered are recorded for each tasks. The assessor will triangulate the reported time data and the problem categories to identify the strengths and weaknesses.

A second approach is to interview the designer(s) after they had completed the design. The following questions will be asked:

- How much time did you spend to complete each design task?
- What problems did you encounter?
- Did you find it difficult to configure? What was difficult?

- Did you find it difficult to design a specific game? Which one, and what was difficult?

The interview data will be transcribed (if audio recording), categorized and coded to identify the strengths and weaknesses.

A third approach is to collect the system log data related to the game designing tasks. When available, the time spent and error encountered can be queried from the system logs. Although these system generated data might be easier to gather in some systems, it might not provide the same depths or insights than the other two approaches where the experiences are provided by the participants directly. On the other hand, these system data can be supplemental to the other approaches. They could be correlated with the data gathered from the other assessment approaches to increase the confident of the assessment.

4.3.4 Game Manager Assessment

A game manager uses the serious game framework to manage the serious game that the game designers created. It is possible that a game manager is also the game designer. Serious game frameworks normally provide certain interfaces for the managers to manage the game. This may involve managing player submissions, monitoring the game state, entering manual resource data, notifying winners of the game, etc.

SGSEAM assesses the game manager stakeholder with the following questions: (a) How much time is required to manage an instance of a serious game using the framework? and (b) How many, and how problematic are the errors that managers encounter during the design process?

Similar to the assessment of game designer experience, SGSEAM proposes three approaches. The experimental study approach gather data from a group of participants about the time spent and problems encountered for each task of managing the serious game. The post-hoc interview approach gather data from the game manger(s) by asking the following questions:

- How much time did you spend to complete each managing task?
- What problems did you encounter?
- Did you find it difficult to manage? What was difficult?

4.3.5 Developer Assessment

The developer stakeholder is different from the game designer stakeholder, in that the game designer stakeholder tailors the framework without requiring any software development, while the Developer stakeholder enhances, corrects, and extends the system by manipulating code.

To investigate how easy it is to understand, extend, and debug a serious game framework from a developer's perspective, SGSEAM assesses how much time it takes to develop an enhancement to the game framework, and how many errors are encountered during the process.

The experimental study assessment approach asks a group of developers to develop a same set of enhancements to the system, and ask them to record the time spent to develop and problems encountered.

A second assessment approach is accomplished by interviewing the developer(s) to answer the following questions:

- How much time did you spend developing and debugging an enhancement to the game framework?
- What problem(s) did you encounter?
- Did you find it difficult to understand, extend and debug the system? What was difficult?

Similarly, the descriptive data will be categorized and coded. The time data will be correlated to the problem data to identify the areas of strength and weakness.

Chapter 5

SGSEAM Evaluation

This chapter describes the experimental design for two assessment tasks: (1) applying the SGSEAM described in Chapter 4 to the Makahiki system described in Chapter 3, (2) applying the SGSEAM to a second IT infrastructure for serious games for sustainability. The goals of these assessments are: (a) obtain insights about the strength and weakness of the Makahiki serious game framework we designed and implemented, (b) obtain insights about the strength and weakness of the SGSEAM.

5.1 Makahiki Assessment Overview

The design of assessment of Makahiki using SGSEAM are two folds: (1) case studies of Makahiki instances in real-world, namely the three Kukui Cup serious games deployed in University of Hawaii at Manoa, Hawaii Pacific University, and East West Center of Hawaii. (2) in-lab experiment of assessing Makahiki system by the students taking the serious game development course in the University of Hawaii at Manoa.

5.1.1 Real-world Makahiki Instances Case Studies

Using the Makahiki as the IT infrastructure, the first and second Kukui Cup Energy challenge of University of Hawaii was held in 2011 and 2012 for over 1,000 first year students living in the residence halls. Hawaii Pacific University (HPU) held a Kukui Cup Energy challenge in Fall 2012 for about 200 students. An international organization called the East-West Center (EWC) held a Kukui Cup Energy and Water challenge for the international residents living in the residenct halls without smart meters, so the resource consumption data had to be entered by the game mangers manually.

The successful creation of serious game challenges by three different organizations provides evidence that the Makahiki serious game engine can be tailored to the differing needs of separate organizations. First, UH uses smart meters by Electro-Industries Inc., while HPU uses smart meters by EGauge Inc., and EWC collected their energy data manually. Second, while UH and HPU challenges involved only energy consumption data, the EWC challenge involved both energy and water consumption data (which was also collected manually). Third, the IT infrastructure at UH and HPU provided authentication services using CAS and LDAP, while EWC used the built-in Django authentication. Fourth, the user interface was customized to "brand" each challenge with the logo, thematic elements, and the education contents of the sponsoring organizations.

5.1.2 In-lab Makahiki Experiment Case Studies

In Spring 2012, Professor Philip Johnson at the Information and Computer Science Department of University of Hawaii used Makahiki to teach a course in serious game development. The students are seniors or graduate students majored in the computer science related fields. During the course, the students will install Makahiki, configure and design a serious game instance with Makahiki, and finally develop an enhancement to the Makahiki system.

I plan to ask these students to voluntarily participate in the assessment experiments of Makahiki, in the aspects of system admin efficiency, game designer efficiency and developer efficiency. This is considered as an in-lab experiment since they are evaluating Makahiki in a class setting and using Makahiki in the development environments.

5.2 Makahiki Assessment

This section describes in details the application of SGSEAM to assess Makahiki using the settings described above.

5.2.1 Player assessment

I plan to apply the SGSEAM player assessment mechanism to the 2011 real-world Kukui Cup instance at the University of Hawaii at Manoa to study the player's experience with the Makahiki framework. There are over 1000 eligible players for this instances. They are the first year college student living in four similar structured resident halls in close vicinity. The challenge lasted for 3 weeks. Makahiki system recorded detailed logging data from every interaction between the players and the website.

To assess the effectiveness of the framework for designing games that improve player literacy in sustainability, we conducted two energy literacy surveys, one before the challenge (pre-game) and one after the challenge (post-game). SurveyGizimo is used to create the surveys which consists of the set of sustainability literacy and behavior questionnaires. The response from the two surveys are analyzed to provide insights about the player's literacy and behavior change.

To assess the effectiveness of the framework for designing games that produce positive change in sustainability behaviors, we recorded and analyzed energy consumption data before, during and after the challenge. Before the challenge, an energy usage baseline was established. The energy consumption data is examined to understand any usage pattern or reduction during and after the challenge.

To assess the usability of the game produced by the Makahiki framework, we conducted the in-game usability survey. The survey asked the questions about the players' experience about the user interface of the game. The response from the survey is analyzed to provide insights about the game usability.

In addition to the surveys and energy data measurement, the following engagement metrics will be calculated based on the log data to assess the engagement level of the instance:

- active participation rate
- number of players per day
- average session time
- submissions per day
- level of social engagement
- website errors

5.2.2 System admin assessment

There are two approaches described in SGSEAM to assess the game designer's experience: One is the experimental case study that uses the in-lab experiments, another is the interview of the system admin of a real world instance.

In the in-lab experiments, the students in the ICS691 Spring 2013 class were tasked with installing the Makahiki system into their local computers as well as the cloud environment. In order

to understand how much time it takes to install the Makahiki and what problems might be encountered, I design a Google form which details the steps of installing Makahiki both locally and in the cloud, and for each step, I ask the students to record the time they spent and the problems they encountered.

Figure 5.1 illustrates a partial google form used for Makahiki system admin assessment. Appendix B includes the complete google form.

Makahiki Local Installation Log

Please follow the steps outlined in this form to install Makahiki locally (including Virtualbox Linux Guest) and log the time you spent for each step.

Please choose the closest value from the list that best matches the time you spent during the installation.

Thank you!

* Required

2.1.1.1.1.2. Install Python *

Complete the "Install Python" section in Makahiki Local Installation Manual (http://makahiki.readthedocs.org/en/latest/installation-makahiki-unix.html#install-python), record the time you spent for this section only:

Record any problem(s) you encountered when installing Python:

2.1.1.1.1.3. Install C Compiler *

Complete the "Install C Compiler" section in Makahiki Local Installation Manual(http://makahiki.readthedocs.org/en/latest/installation-makahiki-unix.html#install-c-compiler), record the time you spent for this section only:

Record any problem(s) you encountered when installing C compiler:

Figure 5.1. Makahiki Developer assessment Form

The students were also asked to provide feedback about their installation experiences in the form of blog post. In the blog post, I ask them to discuss the following topics:

- What is the most difficult step during installation?
- What problems did you encounter during the installation?

- Have you install any database, web server or similar server products prior to this assignment? Are those installations for development or production purpose?
- If you have experience installing other servers before, How does your prior experience of installing other servers compare to the installation of Makahiki?
- What could be improved about the Makahiki installation process?
- Compare your experience of installing Makahiki in Heroku with installing it locally,

The qualitative data collected from the google form response and the blog post from the students will be analyzed to gain insights into how easy it is to install Makahiki, and what contributes to the efficiency of the installation.

In order to gain insights on the experience of a real world system admin who uses the Makahiki, I plan to perform interviews to the system admins of the 2013 Hawaii Pacific University (HPU) challenges.

I will analyze qualitative data collected from the interviews and email changes. The data include:

- time taken to install the Makahiki
- time taken to maintain the Makahiki, such as backup, monitoring
- problems encountered

5.2.3 Game designer assessment

There are also two approaches described in SGSEAM to assess the game designer's experience: One is the experimental case study that uses the in-lab experiments, another is the interview of the game designer of a real world instance.

The students in the in-lab experiments were tasked to design a Kukui Cup like serious game using Makahiki. I designed another google form to ask students to follow the designing steps and record their time and problem encountered during their designing process. Appendix B has the complete google form for the steps the students need to follow.

The students were asked to provide feedback about their installation experiences in the form of blog post to discuss the following topics:

- What is the most difficult step during Challenge Design?

- What problems did you encounter while designed the challenge?
- What problems did you encounter while managing the challenge?
- What could be improved for the Makahiki Challenge Design process?
- What could be improved for the Makahiki Challenge Management process?

I plan to perform interviews to the real world game designers of the 2013 Hawaii Pacific University challenges. We will ask him about his game designing experiences using the Makahiki admin interface.

I will analyze both the qualitative data collected from the interviews and email changes with the game designers, and the quantitative collected from the admin interface log data. The qualitative data includes:

- How much time did you spend to configure the challenge global settings?
- how much time did you spend to setup the player data?
- how much time did you spend to design the individual games?
- What problem did you encountered?
- Did you find it difficult to configure? what is difficult?
- Did you find it difficult to design a specific game? which one, what is difficult?
- What did you like the least when using the system?

The quantitative data includes:

- time taken to configure the challenge with regarding to different designing tasks
- problems encountered in the log file

5.2.4 Game manager assessment

I plan to perform interviews to the real world game managers of the 2013 Hawaii Pacific University challenges to study the experience of the game management using Makahiki.

I will analyze both the qualitative data collected from the interviews and email changes with the game managers, and the quantitative collected from the admin interface log data. The qualitative data includes:

- How much time did you spend to approving the action submissions?
- How much time did you spend to monitoring the game status?
- How much time did you spend to notifying prize winners?
- What problem did you encountered?
- Did you find it difficult to manage? what is difficult?
- What did you like the least when using the system?

The quantitative data include:

- time taken to manage the challenge with regarding to different managing tasks
- problems encountered in the log file

5.2.5 Developer assessment

The students in the in-lab experiment are tasked with developing an enhancement to the Makahiki instance. This involves setting up the development environment, following the tutorial to create the ”Hello world” widget using Makahiki, and finally, develop the enhancement which extends the functionality of the Makahiki system.

The students are asked to submit their development source code to the public source code repository (Github) and write a blog post to discuss their efforts to complete the development activity.

I will review their source code to compare their code to the reference implementation, analyze the blog post from the students, as well as any email correspondence from students discussing problems during the development.

5.2.6 Preliminary Results

At the time of the writing of this proposal, I had completed some of the assessments of Makahiki using SGSEAM. The following Figure 5.2 provides the overview of the status of completed work and the proposed work for applying SGSEAM to Makahiki.

Appendix C describes the results of the completed assessments of applying SGSEAM to Makahiki.

5.3 Lucid Design Dashboard assessment case study

Stakeholder	Assessment	Completed	Proposed work
Players	pre-post effectiveness experimental study	UH 2011	
Players	in-game usability survey	UH 2011	
Players	engagement metrics	UH 2011	
System admins	in-lab experiment case study	ICS691	
System admins	real-world instance case study		HPU 2013
Game designers	in-lab experiment case study	ICS691	
Game designers	real-world instance case study		HPU 2013
Game managers	real-world instance case study		HPU 2013
Developers	in-lab experiment case study	ICS691	
Developers	internal developer case study		New game development for UH2013

Figure 5.2. Status of Makahiki assessment

Chapter 6

Conclusion

This proposal laid out a research plan to investigate the information technology infrastructure that can support effective and efficient development of serious games for sustainability. The research includes the development of An innovative serious game framework for sustainability that combining education and behavior change, and an evaluation framework accessing the effectiveness and efficiency of the IT infrastructure for serious games for sustainability with regarding the most important stakeholder's perspective.

6.1 Anticipated Contributions

The anticipated contributions of this research are:

- developed Makahiki: open source information technology for development of serious games for sustainability.
- Evidence regarding the effectiveness and efficiency of Makahiki as a framework for development of serious games for sustainability.
- Evidence regarding the effectiveness and efficiency of second system as a framework for development of serious games for sustainability.
- Insights into the strengths and weaknesses of the evaluation framework.

6.2 Future Directions

There are a variety of directions that can be pursued once this research is complete, such as:

- Evaluate the other stakeholders experiences

- Build a community to expand content and game library
- Scale / expand to other geographical and cultural different locations.

6.3 Timeline

The planned timeline for the research is given below:

- Fall 2010: Makahiki v1 development start
- October 2011: First UH Kukui Cup start
- Fall 2011: Makahiki v2 development start
- September 2012: HPU and EWC Kukui Cup challenge
- September 2012: UH Kukui Cup challenge began
- March 2013: evaluation of Makahiki using ICS691
- April 2013: UH Kukui Cup challenge end
- Summer 2013: preliminary data analysis
- October 2013: Followup assessments of HPU instance and developer assessments
- May 2014: dissertation defense

Appendix A

Qualitative Feedback Questions

This appendix lists the questions that assess stakeholders' experiences with the IT infrastructure for serious games for sustainability. The questions are separated into sections based on the stakeholder's role.

A.1 Player effectiveness

The following questionnaires are administrated to the players who participated in the game:

1. Do you find the game engaging to play?

Text field for answer.

2. What did you like **most** about the website?

Text field for answer.

3. What did you like **least** about the website?

Text field for answer.

4. Did you change you behavior during the game? if so, how?

Text field for answer.

A.2 Game Designer efficiency

The following questions are asked during the interviews to the game designers:

5. Did you find it difficult to design the smartgrid game, or other games? if so, how?

Text field for answer.

6. What problem did you encounter in design and configuring the game?

Text field for answer.

7. What do you like the least of the system?

Text field for answer.

A.3 Game Manager efficiency

The following questions are asked during the interviews to the game managers:

8. What problem did you encounter in managing the game?

Text field for answer.

9. How often and what info do you look at the status page?

Text field for answer.

10. Is it easy to approve the game action submissions?

Text field for answer.

11. What do you like the least of the system?

Text field for answer.

A.4 System admin efficiency

The following questions are asked during the interviews to the system admins:

12. What problem did you encounter in installing and maintaining the system?

Text field for answer.

13. What were your greatest challenges in setting up the system?

Text field for answer.

14. Did you have to shutdown the system for maintenance? if so, for what reason, and for how long?

Text field for answer.

15. What do you like the least of the system?

Text field for answer.

A.5 Developer efficiency

The following questions are asked during the interviews to the developers:

16. How long did it take you to develop a new game / enhancement?

Text field for answer.

17. What is the most difficult part of learning the system?

Text field for answer.

18. What is the most difficult part of developing a new game?

Text field for answer.

19. What is the most difficult part of developing the enhancement to the system features?

Text field for answer.

20. what are the problems you encountered during env setup, develop, testing

Text field for answer.

Appendix B

Google Forms for In-lab Evaluation Experiments

This appendix lists the google forms that are used by the students voluntarily participated in the in-lab assessment experiments for system admin and game designer experiences.

B.1 System admin Assessment

There are two forms to assess the system admin efficiency.

B.1.1 Makahiki Local Installation Log

Please follow the steps outlined in this form to install Makahiki locally (including Virtualbox Linux Guest) and log the time you spent for each step. Please choose the closest value from the list that best matches the time you spent during the installation.

Thank you!

* Required

2.1.1.1.1.2. Install Python *

Complete the ”Install Python” section in Makahiki Local Installation Manual (http://makahiki.readthedocs.org/en/late
makahiki-unix.html#install-python), record the time you spent for this section only:

- 0 minute (come with the OS install)
- 5 minutes

- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when installing Python:

2.1.1.1.1.3. Install C Compiler *

Complete the ”Install C Compiler” section in Makahiki Local Installation Manual(http://makahiki.readthedocs.org/en
makahiki-unix.html#install-c-compiler), record the time you spent for this section only:

- 0 minute (come with the OS install)
- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when installing C compiler:

2.1.1.1.1.4. Install Git *

Complete the ”Install Git” section in Makahiki Local Installation Manual(http://makahiki.readthedocs.org/en/latest/in
makahiki-unix.html#install-git), record the time you spent for this section only:

- 0 minute (come with the OS install)
- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when installing Git:

2.1.1.1.1.5. Install Pip *

Complete the ”Install Pip” section in Makahiki Local Installation Manual(http://makahiki.readthedocs.org/en/latest/in
makahiki-unix.html#install-pip), record the time you spent for this section only:

- 0 minute (Already installed from previous assignments)
- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when installing Pip:

2.1.1.1.1.6. Install Virtual Environment Wrapper *

Complete the ”Install Virtual Environment Wrapper” section in Makahiki Local Installation Manual(http://makahiki.r
makahiki-unix.html#install-virtual-environment-wrapper), record the time you spent for this section
only:

- 0 minute (Already installed from previous assignments)
- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record the problem you encountered when installing virtual environment wrapper:

2.1.1.1.1.7. Install Python Imaging Library *

Complete the ”Install Python Imaging Library” section in Makahiki Local Installation Manual (http://makahiki.readthedocs.org/en/latest/installation-makahiki-unix.html#install-python-imaging-library), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when installing Python imaging library:

2.1.1.1.1.8. Install PostgreSQL *

Complete the ”Install PostgreSQL” section in Makahiki Local Installation Manual (http://makahiki.readthedocs.org/e
makahiki-unix.html#install-postgresql), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when installing PostgreSQL:

2.1.1.1.1.9. Install Memcache *

Complete the ”Install Memcache” section in Makahiki Local Installation Manual (http://makahiki.readthedocs.org/en
makahiki-unix.html#install-memcache), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when installing Memcache:

2.1.1.1.1.10. Download the Makahiki source *

Complete the ”Download Makahiki source” section in Makahiki Local Installation Manual (http://makahiki.readthedo
makahiki-unix.html#download-the-makahiki-source), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record the problem you encountered when download the Makahiki source:

2.1.1.1.1.11. Workon Makahiki *

Complete the ”Workon Makahiki” section in Makahiki Local Installation Manual (http://makahiki.readthedocs.org/en
makahiki-unix.html#workon-makahiki), record the time you spent for this section only::

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when activating Makahiki virtual environment:

2.1.1.1.1.12. Install required packages *

Complete the ”Install required packages” section in Makahiki Local Installation Manual (http://makahiki.readthedocs
makahiki-unix.html#install-required-packages), record the time you spent for this section only:

- 5 minutes
- 10 minutes

- 30 minutes
- 1+ hour

Record any problem(s) you encountered when Installing required packages:

2.1.1.1.1.13. Setup environment variables *

Complete the ”Setup environment variables” section in Makahiki Local Installation Manual (http://makahiki.readthed
makahiki-unix.html#setup-environment-variables), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record the problem you encountered when setting up environment variables:

2.1.1.1.1.14. Initialize Makahiki *

Complete the ”Initialize Makahiki” section in Makahiki Local Installation Manual (http://makahiki.readthedocs.org/e
makahiki-unix.html#initialize-makahiki), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when initializing Makahiki:

2.1.1.1.1.15. Start the server *

Complete the ”Start the server” section in Makahiki Local Installation Manual (http://makahiki.readthedocs.org/en/la
makahiki-unix.html#start-the-server), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered when starting the server:

2.1.1.1.1.16. Verify that Makahiki is running *

Complete the ”Verify that Makahiki is running” section in Makahiki Local Installation Manual (http://makahiki.readthedocs.org/en/latest/installation-makahiki-unix.html#verify-that-makahiki-is-running), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered when verifying that Makahiki is running:

Your UH email: *

B.1.2 Makahiki Local Installation Log

Please follow the steps outlined in this form to install Makahiki on Heroku and log the time you spent for each step. Please choose the closest value from the list that best matches the time you spent during the installation.

Thank you !

* Required

2.1.1.2.1. Install Heroku *

Complete the ”Install Heroku” section in Makahiki Heroku Installation Manual (http://makahiki.readthedocs.org/en/l
makahiki-heroku.html#install-heroku), record the time you spent for this section only:

- 0 minute (Already installed from previous assignments)
- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered when installing Heroku:

2.1.1.2.2. Add your SSH keys to Heroku *

Complete the ”Add your SSH keys to Heroku” section in Makahiki Heroku Installation Manual (http://makahiki.readthedocs.org/en/latest/installation-makahiki-heroku.html#add-your-ssh-keys-to-heroku), record the time you spent for this section only:

- 0 minute (Already installed from previous assignments)
- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered when adding your SSH keys to Heroku:

2.1.1.2.3. Verifying your Heroku account *

Complete the ”Verifying your Heroku account” section in Makahiki Heroku Installation Manual (http://makahiki.readthedocs.org/en/latest/installation-makahiki-heroku.html#verifying-your-heroku-account), record the time you spent for this section only:

- 0 minute (Already installed from previous assignments)

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered when verifying your Heroku account:

2.1.1.2.4. Setup Amazon S3 *

Complete the ”Setup Amazon S3” section in Makahiki Heroku Installation Manual (http://makahiki.readthedocs.org/e
makahiki-heroku.html#setup-amazon-s3), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered when setting up S3:

2.1.1.2.5. Setup environment variables *

Complete the ”Setup environment variables” section in Makahiki Heroku Installation Manual (http://makahiki.readth
makahiki-heroku.html#setup-environment-variables), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered when setting up environment variables:

2.1.1.2.6. Download the Makahiki source *

Complete the ”Download the Makahiki source” section in the Makahiki Heroku Installation Manual (http://makahiki.readthedocs.org/en/latest/installation-makahiki-heroku.html#download-the-makahiki-source), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered when download the Makahiki source:

2.1.1.2.7. Initialize Makahiki *

Complete the ”Initialize Makahiki” section in the Makahiki Heroku Installation Manual (http://makahiki.readthedocs.
makahiki-heroku.html#initialize-makahiki), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered when initializing Makahiki:

2.1.1.2.8. Start the server *

Complete the ”Start the server” section in the Makahiki Heroku Installation Manual (http://makahiki.readthedocs.org/
makahiki-heroku.html#start-the-server), record the time you spent for this section only:

- 5 minutes
- 10 minutes

- 30 minutes
- 1+ hour

Record any problem you encountered when starting the server:

2.1.1.2.9. Verify that Makahiki is running *

Complete the ”Verify Makahiki is running” section in the Makahiki Heroku Installation Manual (http://makahiki.readthedocs.org/en/latest/installation-makahiki-heroku.html#verify-that-makahiki-is-running), record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered when verifying that Makahiki is running:

Your UH email: *

B.2 Game designer Assessment

There is one form to assess the game designer efficiency.

B.2.1 Makahiki Configuration and Management Log

Please follow the steps outlined in this form to configure and manage Makahiki, and log the time you spent and problems encountered for each step. Record the time you actually spent doing the tasks by choosing the closest value from the list that best matches the time you spent. The Makahiki manual referenced below may use the local instance 127.0.0.1 as the example. For this assignment, you should use the Makahiki instance you deployed in Heroku instead of your local instance.

Thank you !

* Required

0. Update your Heroku Makahiki instance *

Read the ”Updating your Makahiki instance” section in Makahiki Manual (http://makahiki.readthedocs.org/en/latest/i
makahiki-heroku.html#updating-your-makahiki-instance). Follow the instructions to update your Heroku instance with any changes from the Makahiki Git repository. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered in this step:

1. Getting to the challenge design page *

Read the ”Getting to the challenge design page” section in Makahiki Manual (http://makahiki.readthedocs.org/en/late
design.html#getting-to-the-challenge-design-page). Then go to the challenge design setting page of your Heroku instance. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem(s) you encountered in this step:

2. Design the global settings *

Read the ”Design the global settings” section in Makahiki Manual (http://makahiki.readthedocs.org/en/latest/challeng
design-name-settings.html). In your Heroku instance, change the ”Name” of the challenge and the

”Logo” fields to ones of your choosing. Test that your change is in effect by checking the Logo image and label at the top of any page. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

3. Design the teams *

Read the ”Design the teams” section in Makahiki Manual (http://makahiki.readthedocs.org/en/latest/challenge-design-teams-settings.html). In your Heroku instance, add a new team called ”Lehua-C” with the same group membership as the other teams in the default instance. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

4. Set up users *

Read the ”Set up users” section in Makahiki Manual (http://makahiki.readthedocs.org/en/latest/challenge-design-players-settings.html). Add two new users of your choosing to the team ”Lehua-C”. Make sure you assign the players to their team by going to the user’s profile link. Test your changes by logging in as one of the new players, and verifying that the player is on the right team. Record the time you spent for this step only:

- 5 minutes

- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

5. Specify the games to appear in your challenge *

Read the ”Specify the games to appear in your challenge” section in Makahiki Manual (http://makahiki.readthedocs.o
design-game-admin-enable-disable.html). Disable the ”Water Game”, and leave the other games enabled. You should see that the ”Drop Down” page disappears from the top navigation bar. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

6. Learn about how to design the resource goal games *

Read the ”Design the Resource Goal Games” section in the Makahiki Manual (http://makahiki.readthedocs.org/en/lat
design-game-admin-resource-game.html). Record any questions or confusion that arises from reading this section:

6.1. Configure the Energy Goal Game for your new team *

Change the energy goal setting for the team ”Lehua-C” to use manual data, and specify a time for the manual data input time. Test your changes by logging in as a player of Lehua-C, then go to ”Go Low” page. You should see the calendar view of the daily energy goal game instead of the stop light visualization. Record the time you spent for this step only:

- 5 minutes

- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

7. Learn about how to design Smart Grid Games *

Read the ”Design the Smart Grid Game” section in the Makahiki Manual (http://makahiki.readthedocs.org/en/latest/c
design-game-admin-smartgrid-game.html). Record any questions or confusion that arises from reading this section:

7.0. Design on paper *

The default installation defines a Smart Grid Game (SGG) with 3 levels. For this task, design a new Level 4 that extends the existing SGG. Level 4 will have a total of four actions: 3 new actions (Activity, Event, Commitment) that you create yourself, and one old action that you choose from the existing library of actions in the default installation. Design Level 4 with a 2x2 grid layout, including 2 categories of your choice. For this step, you will only design your Level 4 on a piece of paper or a spreadsheet, as described in Makahiki Manual (http://makahiki.readthedocs.org/en/latest/challenge-design-game-admin-smartgrid-game.html#designing-your-smart-grid-game). Specify the unlock conditions for each action to achieve some kind of unlocking sequence(”path”), such as depending on the completion of other actions. Record the time you spent in this step:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

7.1. Create a Level *

Add a new level ”Level 4”, with priority higher than Level 3, and some unlock condition depending on some actions from Level 2. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

7.2 Create a new Activity action *

Create a new activity action with your own content. Make the content meaningful. Fill in the required fields. You will also specify the level (should be level 4), category (your choice), as well as the unlock condition field, which determines the action ”path” of your SGG design as described in step 7.0. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

7.3 Create a new Event action *

Create a new event action with your own content. Make the content meaningful. Fill in the required fields. You will also specify the level field (should be level 4), category field (your choice), as well as the unlock condition field, which determines the action ”path” of your SGG design as described in step 7.0. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes

- 1+ hour

Record any problem you encountered in this step:

7.4 Create a new Commitment action *

Create a commitment action with your own content. Make the content meaningful. Fill in only the required fields. You will also specify the level field (should be level 4), category field (your choice), as well as the unlock condition field, which determines the action ”path” of your SGG design as described in step 7.0. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

7.5 Finalize the grid *

At this point, you should have created 3 new actions and put them in Level 4 of your SGG. For this step, find the final action to complete your 2x2 grid.. Go to the admin interface, find an action in the action library, and modify the level, category and unlock condition field according to your SGG design. Play-test your grid by logging in as normal player, go to the ”Get Nutz” page, unlock Level 4 and all actions in Level 4. Record the time you spent for this step only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

8. Design the Top Score Game *

Read the ”Design the Top Score Game” section in the Makahiki Manual (http://makahiki.readthedocs.org/en/latest/ch
design-game-admin-topscore-game.html), create a new topscore prize of your choice. Test your changes by going to the ”Prizes” page to see your newly created prize. Record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

9. Design the Raffle Game *

Read the ”Design the Raffle Game” section in the Makahiki Manual (http://makahiki.readthedocs.org/en/latest/challe
design-game-admin-raffle-game.html). Create a new raffle prize of your choice. Test your changes by going to the ”Prizes” page to see your newly created raffle prize and you can add raffle ticket to it. Record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

10. Design the Badge Game Mechanics *

Read the ”Design the Badge Game Mechanics” section in the Makahiki Manual (http://makahiki.readthedocs.org/en/l
design-game-admin-badge.html). Create a new badge with an award trigger type of ”smartgrid”. Specify some kind of awarding condition depending on the smartgrid operations. Verify that your

badge shows up in the badge catalog page and you can be awarded the new badge by doing the specified smartgrid action. Record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

11. Manage Action submissions *

Read the ”Manage Action submissions” section in the Makahiki Manual (http://makahiki.readthedocs.org/en/latest/ex
manage-smartgrid-game.html#manage-action-submissions). Approve some actions submitted by you during your playtesting. Record the time you spent for this section only:

- 5 minutes
- 10 minutes
- 30 minutes
- 1+ hour

Record how many actions you approved, and record any problem you encountered in this step:

Your UH email: *

Appendix C

Makahiki Assessment Report

This appendix reports the results of the application of SGSEAM to the Makahiki framework.

We have used Makahiki to create four different Kukui Cup Energy Challenges. Kukui Cup Energy challenges were held at the University of Hawaii (UH) in 2011 and 2012 for over 1,000 first year students living in the residence halls. Hawaii Pacific University (HPU) held a Kukui Cup Energy challenge in Fall 2012 for about 200 students. An international organization called the East-West Center (EWC) held a Kukui Cup Energy and Water challenge for approximately 600 international residents living in their residence halls. Since the halls did not have internet-enabled meters, resource consumption data had to be entered by the game managers manually.

The successful creation of serious game challenges by three different organizations provides evidence that Makahiki can be successfully tailored to the needs of different organizations. First, UH and HPU used different metering infrastructure, and EWC collected their resource data manually. Second, while UH and HPU challenges involved only energy consumption data, the EWC challenge involved both energy and water consumption data. Third, the IT infrastructure at UH and HPU provided authentication services using CAS (Central Authentication Service) and LDAP, while EWC used the built-in Django authentication. Fourth, the user interface was customized to "brand" each challenge with the logo, thematic elements, and the education contents of the sponsoring organizations.

Besides the real world usage of Makahiki in the series of Kukui Cup challenges, we performed in-lab assessment experiments in 2013. Makahiki was used in a serious game development course in Spring semester of 2013 at the Information and Computer Sciences Department of the University

of Hawaii at Manoa. There were a total of 8 students who participated in the experiments. The participants were either senior undergraduates or graduate students majoring in Computer Science. During the course, the students installed Makahiki, configured and designed a serious game instance with Makahiki, and finally developed an enhancement to the Makahiki framework. We asked the students taking the course to voluntarily participate in the assessment experiments of Makahiki, using SGSEAM.

C.1 Makahiki Player Assessment

We applied SGSEAM to assess player effectiveness during the 2011 Kukui Cup Challenge at the University of Hawaii at Manoa, a serious game implemented using the Makahiki framework. There were over 1000 eligible players for this challenge, who were mostly first year college students living in the resident halls. The challenge lasted for 3 weeks. Makahiki recorded detailed logging data from every interaction between the players and the website.

To assess the effectiveness of the framework for designing games that improve player literacy in sustainability, we conducted two energy literacy surveys, one before the challenge (pre-game) and one after the challenge (post-game). 24 players completed both surveys. Out of the total 19 energy literacy questions, the average number of questions answered correctly is 7.54 before the challenge, and 8.96 after the challenge. This result indicates an 18% improvement on the energy literacy. We also surveyed non-players as a control condition, and found that their literacy did not change, indicating that the improvement in player literacy was indeed due to the game.

To assess the effectiveness of the framework for designing games that produce positive change in sustainability behaviors, we recorded and analyzed energy consumption data before, during and after the challenge. Before the challenge, an energy usage baseline was established. During the challenge, compared to the baseline, 12 out of the total 20 teams reduced their energy consumption, with the highest reduction of 16.1%. However, 3 teams actually increased their energy consumption, with the highest increase of 11.7%. Overall, the average reduction of the 20 teams was very low—approximately 2%.

To assess player engagement of the game, we calculated a variety of engagement metrics. The results are shown in Figure C.1:

Measurement	MIN	AVG	MAX
Participation rate	13%	37%	74%
Number of players per day	43	85	147
Play time per day	1 min	27.7 mins	8.5 hours
submissions per day	32	266	1110
social interactions per day	51	208	468
website errors per day	0	0.6	4

Figure C.1. Makahiki Engagement Metrics

The participation rate of this challenge is 37%, which is good compared to other sustainability challenges. Over the course of the challenge, an average player spent about 27.7 minutes per day on the website. One player spent 8.5 hours on one day. There were an average of 266 activity submissions and 208 social interactions between players per day.

In summary, SGSEAM indicates that Makahiki can be successful in achieving player engagement and literacy improvement. SGSEAM could not provide evidence of positive change in behavior.

C.2 Makahiki System Admin Assessment

System admin assessment was done using an in-lab experiment. Students in a serious game class were tasked with installing the Makahiki system into their local computers. In order to understand how much time it takes to install Makahiki and what problems might be encountered, we designed a Google Form explaining the steps required to install Makahiki. We asked the students to record the time they spent completing each step and the problems they encountered. We also asked the students to provide feedback about their installation experiences in the form of blog posts. [45] describes in detailed the Google Form that is used in this assessment.

The results from the Google Form responses show that the average total time to successfully install Makahiki was 1.4 hours, with a maximum time of 2 hours and the minimum time of 0.9 hour. Figure C.2 shows the average time for each installation step.

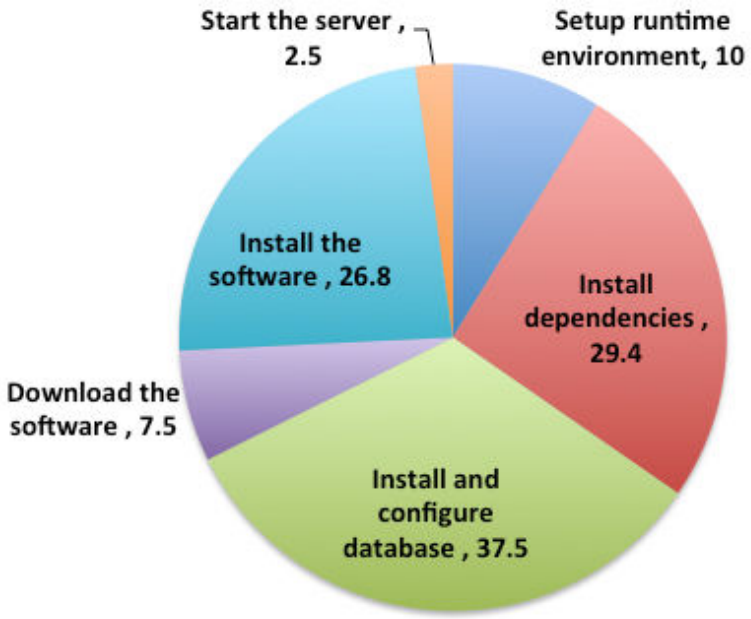


Figure C.2. Average time (minutes) for installation steps (n=8)

We coded and categorized the descriptive problems reported by the students in both the Google Form and their blog posts. Figure C.3 shows the result of the analysis from the feedback of the 8 students that participated in the experiment.

Problem encountered	**Number of participants**
Cannot find configuration file to edit during database installation	4
Documentation of install script is confusing about creation of the DB user	2
More parts of installation could be covered by install script	2

Figure C.3. Makahiki Installation Analysis (n=8)

From the above analysis, we identified that the "Install and configure database" step has the longest average time. It is also has the most participant reported problems. This reflects the issues encountered by students during the configuration process. This assessment determines the areas for future improvement are (1) to improve documentation on DB installation, and (2) to improve the install script to automate more installation tasks.

In summary, SGSEAM identified database installation as a weak point in installation. Otherwise, SGSEAM indicates generally positive results regarding Makahiki with respect to installation.

C.3 Makahiki Game Designer Assessment

We also used the in-lab experiment to assess the game designer experience of Makahiki. One of the class assignments for the students in the experiment was to design a serious game using the Makahiki framework. We asked the students to follow specific design steps and record the time required and any problems encountered during their design process, using a Google Form similar to the one used for the system admin assessment. In addition, students were asked to provide feedback about their design experiences in the form of blog posts. [45] describes in detailed the Google Form that is used in this assessment.

The game designer assessment was generalized into 7 tasks corresponding to distinct types of administrative tasks and game design planning. The time for each task is calculated from the Google Form results. The most time consuming task is ”Smart Grid Game Design”, which took average 107.9 minutes (56% of total time) to complete, while the least time consuming tasks is ”Raffle Game Design”, which took average 7.9 minutes (7% of total time) to complete.

Figure C.4 shows the average time for each design tasks:

We aggregated the problems reported in the feedback of the 7 students that participated in the experiment. Figure C.5 shows the result of the analysis:

In summary, SGSEAM revealed two shortcomings with Makahiki configuration: “Smart Grid Game Design” and “Configure Challenge Settings”. Issues encountered in “Smart Grid Game Design” included 1) difficulty and lack of documentation on the predicate system used to define dependencies between game activities, and 2) difficulty in generating event attendance codes for game activities. Issues encountered in “Configure Challenge Settings” included 1) a bug in the processing of Ajax queries caused by consecutive clicks on the same interface button, and 2) a bug that prevented users with username containing capital letters from logging in.

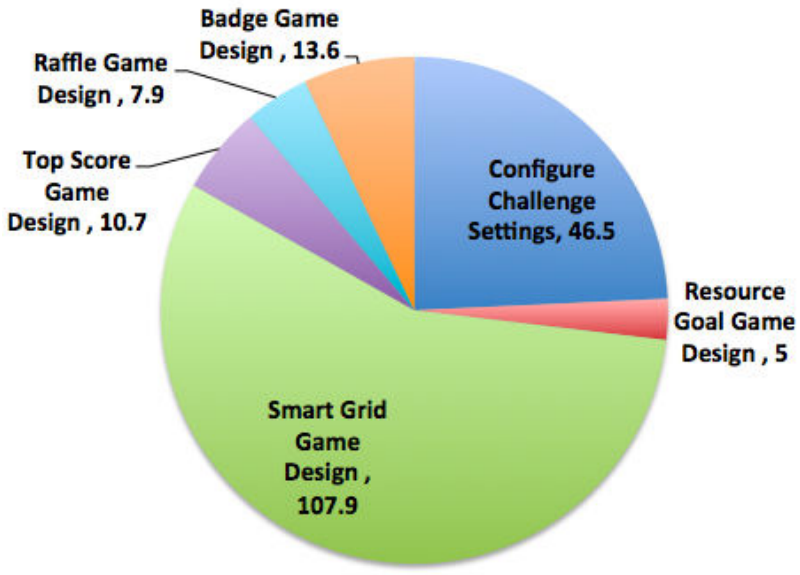


Figure C.4. Average time (minutes) for design tasks (n=8)

Problem encountered	Number of participants
Difficulty in understanding predicate system and unlock condition	7
A bug that prevented users with usernames containing capital letters from logging in	2
A bug in the processing of Ajax queries	1
Difficulty in generating event attendance codes for game activities	1

Figure C.5. Makahiki Game Design Analysis, (n=8)

C.4 Makahiki Developer Assessment

We assessed developer experience using an in-lab experiment. One of the class assignments for the students in the experiment was to develop an enhancement to Makahiki. This involved setting up a development environment, following the tutorial to create a “Hello world” widget using Makahiki, and finally, developing an enhancement to extend the functionality of Makahiki.

The students were asked to submit their development source code to the public source code repository (GitHub) and write a blog post to discuss their efforts to complete the development activity.

All 8 students reported that the first task of creating the simple "Hello world" widget was easy, while the enhancement development was hard. Only one student successfully completed all 5 required features, while the rest successfully completed 1 or 2 features. The main problem students reported was the lack of documentation for the development libraries. One student stated in his blog that he decided to choose Makahiki framework to develop his own serious game because of Makahiki's features and possibility of reducing development effort by using the framework.

In summary, SGSEAM reveals significant problems with developer efficiency. Analysis is still ongoing regarding the specific causes of problems and how best to address them.

Bibliography

[1] Stephen Anderson. Long after the thrill: Sustaining passionate users. *http://www.slideshare.net/stephenpa/long-after-the-thrill-sustaining-passionate-users*, 2011.

[2] Carrie Armel. Stanford arpa-e energy services platform. Technical report, Precourt Energy Efficiency Center,Stanford, May 2012. [retrieved: July, 2013].

[3] R. Bartle. Hearts, clubs, diamonds, spades: Players who suit muds. *Journal of MUD research*, 1(1):19, 1996.

[4] Torie Bosch. Score one for gamification. 2011.

[5] Robert S. Brewer, George E. Lee, and Philip M. Johnson. The Kukui Cup: a dorm energy competition focused on sustainable behavior change and energy literacy. In *Proceedings of the 44th Hawaii International Conference on System Sciences*, pages 1–10, January 2011.

[6] Victor R Basili1 Gianluigi Caldiera and H Dieter Rombach. The goal question metric approach. *Encyclopedia of software engineering*, 2:528–532, 1994.

[7] T. Connolly, M. Stansfield, T. Hainey, I. Cousins, J. Josephson, A. O'Donovan, et al. Arguing for multilingual motivation in web 2.0: a games-based learning platform for language learning. In *European Conference on Games Based Learning*, 2009.

[8] John W. Creswell. *Research design: qualitative, quantitative, and mixed methods approaches*. Sage Publications, Thousand Oaks, California, 2nd ed. edition, 2003.

[9] Sarah Darby. The effectiveness of feedback on energy consumption. Technical report, Environmental Change Institute, University of Oxford, 2006.

[10] Sara De Freitas and Martin Oliver. How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers & Education*, 46(3):249–264, 2006.

[11] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. From game design elements to gamefulness: Defining "gamification". In *Proceedings of MindTrek*, 2011.

[12] Dan Dixon. Player types and gamification. In *Proceedings of the CHI 2011 Workshop on Gamification*, 2011.

[13] Electric Shadows. World without oil, http://www.worldwithoutoil.org/metaabout.htm, 2010.

[14] Ahmad Faruqui, Sanem Sergici, and Ahmed Sharif. The impact of informational feedback on energy consumption–a survey of the experimental evidence. *Energy*, 35(4):1598–1608, 2010.

[15] Scott Haiges. Gaming for good. Technical report, ROI Research Inc, 2011.

[16] Casper Harteveld. Triadic game evaluation: A framework for assessing games with a serious purpose. In *Workshop of the ACM SIGCHI Symposium on Engineering Interactive Computing Systems*, 2010.

[17] Chelsea Hodge. Dorm energy competitions: Passing fad or powerful behavior modification tool? Presentation at the 2010 Behavior Energy and Climate Change conference, November 2010.

[18] IDEO. Hybrid electric vehicle interaction. *http://www.ideo.com/work/hybrid-electric-vehicle-dashboard-interaction*, 2009.

[19] F. Khatib, F. DiMaio, S. Cooper, M. Kazmierczyk, M. Gilski, S. Krzywda, H. Zabranska, I. Pichova, J. Thompson, Z. Popović, et al. Crystal structure of a monomeric retroviral protease solved by protein folding game players. *Nature Structural & Molecular Biology*, 2011.

[20] Amy Jo Kim. Designing the player journey. *http://www.slideshare.net/amyjokim/gamification-101-design-the-player-journey*, 2010.

[21] MJ Koepp, RN Gunn, AD Lawrence, VJ Cunningham, A. Dagher, T. Jones, DJ Brooks, CJ Bench, PM Grasby, et al. Evidence for striatal dopamine release during a video game. *Nature*, 393(6682):266–267, 1998.

[22] A.A. Krentz. Play and education in plato's republic. In *Twentieth Congress of Philosophy. http://www.bu.edu/wcp/Papers/Educ/EducKren.htm*, 1998.

[23] Nicole Lazzaro. Chasing wonder and the future of engagement. In *Talk. http://www.slideshare.net/NicoleLazzaro/chasing-wonder-and-the-future-of-engagement*, 2011.

[24] Lucid Design Group, Inc. Building Dashboard. http://www.luciddesigngroup.com/, Oct 2008.

[25] Lucid Design Group, Inc. Campus conservation nationals, http://www.competetoreduce.org/, 2011.

[26] Igor Mayer. Towards a comprehensive methodology for the research and evaluation of serious games. *Procedia Computer Science*, 15(0):233 – 247, 2012.

[27] J. McGonigal. *Reality is broken: Why games make us better and how they can change the world*. Penguin Press, 2011.

[28] Jane McGonigal. Gaming can make a better world. 2010.

[29] Jane McGonigal. We dont need no stinking badges. *http://www.slideshare.net/avantgame/we-dont-need-no-stinkin-badges-how-to-reinvent-reality-without-gamification*, 2011.

[30] nikeplus. nikeplus. *http://nikeplus.com/*.

[31] Paul Norton. The path to zero energy homes. http://hawaii.gov/dbedt/info/energy/efficiency/RebuildHawaiiConsortium/Events/PastEvents/2010-03-10/2010-03-10%20Norton%20Rebuild%20Hawaii%20ZEB%20.pdf, March 10 2010.

[32] John E. Petersen, Vladislav Shunturov, Kathryn Janda, Gavin Platt, and Kate Weinberger. Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. *International Journal of Sustainability in Higher Education*, 8(1):16–33, 2007.

[33] Seth Priebatsch. The game layer on top of the world. http://www.ted.com/talks/seth_priebatsch_the_game_layer_on_top_of_the_world.html, 2010.

[34] RecycleBank. Recyclebank. *http://www.recyclebank.com/*.

[35] B. Reeves and J.L. Read. *Total engagement: using games and virtual worlds to change the way people work and businesses compete*. Harvard Business School Press, 2009.

[36] Byron Reeves, James J. Cummings, and Dante Anderson. Leveraging the engagement of games to change energy behavior. In *Proceedings of the CHI 2011 Workshop on Gamification*, 2011.

[37] ribbonhero. ribbonhero. *http://ribbonhero.com/*.

[38] Allen Sherrod. *Ultimate 3D Game Engine Design & Architecture*. Charles River Media, Inc., 2006.

[39] Seungkeun Song, Joohyeon Lee, and Insun Hwang. A new framework of usability evaluation for massively multi-player online game: Case study of "World of Warcraft" game. In *Human-Computer Interaction. HCI Applications and Services*, pages 341–350. Springer, 2007.

[40] thefuntheory.com. Piano staircase. *http://www.thefuntheory.com/piano-staircase*, 2009.

[41] E. Vockell. Educational psychology: A practical approach. *Purdue University*, 2004.

[42] Nicola Whitton. Alternate reality games for orientation, socialisation and induction (ARGOSI). Technical report, JISC, 2009.

[43] World Bank Institute. Urgent evoke. http://www.urgentevoke.com/, 2010.

[44] Michael Wu. Sustainable gamification: Playing the game for the long haul. *http://lithosphere.lithium.com/t5/Building-Community-the-Platform/Sustainable-Gamification-Playing-the-Game-for-the-Long-Haul/ba-p/33601*, 2011.

[45] Yongwen Xu. Approach to access system admin and game designer experiences in makahiki. Technical Report CSDL-13-04, Department of Information and Computer Sciences, University of Hawaii, Honolulu, Hawaii 96822, June 2013.

[46] N. Yee. The virtual skinner box. *http://www.nickyee.com/eqt/skinner.html*, 2001.

[47] N. Yee. Understanding mmorpg addiction. *Retrieved February*, 15:2008, 2002.