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

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♢

To my wife
Wen and our son
Christopher: Thanks for
all the love, support, and pa-
tience you have shown me while
I worked on my Ph.D. It
is most deeply ap-
preciated.

♢

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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 [41] 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 [66]); (b) out-source to a commercial provider (as was done at the University of British Columbia in 2011 [72]); or (c) use a minimal tech solution such as a web page and manual posting of data and results (as was done at Harvard University in 2012 [3]).

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 University, 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 applied SGSEAM to Makahiki in order to gain better insight into its strengths and weaknesses as a serious game framework.

The 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 hope 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

In this dissertation, I describe the Makahiki research project, which explores the information technology to provide infrastructure to facilitate the development of serious games for sustainability. The research consists of an open source serious game framework for sustainability and a method for assessing a serious game framework based on the stakeholder experience. In this chapter I explain the motivation of the research, briefly describe the system and the method, as well as the contributions of this research project.

1.1 Motivation in Sustainability

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. In Hawaii, the need for transition is especially acute, as the state leads the US both in the price of energy and reliance on fossil fuels as an energy source (over 90% from oil and coal).

One barrier to this transition 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. 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 [23]. Data from a military housing community on Oahu show energy usage for similar homes can differ by a factor of 4 [62].

1.2 Collegiate dormitory sustainability competition

Over the past decade, running energy and water challenges have become a focal point for sustainability efforts at university and industry campuses, to facilitate and incentivize energy and water reduction. In a 2011 survey [41], Hodge found that 163 universities and colleges held or planned to hold an energy competition during the 20102011 academic year. 40% of these organizations are holding a competition for the first time. Hodge also found that top 25% of universities reducing energy usage within a building by 12% on average.

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 [66]. 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 [52], 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 [53]. 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 [56, 70]. Priebatsch attempts to build a game layer on top of the world with his location-based service startup [68]. 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" [28] 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 [71]. 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 [38]. 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 Serious game assessment

One fundamental question in evaluating a serious game or a gamified application is the extent to which the game or application achieves its "serious" purpose. This is quite different from traditional entertainment games. There is an increasing focus on the evaluation methodology in the field of serious games [55] [40]. These approaches focus on evaluation of a single game, as opposed to a game *framework*. One of the benefits of using a game framework is that, if correctly designed, it will provide useful and reusable "building blocks" with which to develop a variety of serious games. Yet how are we to know if a serious game framework has been "correctly designed"?

There exists some assessment tools such as GEQ (Game Engagement Questionnaire)[12], QUIS (Questionnaire for User Interaction Satisfaction)[39]. We found no prior work concerning comprehensive assessment for the particular needs of a serious game framework.

1.5 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.

1.5.1 Makahiki

We developed an innovative 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 not just to affect behaviors during the course of the game, but also 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 license and development model which makes the technology available without charge and facilitates collaborative development and improvement; (2) support for an "ecosystem" of extensible, interrelated, 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.

1.5.2 SGSEAM

In order to assess the effectiveness and efficiency of IT infrastructure for serious games for sustainability, I designed an assessment method called Serious Game Stakeholder Experience Assessment Method (SGSEAM). In a nutshell, SGSEAM (pronounced "sig-seam") identifies the most important stakeholders of a serious game framework and provides a method for gaining insight into the strengths and shortcomings of the framework with respect to each stakeholders' needs. We consider SGSEAM as an assessment method instead of an evaluation method. The main purpose of an evaluation is to "determine the quality of a program by formulating a judgement" [43]. An assessment, on the other hand, is nonjudgmental. SGSEAM does not try to judge a framework according to a standard, instead, it is used to identify the major strengths and shortcomings of a framework so that the community could benefit from the assessment by learning from the strengths and improving the shortcomings.

1.5.3 Evaluation

I applied SGSEAM to Makahiki to gather evidences of the effectiveness and efficiency of Makahiki, and to gain insight into the strengths and weakness of SGSEAM.

We have used Makahiki to create seven (7) different Kukui Cup Energy Challenges. Kukui Cup Energy challenges were held at the University of Hawaii at Manoa (UHM) in 2011, 2012 and 2014 for over 1,000 first year students living in the residence halls. Hawaii Pacific University (HPU) held a Kukui Cup Energy challenge in 2012 and 2013 for about 200 students. An international organization called the East-West Center (EWC) held a Kukui Cup Energy and Water challenge in 2012 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.

1.6 Outline

The dissertation 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 implementation of the Makahiki system.
- Chapter 4 describes the serious game framework assessment method SGSEAM.

- Chapter 5 lists our research questions and explains the plan to evaluate them.
- Chapter 6 lists our research questions and explains the plan to evaluate them.
- Chapter 7 concludes the dissertation with a list of contributions and future directions.
- Appendix A contains the publications that have come out of this research that I have authored or co-authored.
- Appendix B contains the survey questionnaire to be administered in the game to assess the player self-reported effectiveness and game usability.
- Appendix C contains the google forms to be used in the in-lab evaluation experiments.
- Appendix D contains the SGSEAM assessment guide written specifically for assessing Lucid Design Group's serious game framework.

CHAPTER 2
RELATED WORK

This chapter examines research related to sustainability, serious games and gamification, game design, serious game frameworks, and framework assessment. Section 2.1 and Section 2.2 discusses the needs for sustainability education and the current implementation of collegiate sustainability competitions. Section 2.3 discusses related work on serious games and recent development in gamification. Section 2.5 looks at the applications of "serious game" in the sustainability context. Finally, Section 2.6 and Section 2.7 examine the serious game framework and its assessment.

2.1 Sustainability and Education

Sustainability is defined as "a requirement of our generation to manage the resource base such that the average quality of life that we ensure ourselves can potentially be shared by all future generations"[**?**]. The depletion of natural resource has become a major focus of governments, organizations and citizens all over the world. There is widespread support for a dramatic increase in energy efficiency and change in energy use from fossil fuels to renewable sources (Flavin and Lenssen 1994).

In Hawaii, the need for transition is especially acute, as the state leads the US both in the price of energy and reliance on fossil fuels as an energy source. Almost 90% of the energy used in Hawaii is from imported fossil fuel, primarily oil, [**?**], as shown in Figure 2.1. Launched by the US Department of Energy and the State of Hawaii, the Hawaii Clean Energy Initiative [**?**] aims to achieve 70% clean energy by 2030 with 30% from efficiency measures, and 40% coming from locally generated renewable sources.

Government action is required to change the balance in energy policies, methods of generation and energy consumption. (Roodman 1996; Roodman 1997; Hawken, Lovins, and Lovins 1999). On the other hand, in terms of personal change for a sustainable lifestyle, "green" actions addressing responsibility as consumers such as changing purchasing habits, recycling, and saving energy and/or water need to be pursued (Kagawa2007).

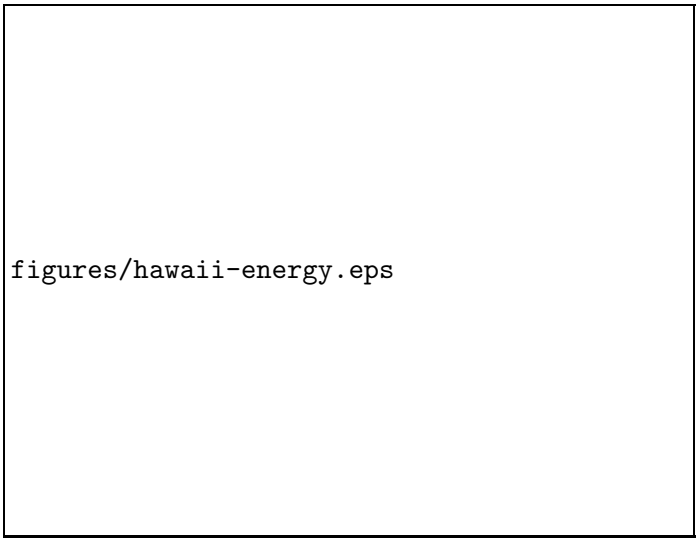


Figure 2.1: Hawaii Energy Sources [**?**]

In order to stimulate household energy conservation, according to some the most cost-effective way to achieve energy savings (e.g. Bertoldi et al., 2000), intelligent education of youngsters is needed, focusing on increasing awareness of the role of energy in our society and energy consumption at home, and influence their (future) energy-related behaviors.

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 [23]. Data from a military housing community on Oahu show energy usage for similar homes can differ by a factor of 4 [62].

2.2 Collegiate Sustainability Competitions

The creation of Makahiki is largely motivated from the needs from colleges and universities in running sustainability competitions for for sustainability education. Energy and water competitions or challenges have been introduced to college dormitories and residential homes as ways to facilitate and incentivize resource reduction to achieve sustainability goals. A survey by Hodge found that there are more than 160 college residence hall energy competitions taking place or being planned for the 2010–2011 academic year in North America [41] to engaging students in sustainability issues.

Hodge found that the average reduction in electricity use during these competitions is 9%.

A basic type of sustainability competition use a "minimal tech" solution such as a web page and manual posting of data and results on a periodic basis such as weekly. The Harvard University Green Cup Competition [3] and the Wellesley College Green Cup [73] are examples of this type of competition. During the 2012 Harvard University Green Cup Competition, there were 4.3% electricity reduction across the participating residence houses and an individual house reduction of 16.6%, as shown in Figure 2.2.

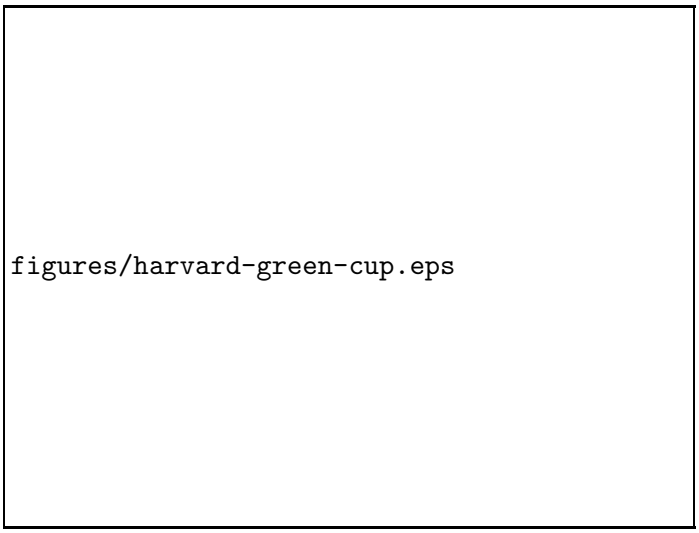


Figure 2.2: Harvard Green Cup Competition for Energy

Some organizations built their own custom in-house solutions to support the infrastructure need for sustainability competitions. Oberlin College dorm energy competition [66], Duke University's Eco-Olympics competition [2], and Western Washington University 's Go for Green Challenge [54] are the examples of this type of competition. Petersen et al. [66] 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. The competition used an automated data monitoring system that was developed in house to provide dormitory residents with real-time web-based feedback on energy and water use. They found a 32% reduction in electricity use across all dormitories and claimed that real-time resource feedback system combined with education and incentives can motivate and empower college students to reduce resource use in dormitories. **??** shows the design

of the Oberlin system.

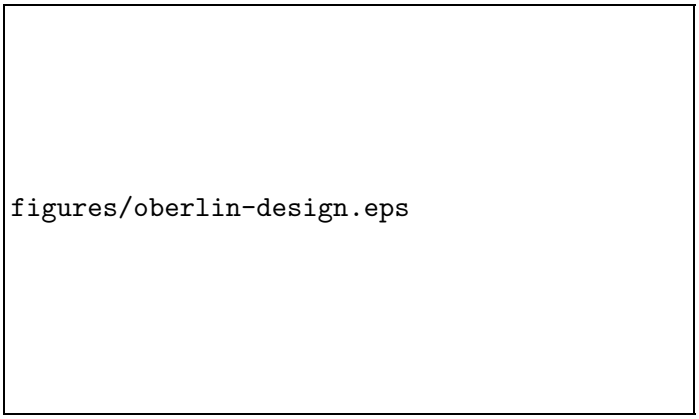


Figure 2.3: Oberlin College's Custom Designed Sustainability Competition [66]

Universities such as University of British Columbia [72] and Bowdoin College[1] chose to outsource the technology to a commercial provider for their sustainability competition. University of British Columbia started the energy competition titled "Do it in the Dark" [72] in November 2010 for the 6 first year student residence house. During the competition, the participated residence reduced overall energy consumption by 16.3%. The competition was hosted by Lucid Design Group's Building Dashboard platform [52] which provided the online real-time feedback of energy usage for the participating residence, and other social interaction such as sharing on Facebook through the web interface. Figure 2.4 shows the interface of the University of British Columbia Energy competition using the Lucid's Building Dashboard platform.

Campus Conservation Nationals (CCN) [53] is a nationwide electricity and water use reduction competition for colleges and universities. It has been running for the fifth year with hundreds of universities participating across North America. In 2014, 109 schools participated in the Energy Competition, which amount to total 1,330 building in the school campus and total 265,000 students and staffs actively involved in the self-chosen 3 weeks competition. Overall the competition resulted in 4.5% average electricity competition reduction in the building level, with the top 10 schools achieved reductions ranging from 11% to 24%. The software infrastructure used in CCN is supported by Lucid Design Group through its the Building Dashboard platform, which is used by the participating schools to get feedback from their energy and water use, compare performance

Figure 2.4: University of British Columbia Energy Competition[72]

and track the competition standings.

In summary, these collegiate sustainability competitions have the same goal of engaging students in sustainability issues using resource feedback and incentives such as some kind of prizes. Some competitions also provide educational content or activities such as organizing sustainability related events. Some competitions includes a simple point scheme that participants can win points for their teams or residence dorms by participating in the events and reducing the consumption. The team or dorm with the most points will win the prize. Some competitions also include the social sharing feature such as sharing their commitments to sustainability on Facebook as a way to enforce and encourage the positive behaviors. Table 2.1 lists the comparison among these competitions. The goal of Makahiki is to provide an open source framework for different organizations to create engaging sustainability serious games, including this kind of sustainability competitions. In addition to provide improvements to all of these features, Makahiki creates a more game-like interface such as tracking individual points and game plays, level progression, raffle game, badges etc.

School	Feedback	Education/ Activities	Point	Social	Infrastructure
Harvard University	manual	×	×	×	simple webpage
Wellesley College	manual	×	×	×	simple webpage
Duke University	manual	✓	✓	×	custom website
Duke University	manual	✓	✓	×	custom website
Western Washington University	manual	✓	✓	×	custom website
Oberlin College	real-time	✓	×	✓	custom website
Bowdoin College	real-time	✓	×	✓	out-source
University of British Columbia	real-time	✓	×	✓	out-source
Campus Conservation Nationals	real-time	✓	×	✓	out-source

Table 2.1: University energy competitions

2.3 Serious Games and Gamification

Differentiating Makahiki from the other collegiate sustainability competition is the game design elements in Makahiki. We consider the sustainability competitions that created by the Makahiki framework are of a type of serious games. A serious game is "a game designed for a primary purpose other than pure entertainment" [87]. It includes categories such as educational games and advergames (advertising), political games, and training games (also known as game-learning). Zyda [94] defines serious game as "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 prominent example is Foldit [45], a multiplayer online game which helps solving problems that computers can not solve very well. In this case, online gamers around the world together 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. Figure 2.6 shows a screen shot of the Foldit game.

An Alternative Reality Game (ARG) is one type of serious game that blends real and virtual world activities in the serious gaming context. McGonigal defines ARG as "games you play to get more out of your real life, as opposed to games you play to escape it" [56]. Her award winning serious ARG game "World Without Oil" [31] and "Evoke" [88] are designed with the goal of empowering people to come up with creative solutions to urgent real-world problems. Figure **??** shows an screen shot of the World Without Oil game. The game started on April 2007 for 32 days and concluded on June 2007. Approximately 2000 players participated in the game. They were asked to

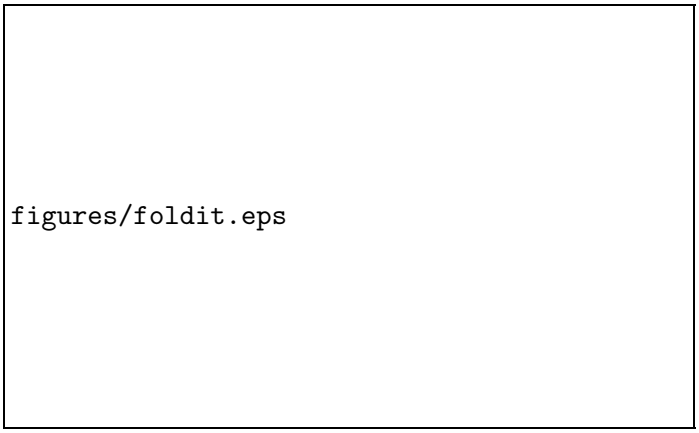


Figure 2.5: Serious Game Example: Foldit is solving a serious problem [45]

imagine what life would be like without oil, or try actually living without oil, then post their stories and thoughts in the forms of letter, emails, voicemails, blog posts, online videos and images. Some players reported that the online game affected their real world behaviors in some ways[56].

Figure 2.6: Serious Game Example: World Without Oil - Play it before you live it. [31]

ARGs have also been used to support learning. Connolly et al. [18] discuss the development of an educational ARG to motivate secondary school students across Europe to learn foreign lan-

guages. The results of the pilot run of the game in 2009 indicated that 92% of students felt the game motivated them to learn a second language. One of problems the team identified is the limitation of Moodle [59] platform the game is based on and there is potential to improve the effectiveness of the game.

The report of the ARGOSI project [86] provides insights into the use of ARGs in game based learning and the challenges they face in the field of higher education. The pilot was run at the University of Bolton with the aim of providing an engaging alternative to traditional methods of introducing students to university life. Adoption 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.

Makahiki shares similarity with the ARGs that they both combined real and virtual world activities to achieve "serious" purposes, be it educational or behavior changing.

While "Serious Games" has been an active research topic for decades, "Gamification", on the other hand, is a relatively new subject. Deterding et al. [28] defines gamification as "the use of game design elements in non-game contexts". The term only came into widespread use starting in 2010 [74] [93]. Gartner [37] predicts that by 2015, more than half of companies managing innovation processes will employ gamification, applying game mechanics to application areas including productivity, finance, health, sustainability, news, user-generated content and e-learning.

Deterding et al. [28] describes the distinctions between gamification, serious games and other related concepts, as shown in Figure 2.7. According to Deterding, a) Gamification is about games. It is different than playful interaction or playful design. b) Gamification uses game elements. It is not a complete game such as a serious game. c) Gamification applies to non-game contexts. Similar to serious games, gamification uses games for other purposes than its normal expected use for entertainment. d) Gamification focuses on design. It is not game-based technology or practice of wider game ecology.

The system created by Makahiki consists of a number of smaller games which combined, pro-

Figure 2.7: Serious Game and Gamification (source: Deterding [28])

vides a game playing experience to the participants. So we consider that Makahiki framework produces a serious game, instead of a gamified educational application. While they are different, both gamification and serious games are trying to solve problems with game thinking. Gamification's main driving force is motivation, similarly, serious games also try to solve the motivation problem and influence people's behavior for "serious" purpose. Bosch [10] considered the serious game Foldit as a successful example of gamification in science.

FourSquare [36] is probably the most recognized example of applying game mechanics to a location based networking application. It is a location based game like service where players check-in to locations for virtual points and rewards. By employing gamification elements such as points, badges, levels and leader boards, it engages users to revisit a location such as a restaurant or pub and become a loyal customer and finally the "mayor" of the place. Certain virtual rewards such as the "mayor" of a particular Starbucks can be converted into real products, e.g. a free coffee. Foursqure proved that simple game mechanics can affect user behavior by engaging 10 million customers with a successful business model.

Nike+ [61] is a social running game that employs game mechanics to encourage runners - both casual and hardcore - to compete and improve their fitness, with the goal of solving the main prob-

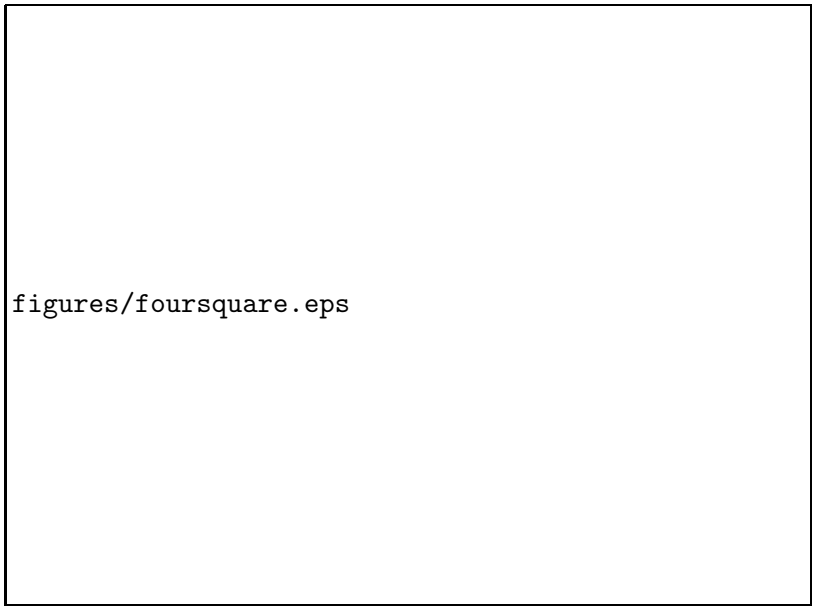
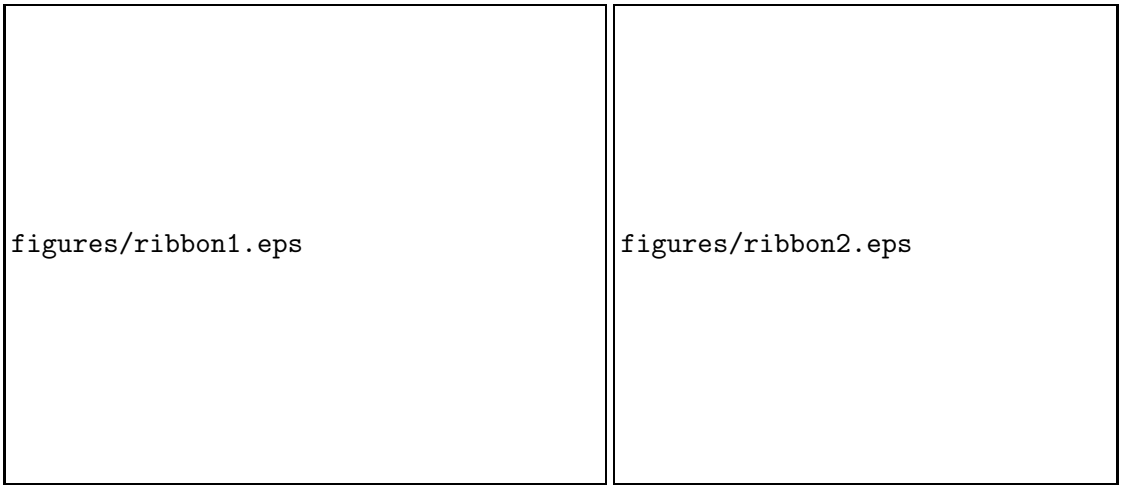


Figure 2.8: Gamification Example: Foursquare makes modern badges popular[36]

lem of most fitness programs: motivation. Nike+ allows runners to upload their exercise data to its web site, and start challenging themselves and their friends. They can also get support from their friends through the web site. The game makes running and exercise fun, which eventually serve the "serious" purpose of making people healthy.

Figure 2.9: Gamification Example: Nike+ makes fitness run[61]

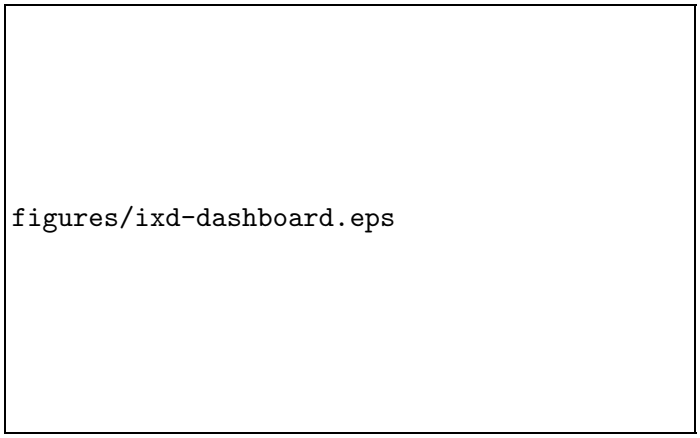
RibbonHero [19] is a game that helps users discover new Microsoft Office features. The goal is to have users build familiarity and expose them to the Office UI, so that they understand what kind of features are available. According to the creator of the game, Office "has a lot of powerful features that users might not know but can be really useful". The game gives users a chance to learn those features through a game interface, rather than reading the software manuals or watching the typically dry IT training videos.



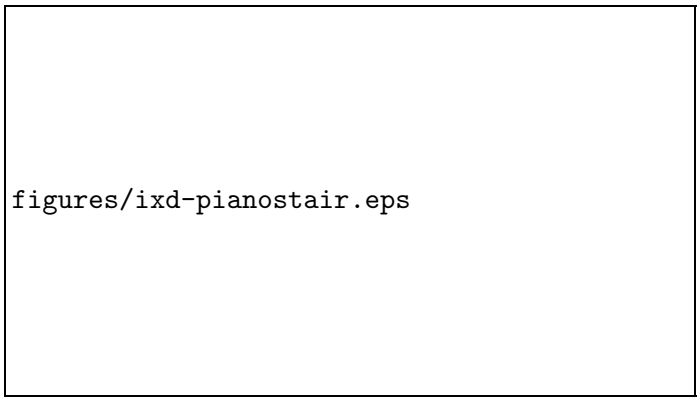
(a) Quest to earn points (b) Competing a task

Figure 2.10: Gamification Example: RibbonHero Helps to Learn Office[19]

Interactive design also applies game elements in their design to achieve sustainability goal. One example is the "SmartGauge" dashboard [44] for Ford's hybrid cars, where a digital plant responds to how energy-efficient the users driving behavior is. The design gives drivers a game, with the goal to grow more lush and beautiful leaves, a visual reward, by driving efficiently and thus promotes a more environmental behavior. Similarly, The design of "Piano Staircase" [80], created by Volkswagen Sweden, installed in a metro station in Stockholm, 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 to play the "piano staircase" game over using the escalator. It is a good example of gameful design for persuading and encouraging energy-efficient behavior.



(a) Efficiency Leaves



(b) Piano Stair vs. Escalator

Figure 2.11: Gameful Design for Sustainability

2.4 Game Design and Motivation

The research in serious games and gamification inspires the design of Makahiki in terms of benefits of a game, game design and how the game design can motivate and engage players in serious contexts.

Why games? Results of a study published in the May 1998 issue of Nature [47] demonstrated that video game players experience regular releases of dopamine during game play. Dopamine is a neurotransmitter that signals pleasure rewards for food, sex and addictive drugs, such as cocaine.

A favorite subject of Greek vase-paintings in the ancient games exhibition in the British Museum's department of Greek and Roman antiquities is Ajax and Achilles playing a kind of board

game called backgammon, as illustrated in Figure 2.12. It is noteworthy that both Ajax and Achilles have the full armor on while playing the game. According to Arthur A. Krentz [49], in Plato's "Republic", 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. Krentz states that "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" .

Figure 2.12: Ancient Games Shown in British Museum

Moving forward a couple of millennia, 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. Nick Yee [92] pointed out that 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" . He claimed [91] that "WoW truly is a virtual Skinner box", smoothly increasing reward and difficulty and reinforcing player commitment along the way.

In her popular and inspiring TED talk "Gaming can make a better world" [57] and in her book "Reality is Broken" [56], researcher and game designer Jane McGonigal makes a case for why good games make us better, and how they can help us change the world. She notes that more than

3 billion hours a week is spent in playing video game by our society. 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 spend in high school and middle school. There are 500 million gamers today, playing on all sorts of platforms from the iPhone to 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 that is the solution to our "Broken Reality". Byron Reeves also argues in his book "Total Engagement" [70], that games, especially MMO type games, can change the way people work and businesses compete.

Psychology professor Mihaly Czikszentmihalyi introduced a specific kind of happiness that he named "flow" [22], which is considered as one of the fundamental reasons that people play games [60]. Flow is a state of absorption, characterized by intense concentration, loss of self-awareness, a feeling of being perfectly challenged (neither bored nor overwhelmed) and a sense that time is flying. In order to achieve flow, the important condition is a balanced goal that is challenging yet achievable within the individual's ability. This balance is referred to as the flow channel as shown in Figure 2.13.

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 [7]:

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

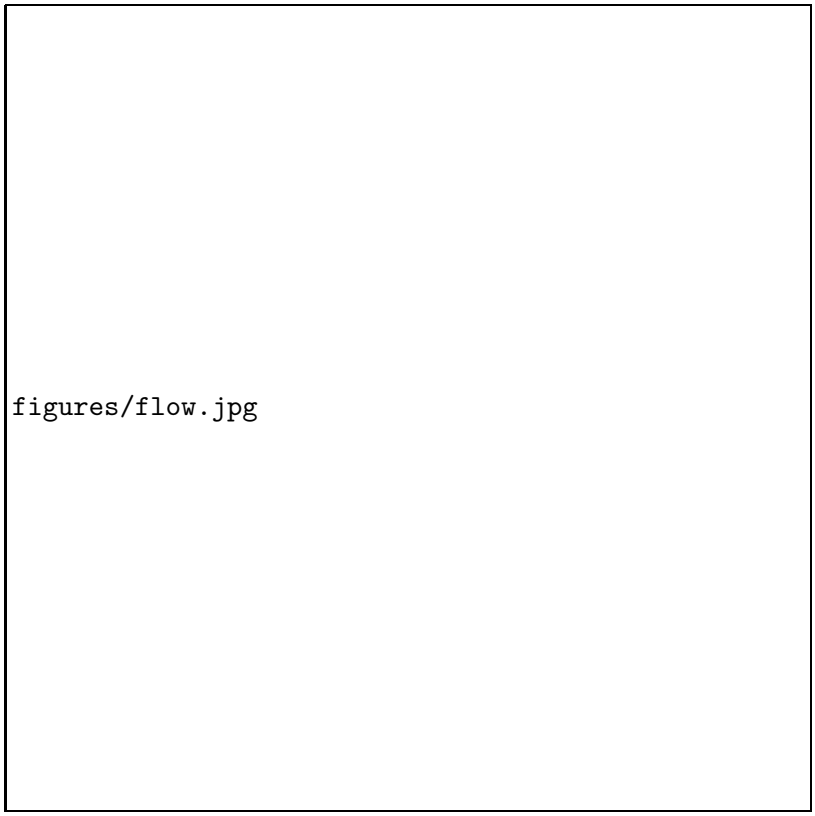
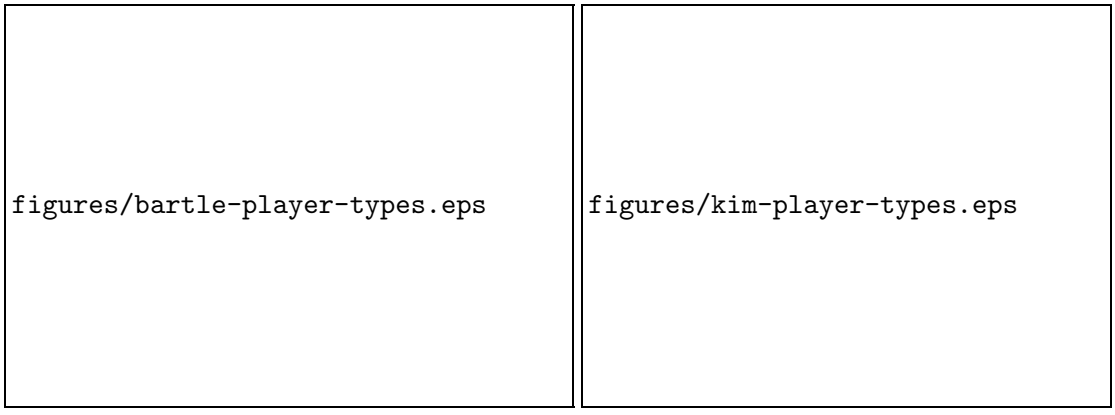


Figure 2.13: The state of flow is achieved between anxiety and boredom (source: Czikszentmihalyi [22])

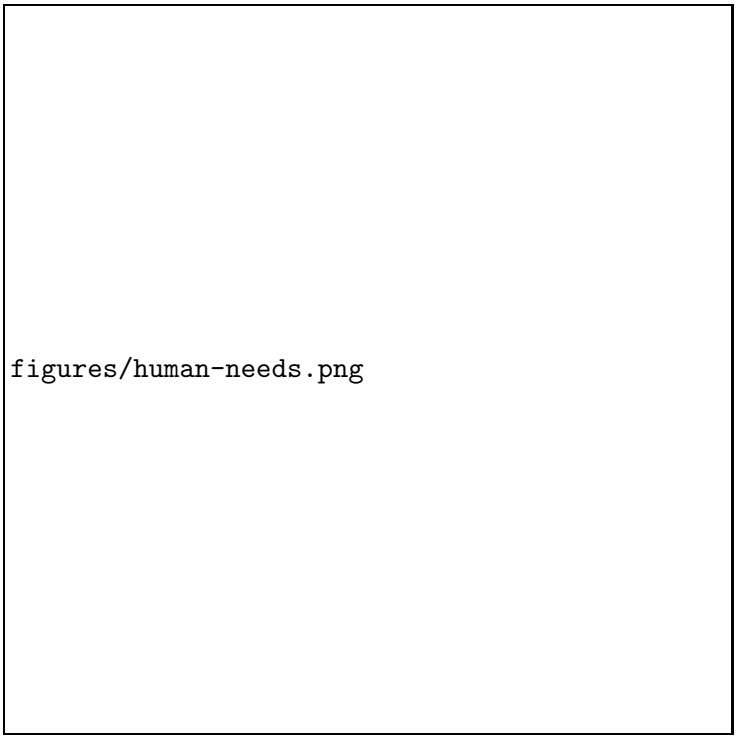
contexts [29]. Amy Jo Kim applied the model in her gamification approach by overlaying social actions from the game on top of the player types [46], as shown in Figure 2.14.



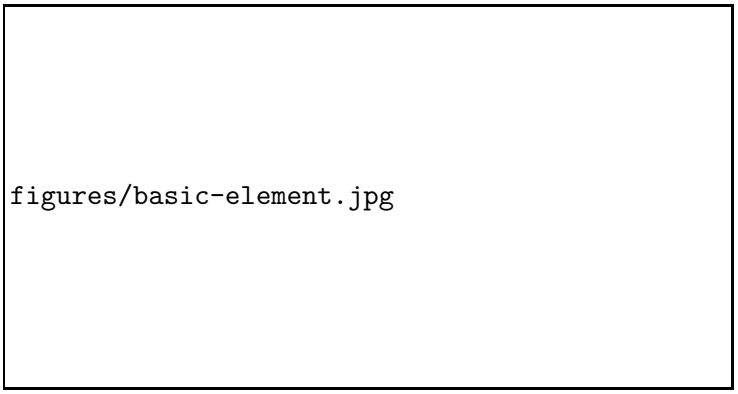
(a) Bartle's Player Types (1996) (b) Kim's Social Actions (2010)

Figure 2.14: Player Types

Different game mechanics and elements can be used to serve different functions in satisfying players' needs, and the basic elements such as points, badges, and leader boards are the defining attributes of the current gamification practices [27]. Figure 2.15 illustrates these basic game mechanics and elements.



(a) Satisfies Human Needs (source: Bunchball[13])



(b) Basic Mechanics (source: Deterding [26])

Figure 2.15: Basic game mechanics and elements

Seth Priebatsch [68] stated that you can get anyone to do anything with 7 game dynamics.

Techcrunch [9] published a "secret" game dynamics play deck that is used by Priebatsch's company SCVNGR. The play deck is a set of 47 flash cards. Each card illustrates one game dynamics. SCVNGR employees are instructed to memorize them and apply in their applications as needed. Social interaction designer Adrian Chan commented that the play deck does not include the sociological factors in social gaming and confuses game mechanics with game dynamics [15].

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

Designer Stephen Anderson claimed that gamification mistakes extrinsic rewards (rather than intrinsic motivation) for the power of games and hence offers only feedback, not goals & rules [4].

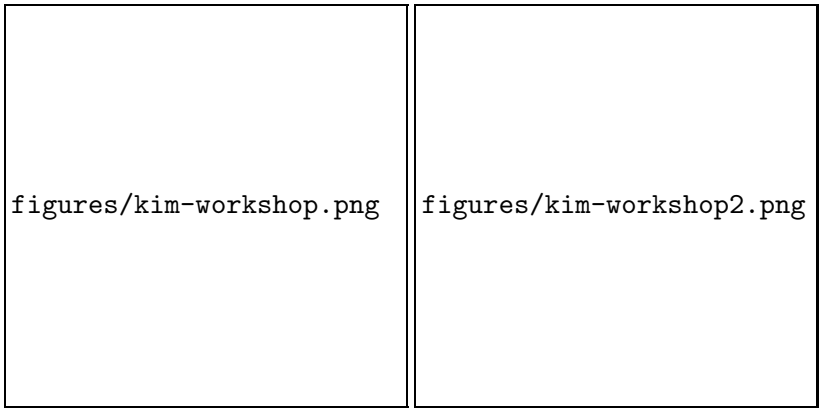
Figure 2.16: Gamification is about extrinsic rewards (source: Anderson [4])

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" [58]. 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 gamification 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 [50]. 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 [85].

Michael Wu argues that extrinsic rewards can jumpstart intrinsic motivation [89]. 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.

In order to design a game that that is intrinsic motivated, Amy Jo Kim presented "Smart Gamification" which focuses on designing an effective "Player Journey" with intrinsic reward preferred over extrinsic reward [46]. Kim pointed out that intrinsic values are greater than extrinsic rewards and "a good game take the player on a journey toward mastery". As illustrated in 2.17(a), when over time players progress from newcomer to regular and finally to enthusiast, they progress from novice to expert to master. Kim also incorporates the MDA framework [42] by using it to guide and motivate the player journey as illustrated in 2.17(b).



(a) Player Journey (b) Game Design

Figure 2.17: Designing Player Journey (source: Kim [46])

Similarly, Sebastian Deterding not only criticized the current practice of simple gamification practices but stressed the important of "meaningful play" and proposed a user experience design around the three most important aspects: Meaning, Master and Autonomy [26], It is an adaptation to the three elements to motivate people in Daniel Pink's book "Drive: The Surprising Truth About

What Motivates Us" [67]. Deterding explained that the reason why we play is because of the meaning and autonomy (choices) in the game. The mastery in the game give us fun and enjoyment.

The design of Makahiki is influenced by the above game design thinking. It combines extrinsic rewards such as prizes and achievement badges with the intrinsic motivation such as improving our environments by learning. Makahiki employs Kim's player journey idea [46] to design the on-boarding and progression of levels in the smart grid game. Other game mechanics, such as the "appointment mechanics" and the "social interaction" described in SCVNGR's game dynamics play deck[9] are being used in Makahiki to improve player engagement.

2.5 Serious Games for Sustainability

Makahiki is a framework for sustainability games. Serious games for sustainability are games designed to achieve the goal of sustainability development.

Vermontivate [84], a type of community sustainability game, shown in Figure 2.18, is similar to the games created by Makahiki. Vermontivate is a team-based game where the players compete to accrue as many points as possible for their towns or schools by participating in a variety of sustainability-focused actions. It runs for six weeks with mainly the participants in the state of Vermont. Because of the difference between the team size, team scores are calculated "per-capita" by adding up a teams total points and dividing by its number of players. A new set of challenges is announced every week with a different theme such as team-building, food, energy, transportation, capital, and future action. According to the initial sponsor of the game, Vermont Energy Investment Corporation, the first Vermontivate game began in May of 2012 and attracted 225 players from 31 Vermont towns. 9495% of players reported average to above-average understanding of and engagement with climate change and sustainability after playing Vermontivate, compared to 78% prior to playing [20]. Compared to Makahiki, Vermontivate game does not have individual points or prizes and more focus on activities and relies on self-reported participation.

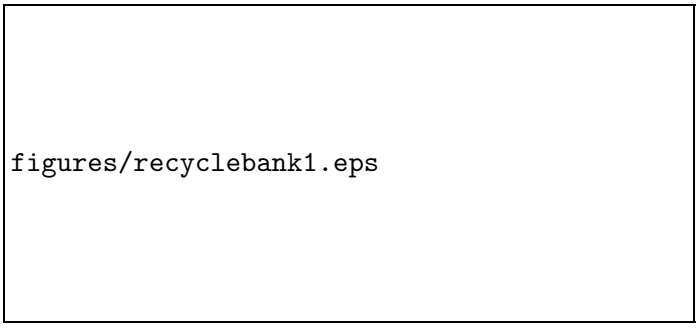
Similar to Vermontivate, RecycleBank's "Green Challenges" [69] is another serious game that used online gaming techniques to motivate participants to learn about green living and to take small green actions to live more sustainable lives offline. 2.19(a) shows a web page from the "Green your

Figure 2.18: Vermontivate Sustainability Game (source: Vermontivate [84])

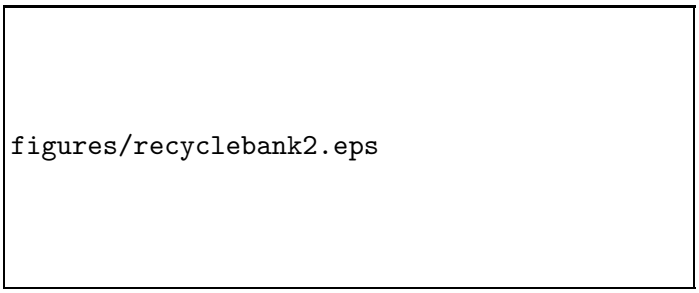
home Challenge" game. According to the "Gaming For Good" report [38], 49,000 individuals participated in the "Green Your Home Challenges". **??** shows a section of the survey results regarding the self-reported sustainability behavior changes after the game. Partnered with Google Analytics and ROI research, they found that:

- Gamification can increase awareness of positive environmental actions. 97% of participants surveyed said the game increased their knowledge of the 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.

The Opower Social Energy Application [63] is another kind of sustainability serious game, available as a Facebook app on both web and smartphones. It is developed in partnership with Facebook and the Natural Resources Defense Council (NRDC) with the intention of making saving energy social [81]. Figure 2.20 shows a screenshot of the game. Through the app, participants can compare their energy use to similar homes, share energy saving tips, compete with friends, and participate in team-related energy reduction challenges. The app lowers the adoption barrier by directly importing the energy usage data from Opower utility accounts. If the participant does not



(a) Green Your Home Challenge



(b) Game Change Behavior

Figure 2.19: RecycleBank - Gaming for Good

have an Opower utility account, he can enter data manually from his utility bills, which requires more efforts and motivation to participate. Compared to Makahiki, the energy usage feedback from Opower is not real-time (monthly), and the home energy saving tips or recommendations are not linked to points, badges, or other virtual or real rewards.

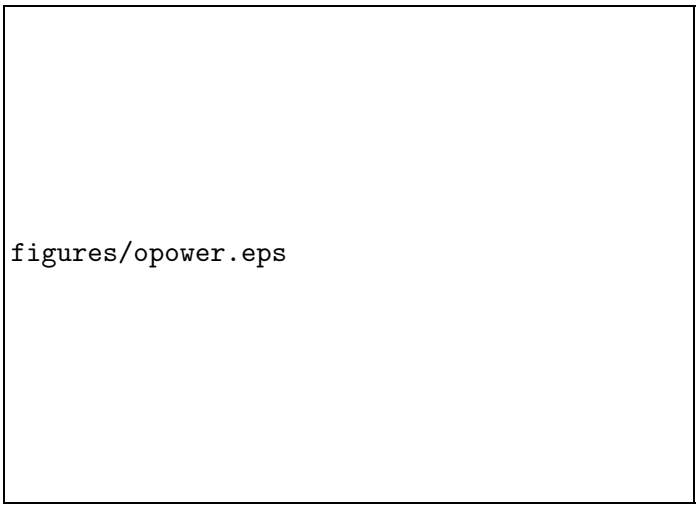


Figure 2.20: Social Energy Application Engaging Consumers (source: Opower [63])

Reeves et al. [71] described the design of Power House, an energy game that connects home smart meters to an online multiple player game with the goal of improving home energy behavior. In the game, real world energy data is 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 2.21 shows a screenshot of the PowerHouse game. The games created by Makahiki share the similarity with PowerHouse in the way of providing real-time energy feedback to the player. Makahiki has more educational activities and less simulation game play than in PowerHouse.

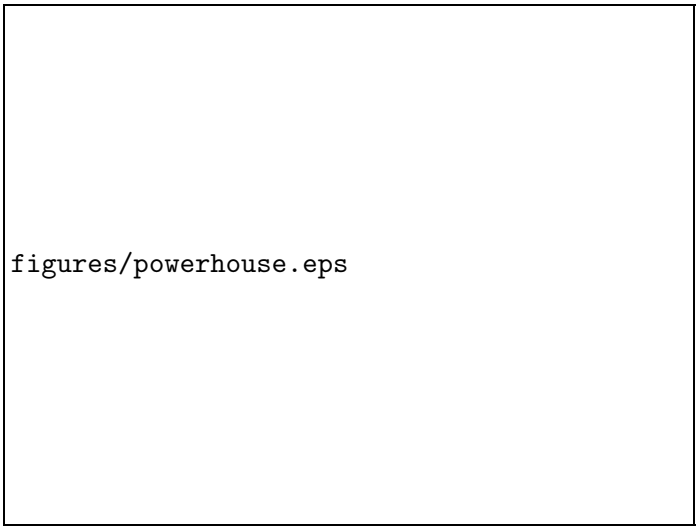


Figure 2.21: Power House Game to Save Energy(source: Reeves [71])

Another simulation based sustainability game worth of mention is the EnerCities [33] developed by Dutch game developer Paladin Studios with a 1.4M budget funded by the European Commission. Awarded the title of "Best Learning Game 2010", offered an online learning game for young people (typical target group: 15-20 years old) to experience energy-related implications. The goal of the game is to create and expand virtual cities dealing with pollution, energy shortages, renewable energy etc. Available both as a standalone website and on Facebook, The game was played by thousands of students from more than 110 schools across Europe. The game offers a semi-realistic simulation with cartoony 3D (via Unity3D plug-in[83]) visual styles with multiple level game play. Figure 2.22 shows a screenshot of the game. Similar to PowerHouse game, EnerCities game engages

player via the graphical simulation of the energy related issues. The player experience is more video game like than the other sustainability games such as the one's create by Makahiki. On the other hand, Makahiki as a extensible and configurable game framework, it is possible to include some simulation games such as EnerCities and PowerHouse inside Makahiki to provide better player experience and engagement.

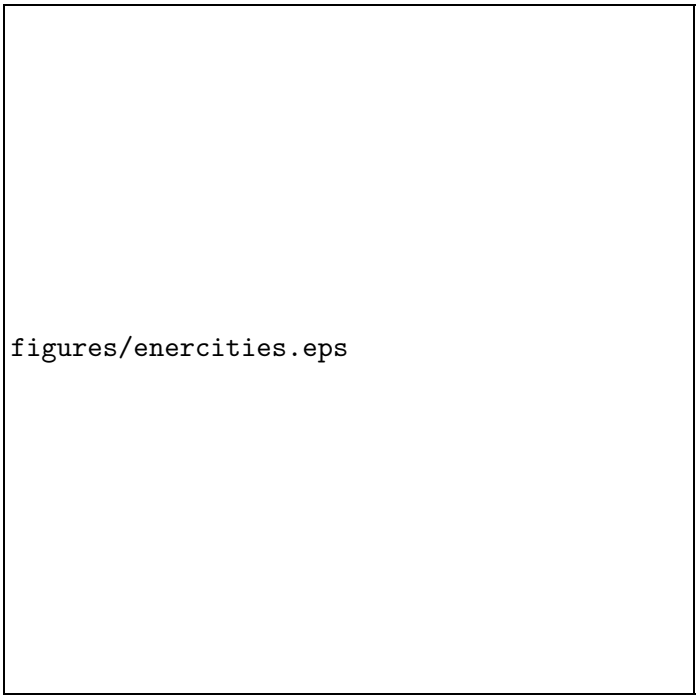


Figure 2.22: EnerCities - simulation based sustainability game(source: EnerCities [33])

Table 2.2 summaries the above serious games for sustainability and compares to the games created by Makahiki.

Game	**Type**	**Targeted player**	**Reward**	**Competition**	**Mobile**
Vermontivate	Website	Community	Prizes	Team	✓
RecycleBank	Website	Community	Prizes	Team	×
Opower	Facebook App	Energy consumer	Virtual	Individual	✓
PowerHouse	2D Simulation	Energy consumer	Virtual	Individual	×
EnerCities	3D Simulation	Schools	Virtual	Individual	×
Makahiki	Website	Schools	Prizes & virtual	Team & individual	✓

Table 2.2: Serious games for sustainability

2.6 Serious Game Frameworks

Game frameworks (also known as game engines) [75] 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". Examples of game frameworks include:

- Unreal [79]: The Unreal Engine is a game engine developed by Epic Games, it is primarily used in first person shooter games, providing tools and building blocks for 3D rendering, collision detection, AI, networking etc.

- PapayaMobile [65]: PapayaMobile is a free cross platform social game engine on Android and iOS platform. It provides an SDK and a platform for mobile game developers to create and release games in a "user-friendly, straightforward way".

- OpenLabyrinth [32]: OpenLabyrinth is an open source game framework that allows its users to create, run and analyze a wide range of different pathway-based activities for healthcare education.

- Fabula [34]: Fabula is an open source Python game engine for adventure, role-playing and strategy games and digital interactive storytelling. It provides a library and game world abstraction intuitive to people who have not been involved in game development before and hide as much as low level technical details as much as possible.

One of the benefits of using a game framework is that, if correctly designed, it will provide useful and reusable "building blocks" with which to develop a variety of games. Similarly, serious game frameworks also provide building blocks that enable the serious game developer to focus more time and thought on content and results instead of on the technical details and infrastructure for creating the serious game.

There are two serious game frameworks related to sustainability development. One such framework is the Building Dashboard [52], developed by Lucid Design Group, as shown in Figure 2.23.

Building Dashboard is commercial platform that "enables energy reduction competition and empowers building occupants to become active participants in energy management". It is used to

Figure 2.23: Building Dashboard (source: Lucid [52])

support the Campus Conservation Nationals (CCN) [53], a nationwide electricity and water use reduction competition on college campuses. In CCN 2014, the framework was used by 109 schools in North America to display the energy and water consumption of the competition participants. It enables viewing, comparing and sharing building energy and water use information on the web through a visual interface.

Building Dashboard is similar to Makahiki that they are both frameworks for supporting sustainability competitions, but the cost of Building Dashboard as a commercial system creates a barrier to wider adoption. In addition, the Building Dashboard solution focuses on providing energy information as a passive media. Besides a scoreboard, there is little interaction between participants and the system. There are less game elements other than providing a scoreboard to display the ranking of the competing teams, moreover, there is no individual points or ranking. Unlike Makahiki, Building Dashboard does not have the concept of individual registered player account, thus it does not have the capability to provide the evidence of individual player engagement.

Another framework related to sustainability is the Stanford Energy Services Platform [6], as shown in Figure 2.24. It provides services to support the creations of energy efficiency program and research. The services include data storage, a recommendation system, user registration and participation assignment, surveys and analytics. It had been utilized to support the implementation of several of Stanford's energy saving projects and energy related serious games, such as the Power House game, Power Down game, and Energy Calculator. At this point, there is not enough

information about the Stanford Energy Services Platform regarding the availability and features.

Figure 2.24: Stanford Energy Services Platform (source: Stanford [6])

2.7 Serious Game and Framework Assessment

This section examines the assessment of serious game frameworks. It starts by looking at the assessment of serious games, then the assessment of game frameworks in general. From my literature search, I have not yet found any prior work concerning the comprehensive approach for the particular needs of a serious game framework assessment. Nevertheless the research in game and framework assessment methods provides ground works for the SGSEAM method that we designed for use in assessing a serious game framework.

2.7.1 Serious Game Assessment

In order to assess a serious game framework such as Makahiki, it is important to assess the serious games the framework produces. 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 [76]. In the field of serious games, there is an increasing focus on the methodology of game evaluation [55].

De Freitas and Oliver [25] point out that there are few frameworks to support the evaluation of education games. They introduce a four dimensional framework for evaluating educational games and simulations. The framework consists of: the context, the pedagogy, the representation, and the learner (or player). Figure 2.25 illustrates the evaluation framework.

Figure 2.25: Four Dimensional Framework for Evaluating Educational Games [25]

Harteveld [40] also agrees that "Evaluatory research for games with a serious purpose is still at its infancy". He proposes an evaluation framework called "Triadic Game Evaluation (TGE)" for assessing serious games. It consisting of three perspectives: Reality, Meaning, and Play, as illustrated in the Figure 2.26.

Effectiveness assessment is often part of the serious game evaluation. In their evaluation of the EnerCities game, Knol and Vries reported that they conducted a survey to test differences in awareness concerning energy-related issues between a group who had actually played the game and those who had not (between-participants design). Examples of the survey questionnaires include:

- What did you find out about energy saving and green energy after playing the game?
- After playing the EnerCities game I was interested in learning more about energy saving and green energy
- Playing the Enercities game has increased my concern about the environment

Figure 2.26: Triadic Game Evaluation (TGE) [40]

- Playing the Enercities game made me aware of the linkages between economy, energy usage and environment
- Playing the EnerCities game made me aware that I should lower my own energy usage

2.7.2 Framework Assessment

The above approaches focus on evaluation of a single game, as opposed to a game *framework*. One of the benefits of using a game framework is that, if correctly designed, it will provide useful and reusable "building blocks" with which to develop a variety of games. Yet how are we to know if a game framework has been "correctly designed"?

Berger and Muller [8] describe their approach of using the Technology Acceptance Model (TAM) to evaluate the custom game engine Fabula [34]. Technology Acceptance Model [24] is a well received theoretical model on assessing user acceptance of computer-based information systems, introduced by Fred Davis in his doctoral thesis in 1985. TAM considers that system use is a response that can be predicted by user motivation, which is influenced by an external stimulus of the system's features and capabilities. Figure 2.27 illustrates the original Davis model. X1, X2 and X3 in the figure represent the system features.

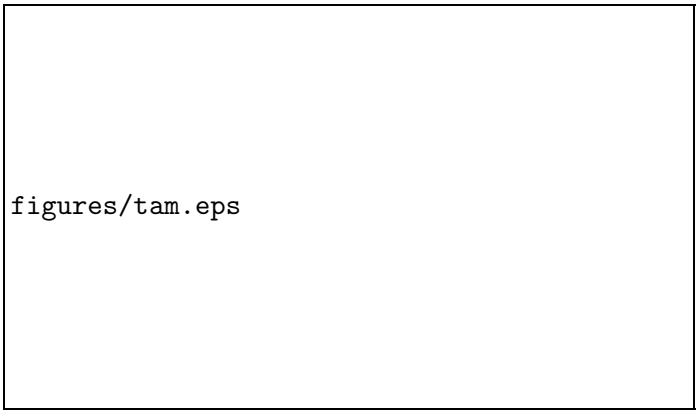


Figure 2.27: Technology Acceptance Model (TAM) [24]

As Chuttur [16] points out in his review of TAM, there is skepticism among some researchers regarding the rigor of the model. There exists other assessment tools such as Game Engagement Questionnaire (GEQ) and Questionnaire for User Interaction Satisfaction (QUIS).

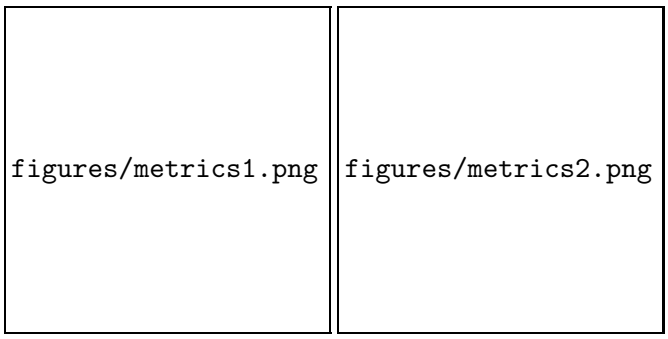
Questionnaire for User Interaction Satisfaction (QUIS) [39] is a usability assessment tool developed in the HCI lab at the University Of Maryland, College Park. It is designed to assess user's subjective satisfaction regarding the human/computer interface of software systems. Currently licensing is required to access the QUIS questionnaires.

Another usability assessment tool is the usability metrics described in Tullis and Albert 's book "Measuring the User Experience" [82]. For a usability procedure about completing transactions, Tullis and Albert suggest measuring task success, user efficiency, issues-based metrics, self-reported metrics, and live website metrics. Task success is a simple metric for a given task, does the user complete it or not? User efficiency is a measurement of the effort required for the user to complete the task. For example, we can measure this by the amount of time spent to complete the task. Issues-based metrics involve measuring the number of times usability issues are encountered. Self-reported metrics are based on user responses to survey questions. Finally, live website metrics can be derived from analyzing the logs created by the website to understand the user experience.

2.7.3 Game Metrics

Game metrics can be as important as creativity in game design. As Nadia Oxford points out, in the game industry, player metrics collection and analysis are widely practiced to provide game designers to determine what the player audience likes and dislikes about a certain game experience [64].

Ducheneaut et al. provides an example of using game metrics to analyze player's experience in a quantitative approach [30]. They reported the relationship of playing time and leveling in the MMORGs, as shown in Figure 2.28:



(a) Average time required to reach a level (b) Average accumulated play time by level

Figure 2.28: Player Metrics (source: Ducheneaut [30])

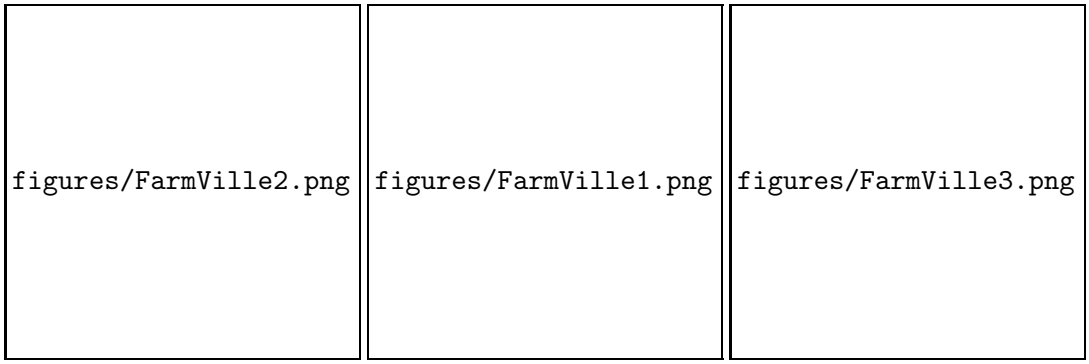
Matt Fairchild [35] and Kontagent [48] lists and explains some of the social games metrics as shown in Table 2.3.

Appdata.com gathers independent application metrics from most of the social game applications. For example, the graphs in Figure 2.29 shows the DAU (Daily Active User) and MAU (Monthly Active User) metrics for the popular FarmVille [95] social game [5]:

While the QUIS [39] is used for measuring user interaction satisfaction in a general software system, Game Engagement Questionnaire (GEQ) [12] developed by Brockmyer et al. is used to assess the engagement in a game. The questionnaire provides a "psychometrically" strong measure of levels of engagement specifically while playing video games. While the GEQ could measure the engagement level of positive game experience, the original intent of the research is to "examine risk and protective factors for negative game impact". Figure 2.30 shows the questionnaire items.

Metrics	Description
DAU	Daily Active Users, is the number of active users over the course of a single day.
MAU	Monthly Active Users, is the total number of users in a given month.
DAU/MAU ratio	Comparing Daily Active Users to Monthly Active Users shows roughly how many days per month the average user engages with a game.
ARPU	Average Revenue Per User, is measured as total revenue divided by the number of users. ARPU can be broken down by type of revenue, day, country, demographic, etc.
Churn	Turnover rate (or attrition rate) of active players.
K Factor	= (Infection Rate) * (Conversion Rate). An Infection Rate is how much a given user exposes the game to other players, such as through status updates or email invites. A conversion rate is when that "infection" results in a new sign up. K factor measures the viral effect of a game. A high K Factor indicates effectiveness of bringing in new players.
Engagement	Measures how long users spend playing a game. How many features do they access? How many pages does the average user view? What percentage are returning visitors?

Table 2.3: Social Game Metrics



(a) FarmVille DAU (b) FarmVille MAU (c) FarmVille DAU/MAU

Figure 2.29: Social Game Metrics Example(source: Appdata.com [5])

2.8 Summary

In summary, this chapter discusses related work on serious games and gamification, game design thinking, serious games for sustainability, serious game framework and its assessment. The design of Makahiki is inspired by the current research in game design thinking in both serious games and gamification. There are some assessment methods for serious games and for general purpose such

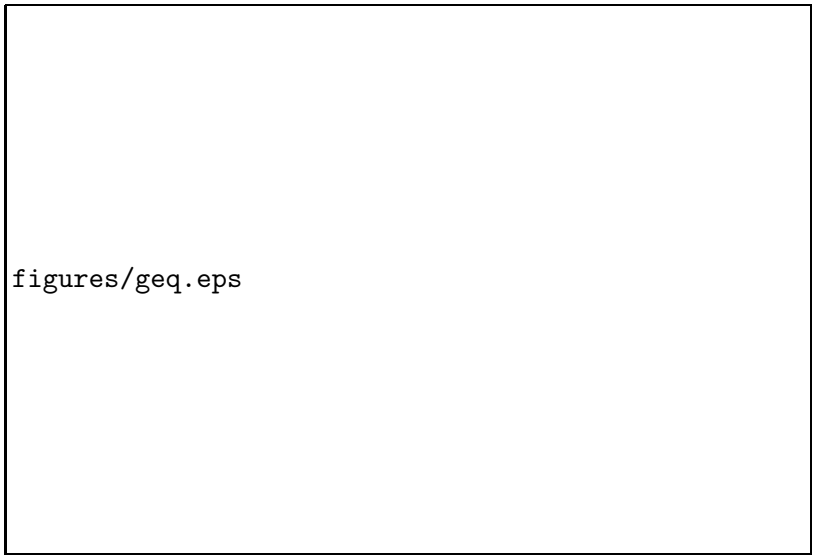


Figure 2.30: Game Engagement Questionnaire (GEQ) items [12]

as system usability. SGSEAM is designed to provide an assessment approach for the particular needs of a serious game framework assessment.

CHAPTER 3
MAKAHIKI DESIGN

This chapter describes the design of the Makahiki, a serious game framework for sustainability. It starts with the overview of Makahiki in Section 3.1, followed by the description of the Makahiki system in Section 3.2 . Section 3.3 describes the architecture of Makahiki, followed by the design features that makes Makahiki an innovated serious game framework.

3.1 Overview

Makahiki is an open source "serious game framework for sustainability". It provides a framework for creating serious games for the purpose of education and behavioral change regarding energy, water, food, and waste generation and use.

The initial version of Makahiki (Version 1) was developed in support of the first Kukui Cup energy challenge [11] held at the University of Hawaii in Fall, 2011. It was originally developed by George Lee [51], Robert Brewer [11] and myself, with assistance from Greg Burgess and Nathan Dorman. The first version of Makahiki provided the following functionalities to support energy challenges at the University of Hawaii: a) A synergistic mixture of real-world and virtual world activities to raise consciousness and literacy regarding energy issues; b) Real-time feedback on energy consumption by residence hall teams; c) Incentives in the form of prizes and raffle games. d) Social networks, both physical (residence hall teams) and virtual (Facebook).

The current version of Makahiki (Version 2) builds upon the prior version with the purpose of providing a serious game **Framework** for sustainability that enables different organizations to easily create customized serious games in the context of sustainability education and behavioral change. In additional to the features from version 1, the current Makahiki framework includes the following features::

- The ability to tailor system functionality to support the requirements of different organizations.

- The ability to support sustainable resource challenges such as water, food, and waste in addition to energy.
- The ability to extend the framework with new game and modules to support different requirements.
- The use of HTML5/CSS3 "responsive" design techniques for support of laptop, tablet, and smart phone interfaces.
- Real-time game analytics to help assess the impact of game mechanics during challenges.
- Support for PaaS (Platform as a Service) facilities such as Heroku. This enables organizations to create and deploy challenges without obtaining physical hardware and its requisite IT support.

The closest technology to Makahiki of which we are aware is the Building Dashboard that supports the Campus Conservation Nationals, which has been used by over 100 schools nationwide in 2014 to implement an energy and water reduction competition. But unlike Makahiki, the Building Dashboard system does not support game mechanics, education, or synergy between real and virtual world environments. In addition, it is not open source.

The next section describes Makahiki system as it is viewed by external users of the system, which includes

3.2 System Description

3.2.1 Software Installation

This section describes the installation process of the Makahiki system from the perspective of system administrators. The design goal is to make installation an easy process and to support multiple installation platforms.

Makahiki supports two forms of installation: local (on your own machine) and cloud-based (to the Heroku application hosting service). Organizations can install Makahiki locally if they wish

to host the system themselves. This requires sufficient hardware resources and IT support to do the installation, perform backups, and monitor the system during the challenge and deal with any outages that occur.

Organizations can instead choose to host Makahiki with Heroku. This incurs a cost (we estimate from $50-$150 per month of during the challenge, depending on the number of players), but has the benefit that no hardware or IT resources are required.

Table 3.1 outlines the installation steps for both local and cloud environments.

Installation Step	**Local**	**Cloud**
1. download software	git clone or download from website	git clone
2. Install tools and dependencies	Python, C compiler, Pip, Virtual environment, Python Imaging Library, Memcache, PostgreSQL	Heroku client
3. Initialize a server instance	initialize_instance	initialize_instance –heroku
4. Start up the server	manage.py run_gunicorn	automatically started in previous step

Table 3.1: Installation process

The main difference between local and cloud installation is step 2, “Install tools and dependencies”. For local install, all the tools and dependencies will need to be installed manually by the system administrators, including the C compiler, Pip and Virtual environment, Python imaging library, memcache as the caching system, and finally the PostgreSQL database, as well as the configuration of the database. This requires adequate skills from system administrators. On the other hand, the cloud installation only requires the installation of a single Heroku client. In the case of cloud installation, all Makahiki dependencies are satisfied by the instance created in the Heroku cloud, thus minimizing the involvement of system administrators.

3.2.2 Player Interface

This section describes the web interface that is viewed by the players of the Makahiki system.

3.2.2.1 Landing Page

Figure 3.1 is the landing page of Makahiki system.

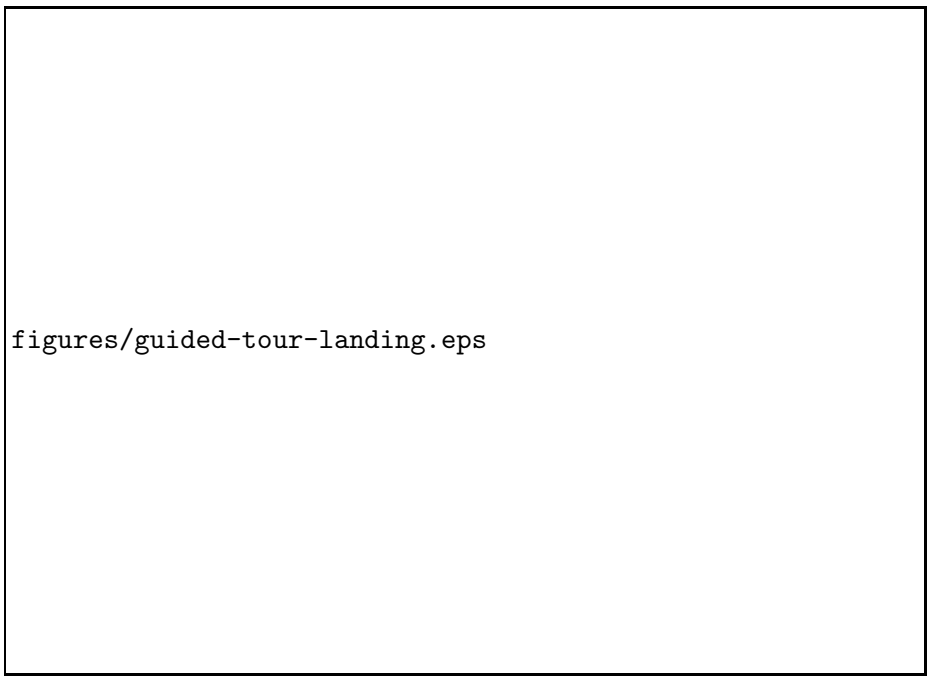


Figure 3.1: Landing page

The landing page is the first page encountered by new player. So far, challenges built using Makahiki have a "closed" registration model; that is, the users of the system are known in advance and set up during the configuration process. Thus, the landing page has two buttons: one for users who live in a particular place and thus should have access to the system, and one for those who are just visiting and would like to learn more about the system.

Most of the content on this page is configurable, including the University logo, the slogan, the text fields and button contents, and the sponsors.

3.2.2.2 Authentication Page

Users who click on the top button on the landing page are taken to an authentication page. Makahiki supports CAS (Central Authentication Service), LDAP, and Django internal authentication mechanisms. Figure 3.2 shows the University of Hawaii CAS authentication screen.

Figure 3.2: Authentication page

Site administrators can configure which authentication scheme(s) are used for any particular challenge.

3.2.2.3 Home Page

After logging in, the players are taken to the Home page, as shown in Figure 3.3. The system sets a cookie when the player authenticates successfully, thus, after the first visit, the player will normally go directly to the home page when retrieving the challenge URL.

Figure 3.3: Home page

There are three UI components in the home pages that are also appear on every page. They are:

- The "Info Bar" is a horizontal UI component at the top of every page. It provides status information about the challenge as well as a logout link. (The player will not normally need to logout unless they are accessing the site from a public computer.)
- The "Nav Bar" is a horizontal UI component below the Info Bar, which provides icons that link to all of the top-level pages in the system. The set of pages in the system is configurable.
- The "Quest Bar" is a horizontal UI component below the Nav Bar. It provides "Quests" (explained in more detail below).

3.2.2.4 Get Nutz Page

The "Get Nutz" page provides the user interface to the primary sustainability education game, also known as the "Smart Grid Game". Players gain points by clicking on cells in the Smart Grid UI widget, which takes them to the online or real-world educational actions such as activities, commitments and events.

Figure 3.4 shows an example of the Get Nutz page (the name of this page and any other top-level page can be configured by the game designer).

Figure 3.4: Get Nutz Page

The page also provides widgets about upcoming events and a scoreboard showing top scored leaders. The set of widgets appearing on this page is configurable. The game designer can use the game design admin interface to customized what widgets to include and where the widgets appear.

Clicking on the link in the middle of the smart grid game takes the player to a page explaining

that educational action. Figure 3.5 shows an example of the action page.

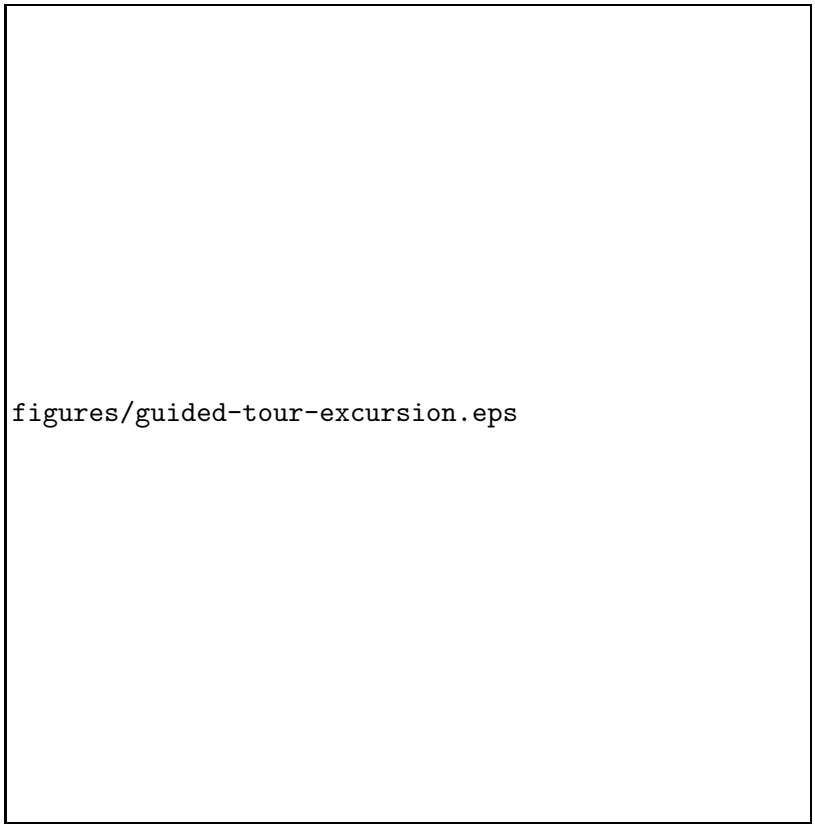


Figure 3.5: Action Page

3.2.2.5 Go Low Page

The “Go Low” page provides the user interface to two “energy” games, as shown in Figure 3.6:

Figure 3.6: Go Low Page

On the left side, the “Daily Energy Goal Game” incentivizes players to reduce their energy usage by awarding them points if they can reduce their team’s energy by a certain percentage below a baseline value. The stoplight visualization tells them whether or not they are currently on track to make the goal.

On the right side, the “Current Power” visualization helps players to see what their current power consumption is in near real-time (typically every 10-15 seconds.)

The page also enables team members to communicate via a shared chat window, and provides a scoreboard widget showing leaders in energy conservation.

3.2.2.6 News Page

The “News” page provides information about the state of the challenge and the team of which this player is a member, as shown in Figure 3.7:

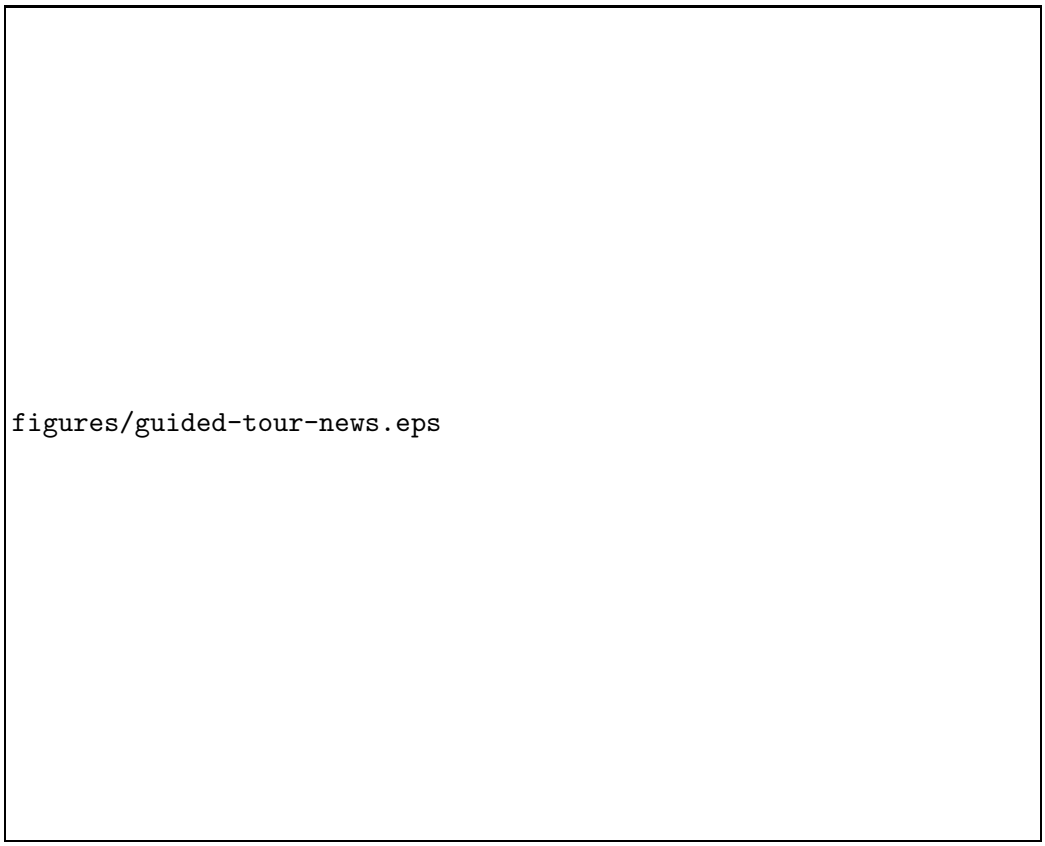


Figure 3.7: News Page

Widgets such as “Lounge Members”, “Most Popular Excursion”, “My Public Commitments”, etc. all provide a sense for the state of the competition and encourage players to participate by learning about what others members are doing.

3.2.2.7 Prizes Page

The "Prizes" page provides access to two games: the "Top Scorer" game and the "Raffle" game, as shown in Figure 3.8:

Figure 3.8: Prizes Page

The Top Scorer game, illustrated by the widget on the left, shows the prizes that can be won by top scorers in the competition.

The Raffle Game provides an alternative route to winning. Here, players earn in-game raffle tickets based upon their point score that can be allocated to any of a collection of raffle prizes. The odds of winning are based upon the percentage of their tickets allocated to the prize, which is picked at random at the end of a round by administrators.

The Raffle Game provides an incentive for players to do activities and earn points even if they do not stand a chance of winning one of the Top Scorer prizes.

3.2.2.8 Profile Page

The "Profile" page provides access to profile information for this player, as shown in Figure 3.9:

Figure 3.9: Profile Page

The user can set their display name, their picture, and how they wish to be contacted for reminders. It also shows information about their badges and a complete record of how they earned all of the points in the game.

The profile page also allows them to change the theme associated with the site. A variety of themes are available. In this configuration, the default theme is "Forest", but users can go to the Profile page to set a different theme for their own personal preferences.

3.2.2.9 Help Page

The final page available to players is the Help page, which simply provides access to explanatory material about the system, as shown in Figure 3.10:

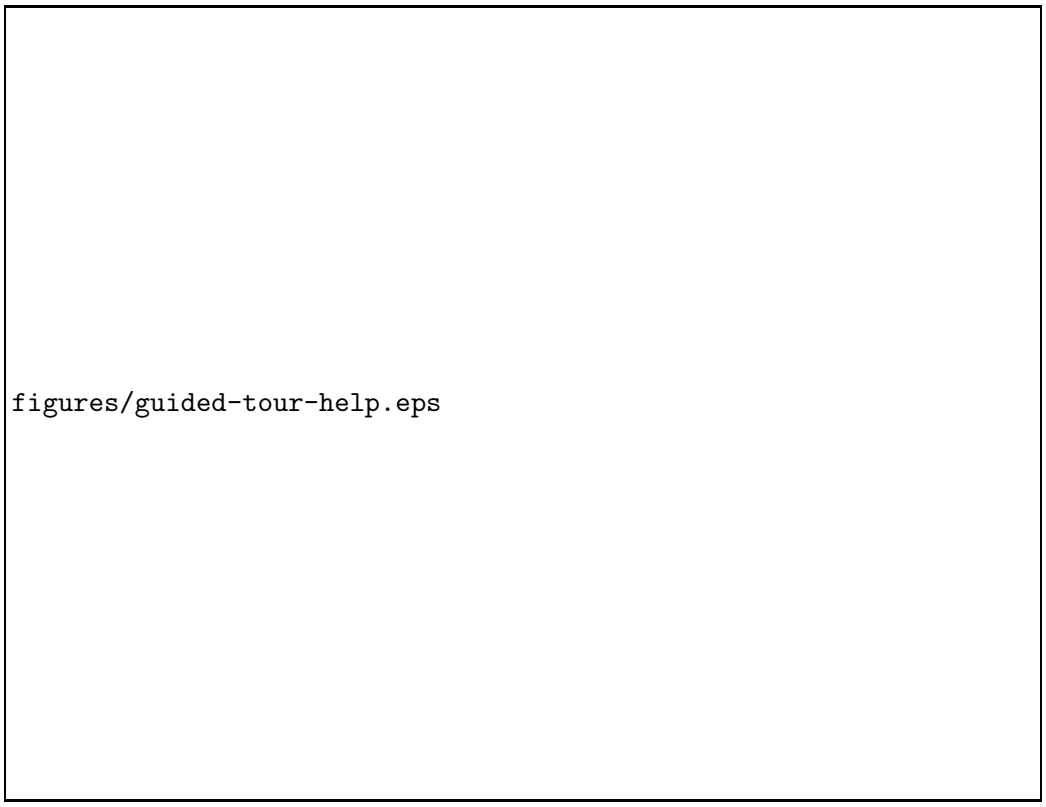


Figure 3.10: Help Page

3.2.3 Admin Interface

The admin interface is used by System admin, Game designers, Game managers and Developers.

3.2.3.1 Settings Page

The settings page is restricted to administrators, as shown in Figure 3.11:

Figure 3.11: Settings Page

Administrators use the Settings page to configure the site, design the challenge, manage a running challenge, generate analytics after the challenge is over, and support new development.

3.2.3.2 Smart Grid Game Designer Page

The Smart Grid Game Designer page is also restricted to administrators, specifically, the game designers. It is designed to to help build the Smart Grid Game, as shown in Figure 3.12:

Figure 3.12: Smart Grid Game Designer Page

Game designers use this page to construct the Smart Grid Game, by dragging and dropping the squares (game actions) into the grid with the intended layout.

3.2.3.3 Status Page

The "Status" page, also restricted to administrators, displays a large number of different widgets with various kinds of information about the state of an ongoing challenge. Figure 3.13 shows a screenshot of part of the Status page:

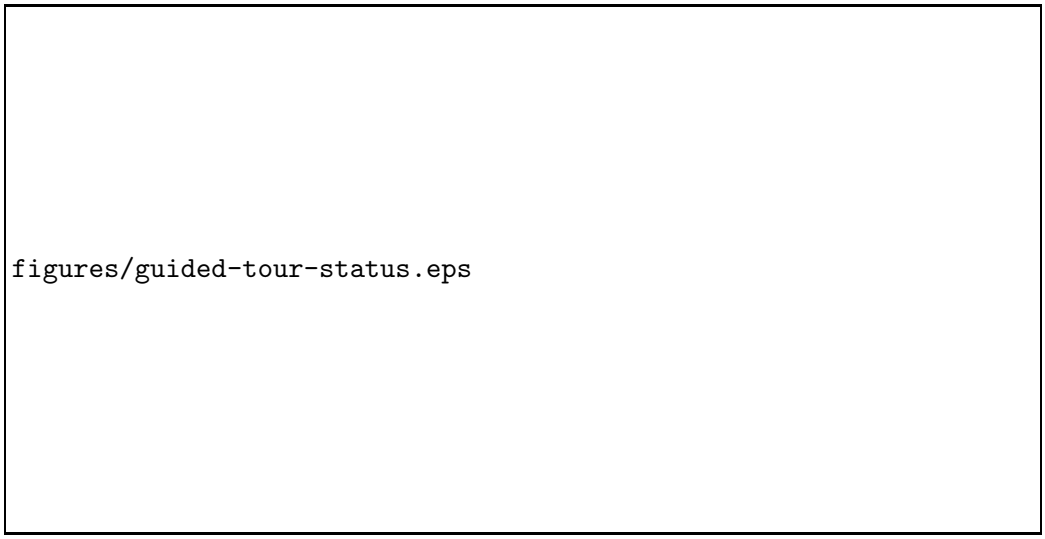


Figure 3.13: Status Page

The Status page is designed to help administrators to monitor the progress of their challenge, detect problems with the system and/or state of play, and intercede to correct them in a timely manner.

3.3 System Design

3.3.1 Architecture

Figure 3.14 illustrates the overall architecture of Makahiki.

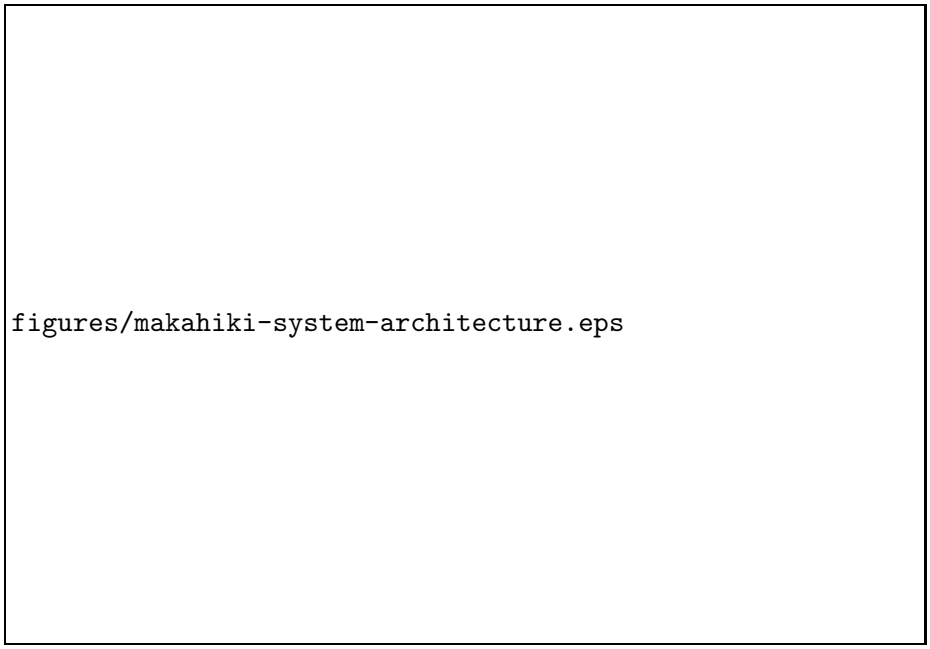


Figure 3.14: Architecture of Makahiki

The core component of Makahiki is a configurable game engine that can be customized to the needs of different organizations. It includes two libraries of games and game mechanics. These libraries consists of a set of pre-built "widgets". By selecting and configuring these game and game mechanics widgets, an organization can create a customized energy and water challenge (or serious game) in which players compete both individually and in teams, earn points by reducing their energy consumption as well as by learning about energy concepts in general, with the incentives such as top score prizes and raffle prizes.

Makahiki interfaces with the outside environment in third different ways.

First, the top side of the architecture diagram shows that Makahiki has two primary user interfaces: one for the players of the serious game, who directly interact with the game and game

mechanics widgets; the other for the administrators of the system, who configure the system and monitor the real-time game analytics.

Second, the right side of the diagram illustrates that Makahiki must obtain real-world environmental data as the challenge progresses in order to provide feedback to users about the impact of their actions. In some cases, environmental data can be input automatically into the system through a combination of "smart" meters and additional services (such as the WattDepot system for energy data collection, storage, and analysis). If that is not possible, then manual meters can be read by administrators on a regular (typically daily) basis and input into Makahiki using and administrator interface.

Third, the bottom side illustrates that Makahiki stores its data in a database repository (currently PostgreSQL). To reduce database access and improve performance, Makahiki provides support for caching (currently memcached).

Figure 3.15 illustrates the internal architecture of Makahiki. It provides a perspective on Makahiki's internal architecture in terms of three kinds of "components": Django-related infrastructure, Widgets, and Managers.

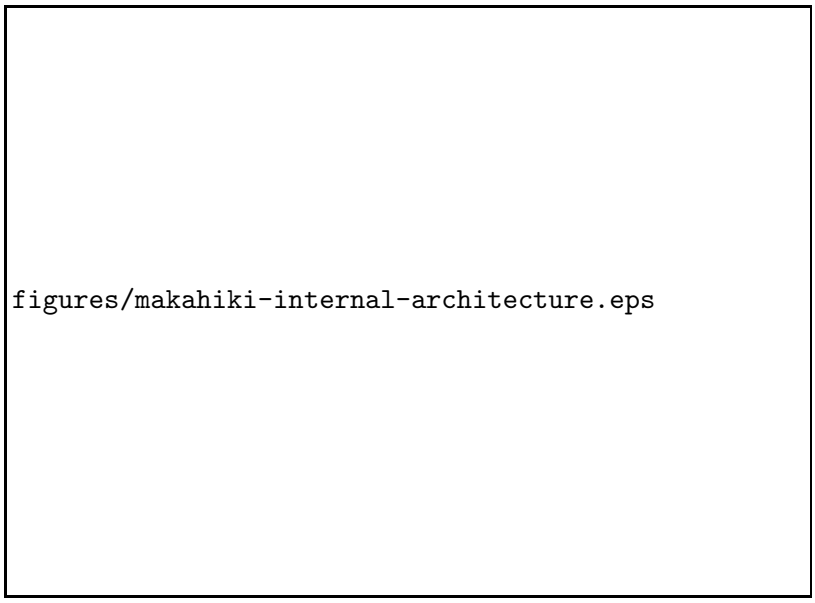


Figure 3.15: Internal Architecture of Makahiki

Managers are modules that provide Makahiki capabilities that do not involve a (player) user interface. They might provide interaction with administrators via the Django admin interface. Managers can implement game mechanic data structures (such as scores, players, and teams) or more generic web service functions (transactions, authorization, etc.)

Manager	Module Name	Functionality
Authentication Manager	auth_mgr	Provides authentication services for Makahiki including administrative logins and CAS authentication
Cache Manager	cache_mgr	Manages caching data structures
Challenge Manager	challenge_mgr	Maintains state information about an entire Challenge, including what widgets are enabled, the round information
Log Manager	log_mgr	Provides logging services to track the actions of logged in users
Player Manager	player_mgr	Supports definition and processing of players
Resource Manager	resource_mgr	Provides supports for resource management, such as updating energy or water data, checking daily goals
Score Manager	score_mgr	Manages score keeping, scoreboard calculation
Team Manager	team_mgr	Support definition and management of teams

Table 3.2: Makahiki Internal Manager Modules

Widgets are modules that provide Makahiki capabilities that do include a player user interface. Widgets can be roughly characterized in three ways. "Info widgets" provide state information about the challenge to players but little in the way of interaction. "Mechanics widgets" provide game elements such as Quests and Badges. The third category, "game widgets", refer to full-fledged interactive games.

3.3.2 A Library of Configurable Games and Mechanics

Makahiki builds in a set of configurable games and mechanics that can be turned on or off, or customized by the game designers to the needs of different organizations. The rest of this section describes these games and game mechanics and how to configure them.

3.3.2.1 Selecting a Game or Game Mechanics from the Library

A challenge designer can decide which of the built-in game and mechanics will appear in a sustainability challenge for his organization. The challenge design setting page includes a widget called

"Game Settings", which lists the set of games available and whether or not they are currently enabled, as is shown in Figure 3.16.

Figure 3.16: *Selecting a Game from Game Settings*

The small green and red icons on the right side indicate whether a game is currently enabled for the challenge. In this case, all of the games but one (Water Game) are enabled. Clicking on the title of a game will let you enable or disable the game and its widgets. After clicking on the title link in the Game Admin widget, a page similar to the Figure 3.17 will appear:

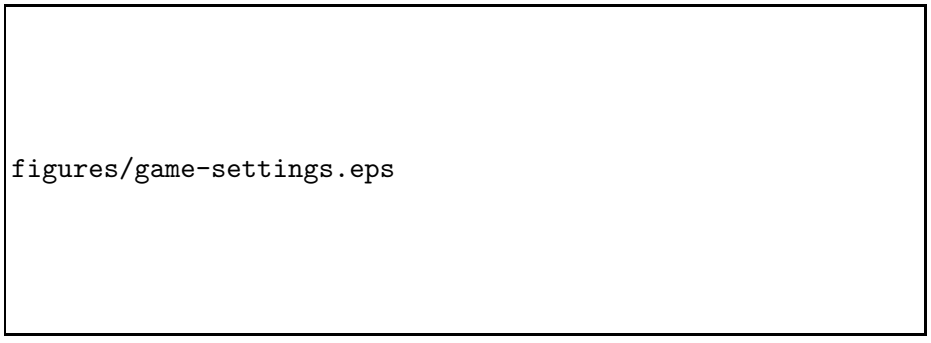


Figure 3.17: *Change a Game's Setting*

You can check or uncheck the “enabled” checkbox to enable or disable the game.

A game’s UI is represented by a set of widgets which is visible in the game website. The widgets belong to a game is listed under the Game Settings section, as shown from the above screen shot. If you disable the game, all the widgets belong to this game will not be shown in the web page.

Makahiki currently allows you to create a challenge out of the following games and game mechanics:

- *Energy Game*. This game awards points to players depending upon their ability to lower their energy consumption.
- *Water Game*. This game awards points to players depending upon their ability to lower their water consumption.
- *Smart Grid Game*. This game is the principle interface to the educational component of Makahiki. The SGG awards points to players for successfully completing activities, commitments, excursions, and events.
- *Top Score Game*. This game awards prizes to players and teams for earning the highest number of points during a round.
- *Raffle Game*. This game awards prizes to players if they have allocated their raffle tickets to a particular raffle prize, and that raffle ticket was randomly selected by the system at the end of a round.
- *Participation Game*. This game awards points to players if they can successfully get a certain percentage of their team members to participate in the challenge.
- *Quest Game Mechanics*. This game mechanic provides a way for players to learn about features of the challenge by guiding them through Quests.
- *Badge Game Mechanics*. This game mechanic provides a way for players to earn badges for playing the game in a variety of ways.

- *Referral Game Mechanics*. This game mechanic provides a way for players to earn points by getting other people to participate in the challenge.

The following sections explain the design and configuration of each game and game mechanics.

3.3.2.2 Energy and Water Game

A fundamental requirement for enabling more active participation in sustainability behavior is feedback regarding their resource such as energy and water usage. The Energy and Water game in Makahiki are implemented as the Daily Resource Goal Game, which includes Daily Energy Goal Game and Daily Water Goal Game.

The Daily Energy Goal Game widget provides a way for players to see the outcome of the energy reduction behavior, and to make it a game by earning points from their behavior. By reducing their teams' daily energy consumption from a baseline by a set percentage, the players in the team will all earn the configured amount of points. This baseline is calculated using historical data and 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 3.18 illustrates this widget.

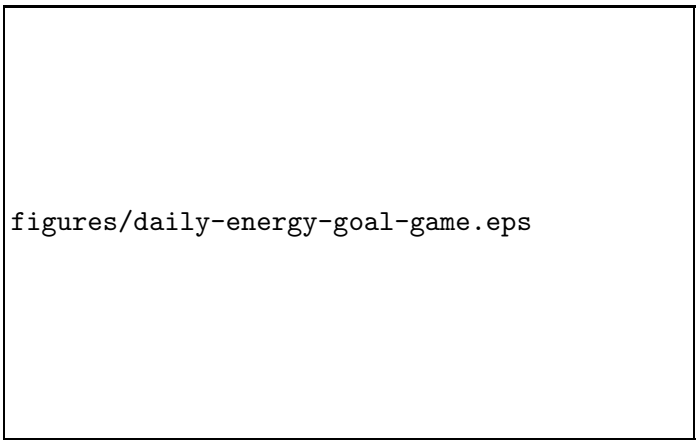


Figure 3.18: *Daily Energy Goal Game widget*

As you can see, this interface uses a stoplight metaphor to show at a glance whether or not the team is making the goal. In this case, the stoplight is green, indicating they are currently below the

goal.

The goal for each team is typically a percent reduction from their baseline usage. When a player goes to the "Go Low" 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.

While the stoplight visualization provides good feedback to a team regarding their current progress toward making the current day's goal, we have found additional perspectives to also be useful.

One useful perspective to a team is a realtime power meter visualization that shows the current power usage of a team, as shown in Figure 3.19.

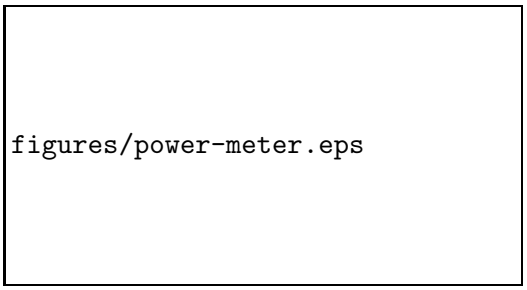


Figure 3.19: *Power Meter widget*

This visualization displays the realtime power consumption which updates in a specified interval. This give players the sense of energy consumption at the moment. For example, someone turns on a high power microwave, they might see a spike in the realtime power meter reflecting the power usage at that moment.

Another useful perspective to a team is a historical, calendar-based visualization that shows the results of the energy goal game for each day of the current round, as shown in Figure 3.20.

This visualization is useful for helping teams to see if there are patterns to their ability to make their goal. The above display shows that they have been making their goal more regularly in the recent past, indicating perhaps that they have identified a useful strategy for conservation.

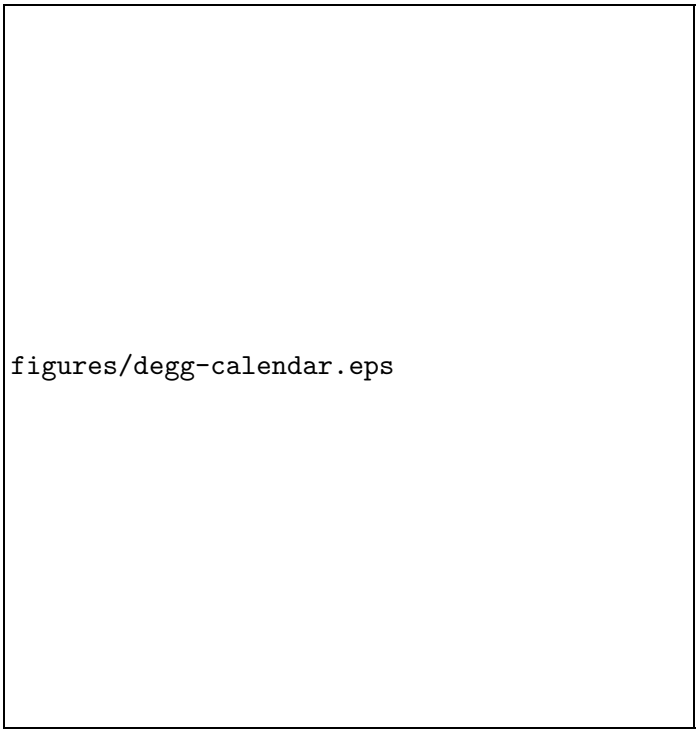


Figure 3.20: *Daily Energy Goal Game Calendar widget*

Yet another perspective of the energy consumption is illustrated in Figure 3.21. It is the Daily Energy Goal Game Scoreboard, which shows how teams are faring relative to each other. It can incentivize teams to conserve not only to earn points, but also to do better than other teams as respective energy consumption. The scoreboard shows that the number of times that a team makes their daily energy goal and the average reduction percentage.

The Daily Water Goal Game is similar to the Energy Goal game, with the only difference is the data, and whether the data is automatically or manually collected. With the installation of smart water meter and the availability of automatic data collection system, all the visualization discussed above will be available to the Water game. Otherwise, the water consumption data have to be manually input daily. In this case, the hourly Water Goal Game widget and the near realtime Power Meter widget will not be available to the players, while the daily water scoreboard widget and calendar view widget will be available.

Figure 3.21: *Daily Energy Goal Game Scoreboard*

3.3.2.3 Smart Grid Game

Smart Grid Game (SGG) is Makahiki's approach to support "gamified" delivery of educational experiences. It is the primary place players go to learn about sustainability issues and earn points. Educational actions are organized into a grid of squares (hence the name "Smart Grid") and organized by category columns and levels. Players use its grid interface to discover "actions" they can perform. Successful completion of an action earns the player a variable number of points depending upon the difficulty of the action, and can potentially "unlock" additional actions and higher levels in the SGG. Figure 3.22 shows a typical Smart Grid Game interface for players:

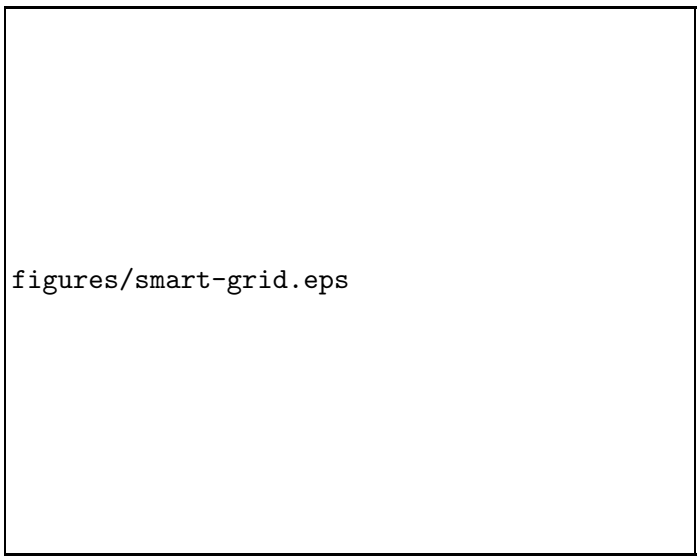


Figure 3.22: *Smart Grid Game widget*

There are three types of actions in the grid:

Activities are the most basic action available in the Smart Grid. In order to get points for an activity, a player must input a response to the system, which is reviewed and approved or disapproved by administrators. These responses can be a short textual answer or an uploaded picture. If a submission is approved, the player receives the points for their submission. Otherwise, the system notifies the player that their submission was not approved, along with a comment (written by an administrator) explaining why it was rejected. The player can change and resubmit their response and still earn the full point value for that task.

Most activities have fixed rewarding points if completed. Creative activities are special kind of activities that worth a variable number of points, which depends on the effort made by the player and the quality of the outcome submitted. It is judged by the administrators. These activities enable players to exercise their artistic talents.

Commitments are pledges that the player will carry out a specific action for a specific amount of time (typically 5 days). Examples include: reducing shower time, taking the stairs, and turning off the lights when leaving a room. Unlike activities, commitments are not easily verifiable, and so they are usually designed with fewer points than activities. Furthermore, a player can only enter into five commitments at any given time. After the commitment period is up, the player can declare that they completed the commitment and immediately earn the associated points. They can then enter into another commitment, including the one they just completed.

Events are actions tied to real world meetings. To help organizers gauge interest in events, players can earn points by signing up in advance. Players that do this (and then actually attend the event) earn a signup bonus (typically 2 points). Players can also set up a reminder that is sent to their email and/or their mobile phone before the meeting takes place. At the event, a challenge administrator provides players with "attendance codes" printed on slips of paper that can be later entered in the system by the player to get their points. (The paper slips provide a form of verification that the player physically attended the event.) Attendance codes are generated by Makahiki and can only be used once. To discourage players from signing up and not attending, a penalty (typically 2 points) is assessed 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.

To make your SGG more interesting to players, and more pedagogically sophisticated, Makahiki supports the definition of "*Path*" through the educational content or actions. In most cases, when a new player sees the SGG for the first time, there should only be a few actions available to them possibly only one. All of the rest should be locked. Makahiki provide a set of predicates that can be used to define the "path". The predicates determines if an action or level is locked or unlocked for a player, which in term depends on the outcome of another action or multiple other actions. 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.

To incentivize players to work together during a challenge, Makahiki also supports "*Social Bonus*". The social bonus is an optional attribute of any Smart Grid Game action which awards extra points if the player has done the action with someone else. Examples of actions which commonly include a social bonus are: attending an event, recording a song related to energy, or measuring a shower water flow rate. When a player submits a response for a action that supports the social bonus, the player can provide the email address another player who jointly completed the action. Once the other player also completes the task, the social bonus is awarded. Social bonuses are not bi-directional; if the second player does not provide the first player's email address, only the first player will get the social bonus.

Designing the Smart Grid Game is not easy, in fact, it is the most complicated task for a game designer when designing a serious game using Makahiki. Makahiki provides a tool called Smart Grid Game Designer to ease this task. The designer page is accessible only by administrators.

Figure 3.23 shows the basic components of the designer widget interface:

Figure 3.23: *Smart Grid Game Designer widget*

The Designer Widget has three columns, Library Actions, Designer Grid, and Palette.

The Library Actions Column holds a library of Activities, Commitments, and Events. The

Library is a reusable set of actions for a sustainability serious game. These actions are divided into three tabs, Activities, Commitments, Events. They are generic actions without any dates or locations associated with them. You can drag these library actions into the Designer Grid. If the Action is an Event you will be asked to provide the event date and location. After the action is dragged into the grid, you can override any of the attributes of the action to be tailored to the need of a specific instance of the serious game challenge.

The grid that the Smart Grid Game Designer creates is called "draft". Designers can adjust the Designer Grid, adding or removing actions, columns and levels and players will not see the changes until they are published. Multiple drafts can be created by saving the current grid to a different name. Multiple grids allow human game designers to explore different layouts and paths through the Smart Grid Game. Once the designer is satisfied with the draft grid, he can click the "publish draft" button to update the live Smart Grid Game that players will see.

The Smart Grid Game Designer also includes a Grid Consistency Checker (GCC) Tool. Because the complexity of grid, especially the interdependency (specified by the predicates) of the grid actions, a draft grid often contains errors and inconsistency. The GCC will be automatically run when the "publish the draft" button is pressed and display all the potential errors in the grid. Users should modify the draft to fix any errors found by GCC in order to successfully publish to the live smart grid game.

Figure 3.24 shows a list of items that checked by the GCC tool.

Figure 3.25 shows the action dependency tree that is inspected by the GCC tool.

Figure 3.24: *Grid Consistency Checker Widget*

Figure 3.25: *Action Dependency Tree*

3.3.2.4 Top Score Game

The Top Score Game enables you to design a challenge in which prizes are awarded to individuals and teams who earn the most points during the challenge (and/or each round in a challenge). It also enables you to award prizes to the teams that conserved the most energy (or some other resource such as water) during the challenge (and/or each round in the challenge).

The Top Score Game includes both a Leaderboard widget (Figure 3.26) that shows the top players/team in contention for each round, and a Prizes widget (Figure 3.27) that shows the prizes for for each round and the current team/individual in line to win them.

Figure 3.26: *TopScore Game Scoreboard*

Designers can configure the prizes for a particular challenge by using TopScore Game configuration on the "Settings" page. Figure 3.28 shows the interface to specify a prize for the challenge.

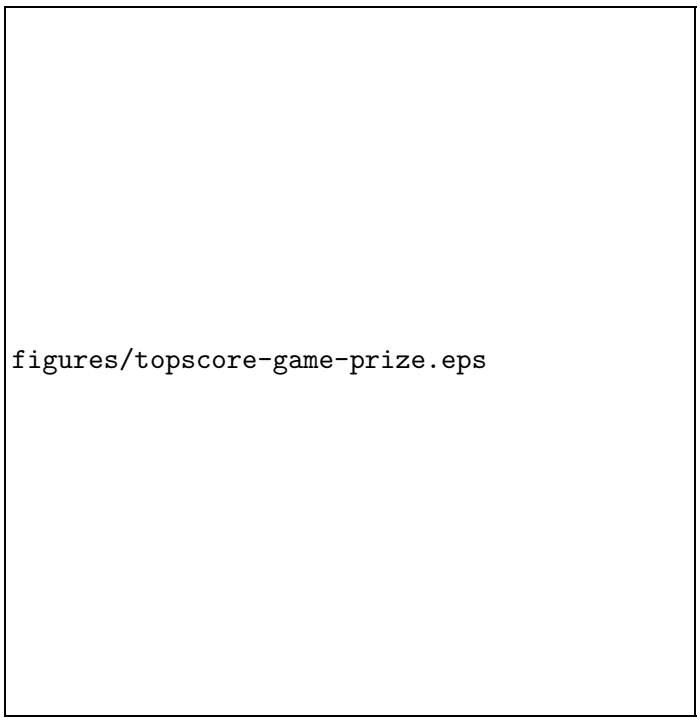


Figure 3.27: *TopScore Game Prizes*

Figure 3.28: *Specifying a TopScore Game Prize*

3.3.2.5 Raffle Game

The Raffle Game was designed to solve the problem of incentivizing players who cannot hope to be a top competitor in the Challenge. When several hundred players are competing, only a handful have a realistic chance to be the top scorers for a round. Once a player knows they cannot beat all of the other players, there can be an urge to simply give up.

The Raffle Game is designed to enable all players to have a chance to win a wide variety of prizes, where their odds of winning increase based upon the number points they have earned in the game; thus incentivize participation from all individuals, even those who are not in the running for a top prize. Figure 3.29 shows an example of the Raffle Game.

Figure 3.29: *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.

The Raffle Game works in the following way. For every 25 points (by default) that 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. 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; allocating a raffle ticket does not affect their rank.

As the screen image above shows, each player can see in real-time how many Raffle Game Tickets they have earned, which prizes they have allocated them to, and the resulting percentage chance they have of winning based upon the tickets allocated by others to that same prize. Of course, these odds can change on a moment-to-moment basis as players allocated and deallocated tickets.

The Raffle Game, in addition to providing an incentive for the non-top players to earn points, also creates an incentive for players to come back to the site on a regular basis to see the updated odds associated with their choices.

Designers can configure the raffle prizes for a particular challenge by using Raffle Game Configuration link on the "Settings" page. Figure 3.30 shows the interface to specify a prize for the challenge.

Figure 3.30: *Specifying a Raffle Game Prize*

The "Winner" of the raffle prize is randomly picked by the system at the end of the round. At the end of the page, you can also see a list of users that allocated raffle tickets for this raffle prize.

3.3.2.6 Participation Game

One of the design constraints of the sustainability serious game such as the Kukui Cup challenge is that, the players associated with each team in a challenge must be specified in advance of a challenge. Thus, as the challenge runs, it is possible to know exactly what percentage of each team's players are actively playing the game (in the sense that they have logged in at least once).

The Participation Game is designed to incentivize active players on a team to recruit other members of their team to login and try the game. It does this by providing extra points to all active players on a team when the percentage participation by that team reaches certain thresholds (currently 50, 75, and 100).

The current percentage participation by a player's team is shown in a scoreboard, as shown in the Figure 3.31. Players will receive an in-game notification whenever they reach a threshold participation where points are awarded.

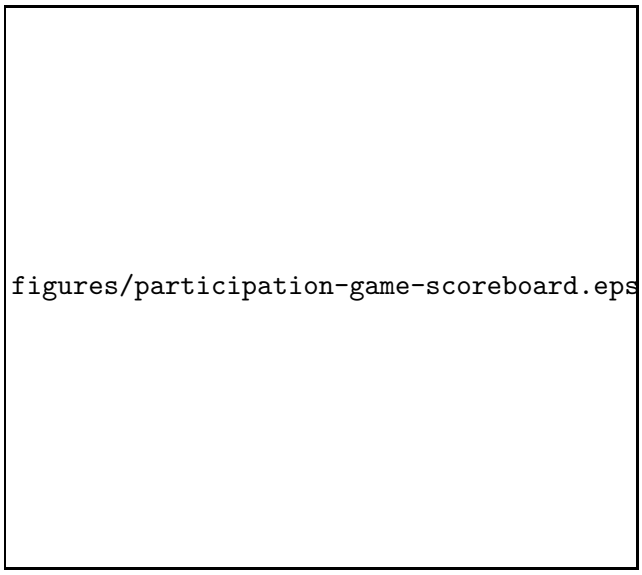


Figure 3.31: *Participation Game Scoreboard*

To configure the participation game, click on the "Participation Settings" link in the Participation Game Admin widget on the "settings" admin page. Figure 3.31 shows the settings of the participation game. You can change the points to award for each participation percentage. Currently, the percentages (50, 75, and 100) are hardwired into the system.

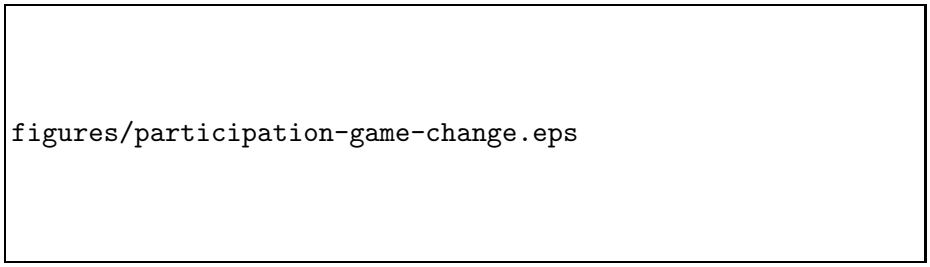


Figure 3.32: *Specifying a participation Game Settings*

3.3.2.7 Quest Game Mechanics

One fundamental challenge faced by any game is: how do players learn how to play it? This is generally known as the on-boarding problem. Makahiki provides a configurable "Quest Engine", that enables the definition of quests and the dependencies among them. That enables site developers to create a kind of structured, proactive user guide for the system. Instead of stumbling on a random playable feature of the game, players learn about the capabilities of the site by performing discrete sequences of actions, call "Quests".

Quests are made available to the player in a collapsible/expandable window right below the navigation bar. The set of Quests shown to a player can depend upon their game state, so that "simple" Quests can be presented initially and more "complicated" Quests presented as the player gains in expertise. Quests generally guide the player through the various workflows of the Challenge, such as completing a task, signing up for an event, or allocating a raffle ticket.

The system shows a maximum of three Quests at a time. Figure 3.33 shows an example of an expanded quest and its content. Once the player accepts the quest, and follows the instruction to complete the quest, the notification dialog box will appear to the player indicating the accepted quest had been completed. A new potentially harder quest will appear in the quest window replacing the completed quest.

Quests are created by the administrator prior to the Challenge. Administrators have the option of specifying a set of predicates to determine when the player could be shown a Quest and when the player has completed the Quest, and it should no longer be shown.

Designers can configure the quests for a particular challenge by using Quest Game Mechanics

Figure 3.33: *Quest Game Mechanics*

Configuration link on the “Settings” page. Figure 3.34 shows the interface to specify a quest for the challenge.

Figure 3.34: *Specifying a Quest Game Mechanics*

3.3.2.8 Badge Game Mechanics

Makahiki provides the badge game mechanics to motivate and engage players. The badge mechanics is implemented in a customizable way so that game designers can create as many badges as they like. Each badge can be triggered by the achievement of a certain award condition, which is defined by the flexible predicate system in Makahiki.

Badges are a common game mechanic, in which players receive recognition for various accomplishments. Makahiki allows the challenge designer to specify the set of badges available in a challenge, and to define new ones. The challenge designer has the option of making badges worth points. Finally, the designer can use the Makahiki predicate system to award a badge automatically (for example, when a player has completed a Level in the Smart Grid Game), or manually award the badge through administrator action (for example, when a player reports a significant bug in the system).

In many systems, each badge has a custom design, but in Makahiki, we decided that the overhead of providing a custom graphic for each badge outweighed the benefits. Providing a custom graphic also would creates complexity with another feature of Makahiki: the ability to create "themes" with different colors. To be consistent with the themes in Makahiki, badges have a common look and feel consisting of a circle and a multi-character ID. Its actual colors are specified by the theme, and can thus vary from theme to theme.

Figure 3.35 shows an example of the badges available in the Makahiki system:

Designers can configure the badges for a particular challenge by using Badge Game Mechanics Configuration link on the "Settings" page. Figure 3.36 shows the interface to specify a badge for the challenge.

Figure 3.35: Badge widget

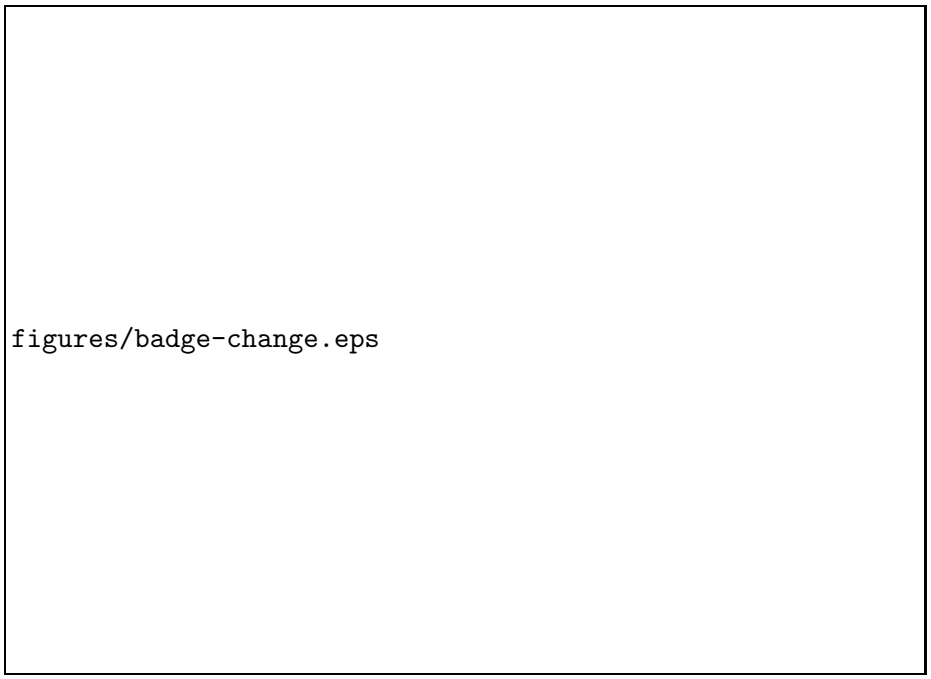


Figure 3.36: *Specifying a Badge Game Mechanics*

3.3.2.9 Referral Bonuses Game Mechanics

Similar to social bonus described in the Smart Grid Game above, the Referral Bonus is 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.

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.

When enabled, the referral bonus is implemented as a step in the first login process, as shown in Figure 3.37.

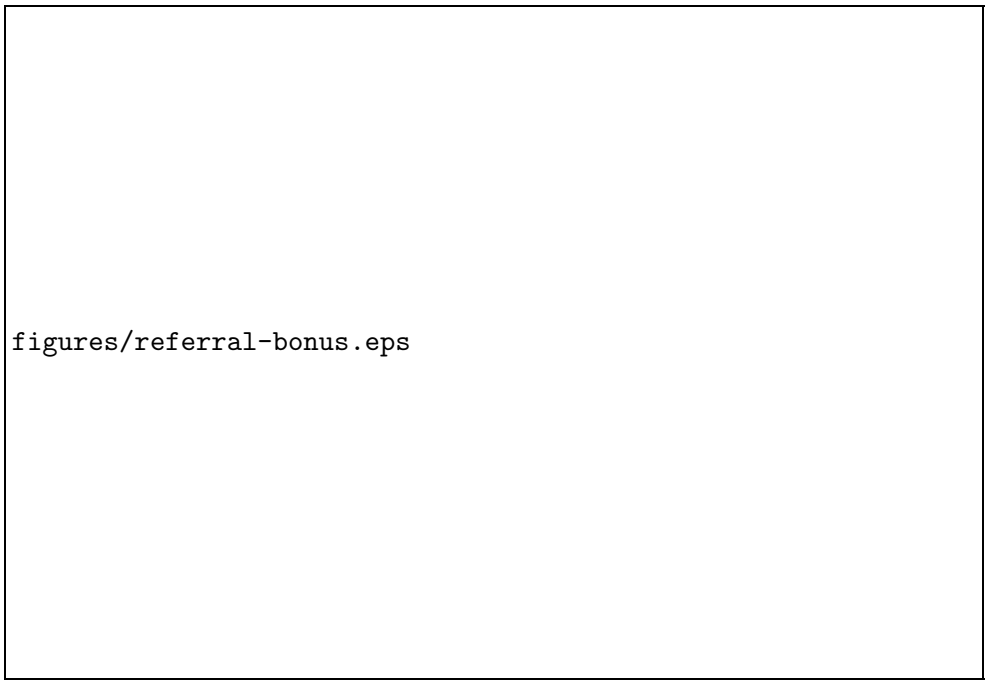


Figure 3.37: *Referral Bonus Game Mechanics Widget*

If the new player was referred to the challenge by another player, they can use this step to

input their email address. Once the new player earns 30 points in the competition, both players are awarded a referral bonus of (typically) 10 points. Typically, going through the setup process gives you 25 points, so a threshold of 30 points means the new player has to complete at least one additional task in order to get the referral bonus.

You can disable the referral game mechanics by clicking on the "Referral Game Mechanics" link. If referral game mechanics is disabled, then this window is omitted from the first login wizard and players will not be able to get points by referring other players.

The referral bonus also has a "dynamic bonus" capability. If enabled, then you can vary the amount of points awarded depending upon the participation level of the team associated with the new player. This incentivizes players to not just recruit new players for their own team, but to also recruit players for other teams who might not have much participation.

If the referral game mechanics is enabled, which is true by default, you will see the "Referral settings" link in the Game Admin widget. After clicking on the "Referral Settings" link , You will see the overview of the referral settings, clicking on any of the links, will bring you to a page (Figure 3.38 to change the settings:

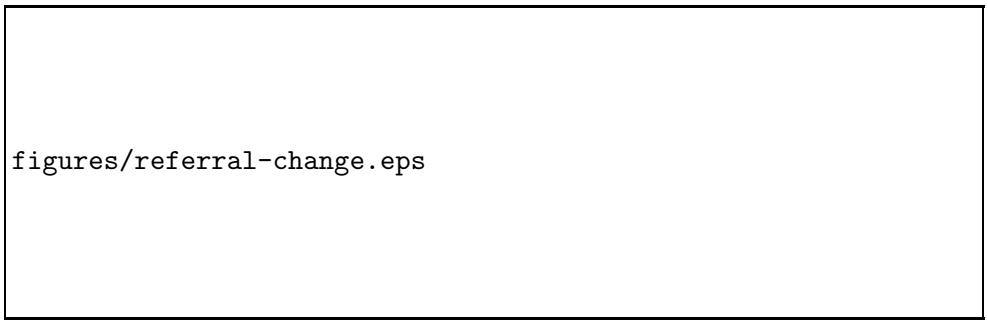
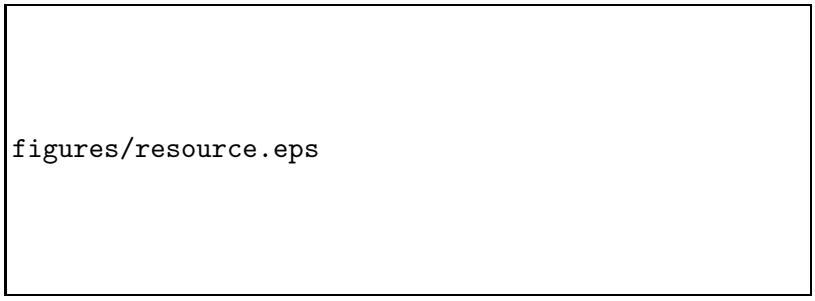


Figure 3.38: *Changing the Referral Bonus Game Mechanics Settings*

By default, only the "Normal" referral points value is used. If you check the "Start dynamic bonus" setting, then the "Super" and "Mega" values are enabled depending upon the team participation rate of the new player.

3.3.3 Configurable resource

In Makahiki, different resources can be tracked and configured. The admin interface is built in to support the configuration of different resources. Makahiki supports three kinds of resources: energy, water, waste, which have different attributes. Some resource data can be obtained automatically from smart meters, while some resource data has to be input manually. In the case of manually data entry, the time of manual entry can be configured as well. Figure 3.39 shows the Makahiki admin interface to configure the resources.



(a) Supported resource types

(b) Manual resource

Figure 3.39: Configurable resource

Makahiki supports both automated and manual data collection. With respect to automated energy collection, Makahiki queries a WattDepot server once an hour to get an update on each team's

consumption during the previous hour, and then updates the stoplight visualization. At midnight, Makahiki determines whether the conservation goal was achieved by the team and updates the calendar-based view with the results for that day.

However, not all challenge player communities have meters that are internet-accessible and thus allow this kind of real-time, automated update. Instead, they might have a traditional, analog meter.

The Energy Goal Game can be configured to support manual data collection. To accomplish this, the challenge designers must first tell the system the time each day at which they will read the meters manually. (To make the energy goal game workable, the challenge designers must commit to reading the energy meters for each team at approximately the same time each day so Makahiki can assume the data represents equal, 24 hour intervals. Team meters can be read at different times, but the time must be consistent for each team.)

Then, each day during the challenge, the challenge designers read the meters, then login to the system and update Makahiki with the latest readings. From this, Makahiki can determine which teams made their energy goal for the previous day.

From a user interface perspective, the basic difference is that the stoplight visualization is not available. Instead, the primary interface to the Energy Goal Game is the calendar-based visualization, which shows the results for each day.

Once we had support for both automated and manual energy data collection, we could also support Water Goal Games, Food Goal Games, Waste Goal Games, or any other "resource" for which teams are responsible. Currently, Makahiki provides built-in support for two resource goal games: energy and water. Each of those games, when enabled, results in a page devoted to that resource in the web application. The default configuration enables support for the Water Goal Game and the Water page.

Extending Makahiki to support an additional resource goal game is straightforward, but requires developer-level capabilities.

3.3.4 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 3.40 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.

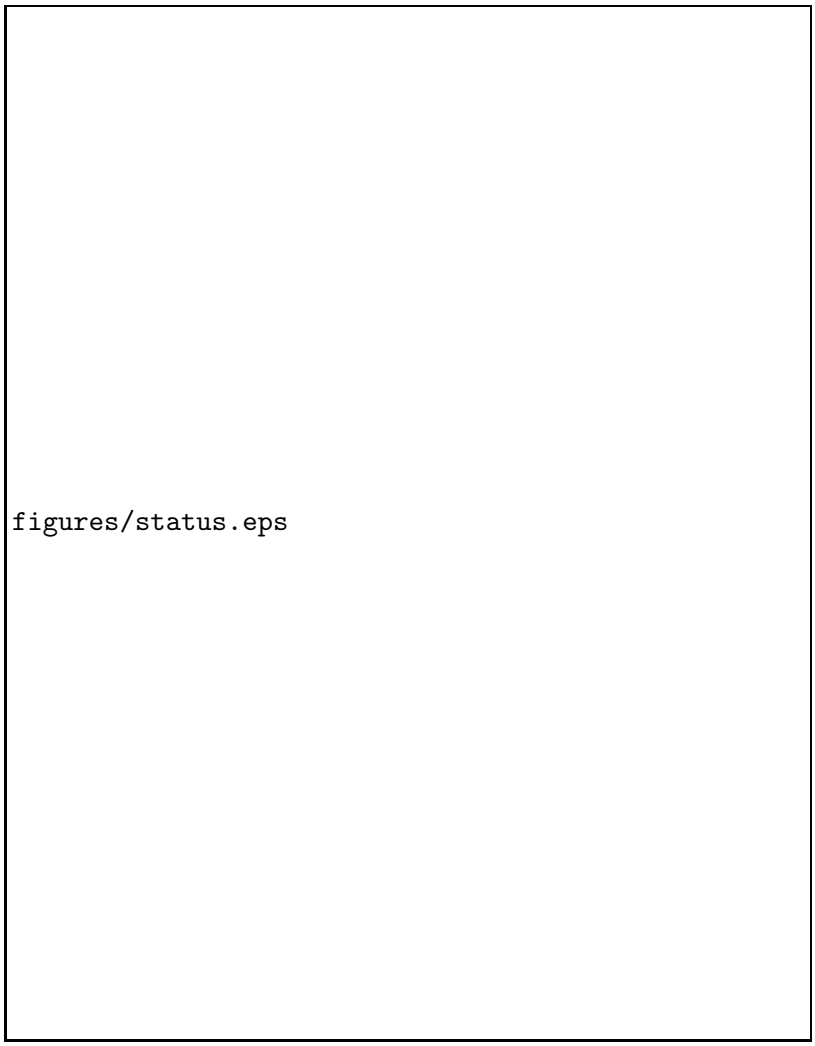


Figure 3.40: Game analytic widgets: User Stats and Energy Goal Status

3.3.5 Responsive mobile support

We believe that mobile support is essential for this kind of sustainability challenge, especially for the new generation players. Makahiki implemented responsive web design technology to support multiple devices to enhance the player experience. Figure 3.41 shows the responsive interface in Makahiki that supports both desktop view and mobile view with the same code base.

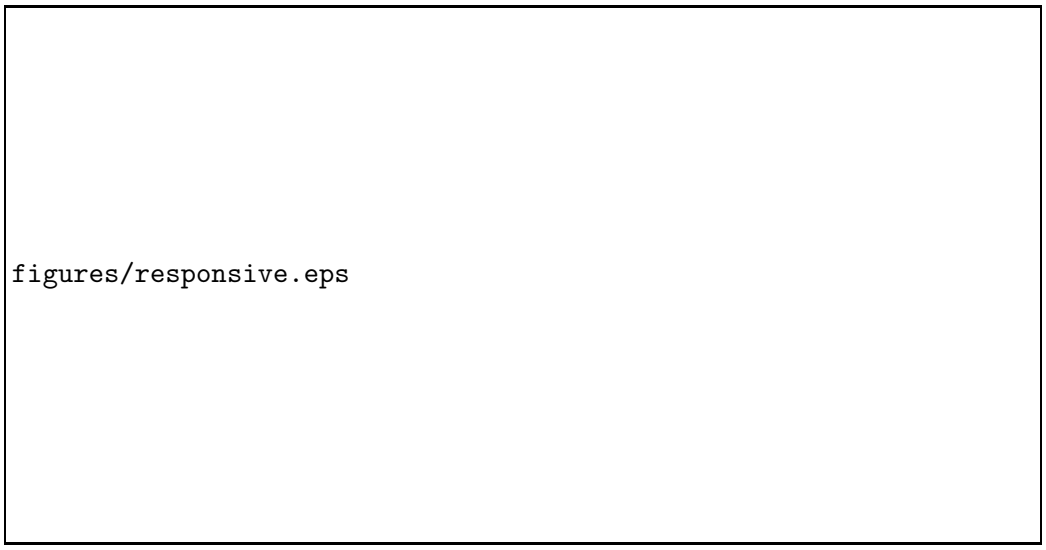


Figure 3.41: Responsive design supports both desktop and mobile

3.3.6 Cloud deployment support

Another feature we implement in Makahiki is the ability to deploy to a Cloud platform. Cloud computing has the advantage of simplify IT administration by eliminating the need of acquiring the hardware, installing software etc, thus lower the cost of the software deployment. Figure 3.42 shows a screen shot of the Dashboard showing the 2012 East West center Kukui challenge deployed in the Heroku, one of the cloud platform provider. The monthly cost for the IT infrastructure in this instance is fairly affordable.

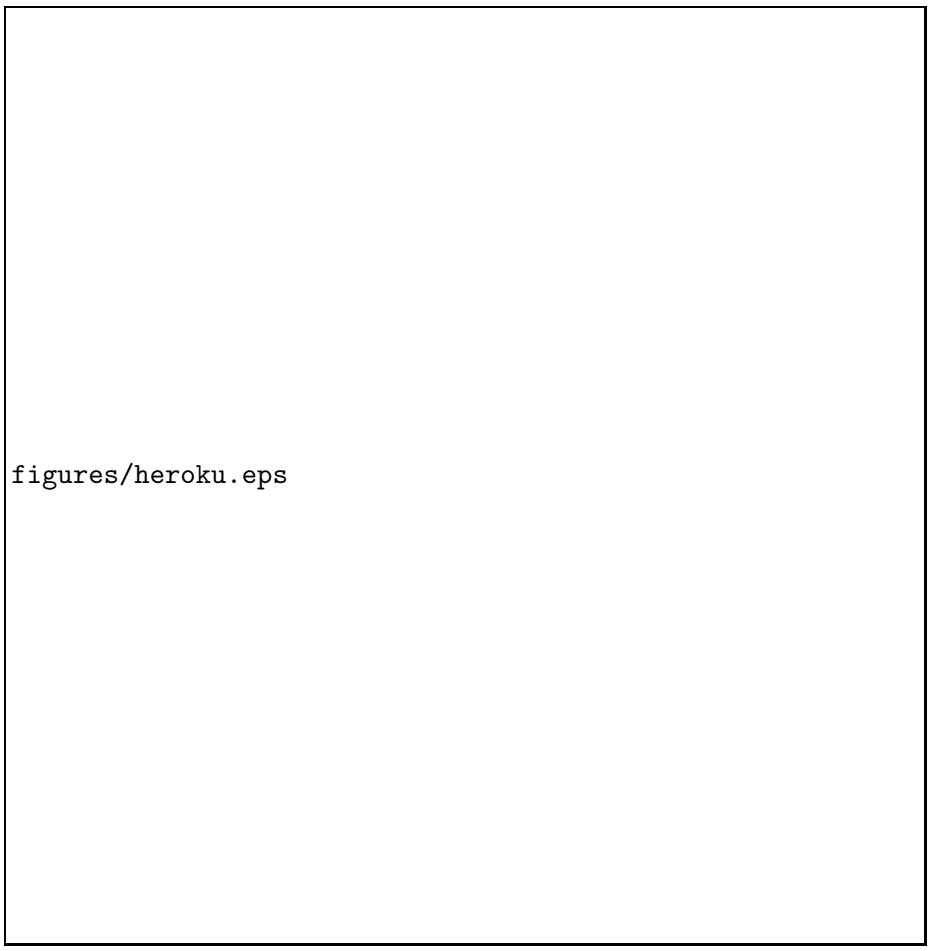


Figure 3.42: Heroku cloud deployment

3.3.7 Customization and Extension Development Support

Makahiki, as a framework, provides facilities to help developers to create customization and extension to fit different requirements from organization. The following section describes the two customization that can be implemented by developers through minimum programming.

3.3.7.1 Theme Development

A "theme" in Makahiki consists of a specification of the background image (or color), as well as with the background and font colors for various structural elements of the system. Players have the ability to select themes from the Profile page, making it unnecessary to develop a "perfect" theme for your challenge. Figure 3.43 shows the widget that a player can change the theme they like the best for their personal website feel.

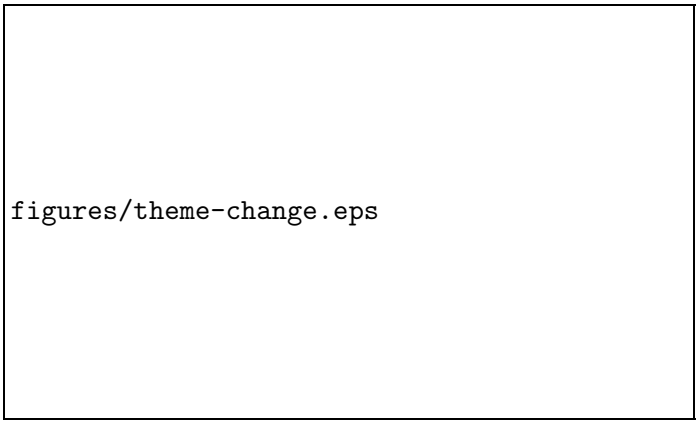


Figure 3.43: Change the Website Theme

Makahiki provides a set of pre-built themes for players to choose from. Figure 3.44 lists all the installed themes in Makahiki. These installed themes will show up in the "Theme" drop-down that can be selected by a player as shown in Figure 3.43.

Figure 3.44: Makahiki Pre-Built Themes Defined in settings.py

Makahiki, as a framework, allows developers to create additional themes. Makahiki's themes are implemented using LESS, which is the enhanced version of CSS that supports variables and

other capabilities not available in standard CSS. There is no need to know about LESS in order to create Makahiki themes. Most developers should be able to create themes simply by copying and editing a pre-existing theme file and changing some of the LESS variables in the new file. All the theme files are located in the "makahiki/static/less" directory. Most of the times, a theme developer only needs to pick the color for the theme and specify which color he want for a specific UI elements in the LESS file. Figure 3.45 shows a snippet of the theme-google.less file.

Figure 3.45: theme-google.less Defines the Google Theme

Once the theme file are created, it should be included in the "INSTALLED_THEMES" section in the settings.py file as shown in the previous Figure 3.44. To see the results of the new theme, Makahiki provides a special page called theme-display. The developer can use the browser to go to this page to test all of the theme-able elements in a single page. Figure 3.46 illustrates the result of the new theme.

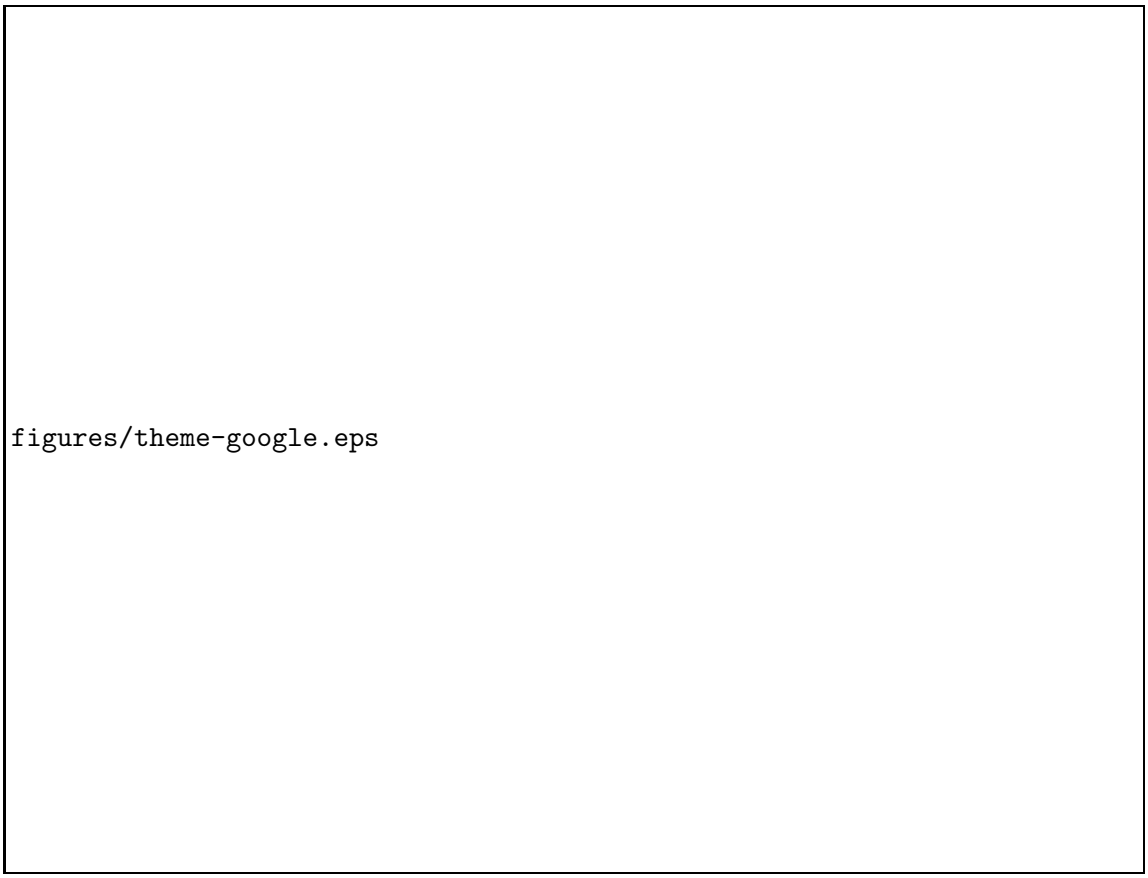


Figure 3.46: The Result of theme-google.less

3.3.7.2 New Game Widget Development Support

As discussed before, Makahiki includes a set of pre-built game and game mechanics widgets for game designers to select and configure for their serious game challenges. In some cases, game designers may wish to implement additional games or mechanics and integrate into the Makahiki system. It is achievable by the new game widget development support from the Makahiki framework. It is done in the programming level by developers. As we know that Makahiki is developed using Python and the Django web application framework, in order to develop new games, programming knowledge of Python and Django is required. This is unlike the theme development where there is no need to know LESS or any programming,

Developing a new widget for Makahiki includes the following four steps::

The **First Step** is to create the new widget package structure. Makahiki provides a command line tool called "startwidget" integrated into the standard Django manage.py utility. It is the easiest way to create the basic file structure for a new widget . Figure 3.47 illustrates the command to create a hello_world widget and the base files and directory structure that are created by the tool.

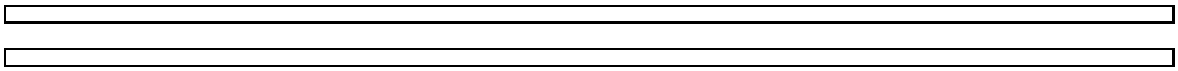


Figure 3.47: Makahiki Tool for Creating a New Widget Structure

The command creates a directory named after the new widget in the directory "apps/widgets", and four files underneath:

- *__init__.py*: this file indicates that the directory is a Python package.
- *views.py*: this file implements the widget logic and provide data to the UI.
- *index.html*: this file defines the UI that displayed to players.
- *tests.py*: this file provides the skeleton of the unit testing for the new widget.

These files are the starting points for building a new widget. The subsequent steps describe their usage in details.

The **Second Step** is to implement the logic of the widget and provide the data for display. It is done in the views.py by calling the Application Programming Interfaces (APIs) provided by Makahiki.

Makahiki API provides a generic mechanism for supply data for display. When the player loads a page, the Makahiki module "**apps.pages.views.index**" is called. This module determines the name of the page dynamically and creates a Python dictionary, called "**view-objects**". From the page configuration, it determines which widgets are enabled for the given page. It then loops over each widget and calls their "**apps.widgets.widget_name.views.supply**" function. So the entry point for the widget is the supply function in its views.py file.

The startwidget command provides the empty supply function in the views.py it created, as shown in Figure 3.48.

Figure 3.48: supply function template provided in the views.py

A developer needs to fill in the supply function to provide the data. Makahiki also includes a library of manager modules that provide the APIs to interact with the system. Table 3.2 lists all the manager modules and their functionality.

For illustration purpose, the hello_world widget will display three kind of data obtained from the Makahiki system. One is the name of the player, which is stored in the name attribute of profile object. The second is the name of the team the player belongs to. It is stored in the team attribute of the profile object. The third data is the current point score of the player. It can be retrieved from calling the function "player_points" in the "score_mgr" module. Figure 3.49 shows the complete example of views.py for hello_world widget.

Figure 3.49: An complete example of views.py

The **Third Step** in create a new widget is to define the UI component. It is done in the index.html under the templates directory. Figure 3.50 shows the base index.html created by the startwidget command.

Figure 3.50: The base index.html

Makahiki provides many different styles and CSS classes. Normally, widgets are contained in a content-box . The context-box is a rounded, shaded box with two parts, content-box-title, and content-box-contents. A developer can replace the "Widget name" in the title box and the "Widget content" in the content box, to display the data provided from the views.py. A complete example of the index.html file of the hello_world widget is shown in Figure 3.51. The data provided from the views.py are referenced by the convention of "**view_objects.widget_name.variable**".

Figure 3.51: An complete example of index.html

Finally, the **Fourth Step** for developing a new widget is to add the widget to a page. In order for a new widget to be available to the system, you need to edit the Makahiki "settings.py" file and add the widget name to the INSTALLED_WIDGET_APPS variable. Figure 3.52 shows a portion of the settings.py file after adding the new hello_world widget.

Figure 3.52: Add the new widget to settings.py

This last step makes the newly developed widget available to the Makahiki system. It concludes all the steps a developer needed to create a new game widget. Once it is available to the system, a game designer will be able to add the widget to an existing page using the admin interface.

The "Page Settings" link in the admin interface is used to configure the widgets in a page. Figure 3.53 shows the hello_world widget being added to the existing Profile page.

The hello_world widget is added to the left side location with the priority set to "1", which indicates that the new widget will be displayed first and before the "My Info" widget (priority 2) on the left side column on the page. The widget will also need to be enabled by checking the "enabled" checkbox. Figure 3.54 shows the final result of the hello_widget displayed in the Profile page.

Figure 3.53: The Hello World Widget added to the Left column

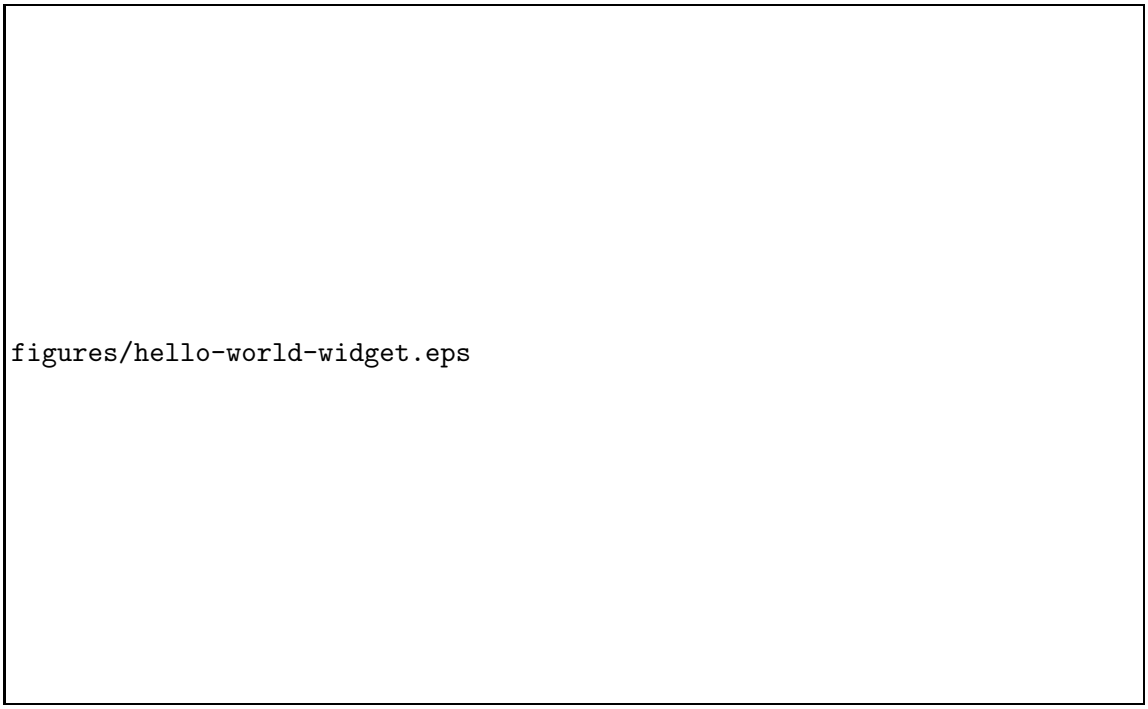


Figure 3.54: The Hello World Widget Displayed in the Profile page

CHAPTER 4
SGSEAM DESIGN

This chapter describes the design of the Serious Game Stakeholder Experience Assessment Method (SGSEAM) for assessing serious game frameworks. It starts with an overview of SGSEAM, followed by a discussion of assessment methodology, and the detailed steps of the assessment method. Finally, Appendix D illustrates an example of an SGSEAM assessment guide written for a specific serious game framework.

4.1 Overview

One of the benefits of using a serious game framework such as Makahiki, is that if correctly designed, it will provide useful and reusable "building blocks" with which to develop a variety of serious games. Yet how are we to know if a serious game framework has been "correctly designed"? As we discussed in the Related Work, there are a few tools for general purpose assessment of software systems, but I have not yet found any prior work concerning the comprehensive approach for the particular needs of a serious game framework assessment. This is the motivation for the Serious Game Stakeholder Experience Assessment Method (SGSEAM). It is designed for assessing serious game frameworks in particular.

Serious Game Stakeholder Experience Assessment Method (SGSEAM) describes a method for assessing serious game frameworks from the stakeholder experience perspective. 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 emulate, and (b) major shortcomings of the framework, which aids the community by indicating features to avoid. The benefits of SGSEAM assessment are for the developers of serious game frameworks to learn and improve from the findings of the assessment.

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. They include content experts, instructional designers, etc.
- **Game managers**: those who manage the game during the period of game play.
- **Game Developers**: those who use the game framework to customize, extend and enhance their games.
- **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 data collection if the serious game requires data, 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 only assesses the experiences of the players, system admins, game designers, game managers, and game developers, because these are the stakeholders whose perspectives impact on the software infrastructure.

Figure 4.1 illustrates the steps required to apply SGSEAM to a framework.

There are three steps in the process of applying SGSEAM:

1. Step one is to **Plan the assessment**, including identifying the stakeholders, determining assessment approaches, and creating the assessment schedule. The deliverable for this step is the ***assessment plan*** document.

Figure 4.1: Applying SGSEAM to a framework

2. Step two is to **Gather data** by carrying out the assessment, recording and obtaining related data. The deliverable for this step is the assessment ***data repository***.

3. Step three is to **Produce the assessment report** by analyzing the data and interpreting strengths and weaknesses. The deliverable for this step is the ***improvement action*** document.

The following sections describe the methodology used in SGSEAM, followed by the detailed description of steps in applying SGSEAM to serious game frameworks.

4.2 Methodology

SGSEAM is an assessment method instead of an evaluation method. The main purpose of an evaluation is to determine the quality of a program by formulating a judgment. An assessment, on the other hand, is nonjudgmental. SGSEAM does not try to judge a framework according to a standard, or to compare one framework against another. Instead, it is used to identify the major strengths and shortcomings of a framework to benefit the developers of the framework.

Creswell [21] 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 methods reflect a post-positivist paradigm where hypotheses are specified *a priori* and tested by experimental design. Qualitative methods reflect a constructivist or participatory paradigm where knowledge is acquired by observation and open-ended design. SGSEAM employs the mixed methods approach which is based on pragmatic knowledge claims and the as-

sumption 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 described in Creswell's 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).

SGSEAM shares much in common with the "Goal-Question-Metric" (GQM) approach [14] 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. As there are many metrics related to user experiences [82], SGSEAM focuses on the metrics that are useful to provide insights about the strengths and weaknesses of a serious game framework.

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 are described.

4.3 Plan the Assessment

This is the first step of SGSEAM. It first identifies the stakeholders, determines the appropriate assessment approaches according to the available resources, and creates the assessment schedule. The deliverable for this step is the assessment plan document which includes the details of stakeholders, approaches and schedule.

4.3.1 Identify stakeholders

SGSEAM assesses the experiences for the stakeholders listed in Table 4.1.

For each stakeholder, identify the population, the name and contact if possible. For example, the player stakeholder can be identified as the users interact with the game interface, perform certain tasks given by the interface, or winning the prize. The system admins install, backup, monitor the software system. The game designers create the content for the game and design what game

Stakeholder class	Definition	Examples
Player	participate in the game produced by the framework.	students, residents
System admin	install and maintain the technological game infrastructure.	system admin, IT staffs
Game designer	design the content and game mechanics.	instructional designers, content experts
Game manager	manage the game during the period of game play.	sustainability coordinators, residential staffs
Game developer	develop customization, extend and enhance the game.	programmers, internal developers

Table 4.1: SGSEAM Stakeholders

mechanics to used. The game managers manage the game during the game period. Finally the game developers develop enhancements and perform customization using APIs provided by the framework.

It is important to be able to contact the stakeholders in some way, either via email or phone, to get the feedback from their experiences with the framework.

4.3.2 Determine assessment approach

There are usually multiple assessment approaches for each stakeholder. Table 4.2 provides an overview of the assessment method and the approaches. The appropriate assessment approaches should be determined according to the resources available. The approaches for a stakeholder are assumed to be additive. The more approaches applied, the higher one's confidence in the accuracy of the assessment results.

The assessment approaches is divided into in-vivo and in-vitro assessments. The in-vivo approaches, such as pre-post test, in-game surveys and post-hoc interviews, assess a real world instance of the game. The in-vitro approaches use in-lab experiments in a simulated environment. Different assessment approaches will have different levels of rigor or validity. For example, the in-lab experiments (in-vitro) can enlist several subjects to perform the same pre-defined tasks and collect comparable data in a more controlled setting. It is rigorous because of the generality achieved from the larger population of participants under study. On the other hand, in-game surveys or interviews in the in-vivo approach typically collect data from different uncontrolled settings with

Stakeholder	Assessment goal	Assessment approaches
Player	Determine the extent the framework affect and engage players.	Pre-post effectiveness study(4.3.2.1.1); Self-reported usability survey(4.3.2.1.2); Engagement metrics(4.3.2.1.3)
System admin	Determine strengths and weaknesses in system install and maintenance.	Post-hoc admin interview(4.3.2.2.1); In-lab system admin study(4.3.2.2.2)
Game designer	Determine strengths and weaknesses in facilitating the game design process.	Post-hoc designer interview(4.3.2.3.1); Game design log data analysis(4.3.2.3.3); In-lab game design study(4.3.2.3.2)
Game manager	Determine strengths and weaknesses in managing the game.	Post-hoc manager interview(4.3.2.4.1); Management log data analysis(4.3.2.4.3); In-lab game management study(4.3.2.4.2)
Game developer	Determine strengths and weaknesses in developing system enhancement.	Post-hoc developer interview(4.3.2.5.1); In-lab game development study(4.3.2.5.2)

Table 4.2: SGSEAM approaches

less rigor. But the in-vivo data reflect the real world interaction between the stakeholders and the framework, thus providing better insights to the real world settings.

The following sections describe the different approaches for each stakeholder. Each assessment approach describes the goal of the assessment, what data to collect, how to collect the data and how to analyze the data to obtain insights about the strengths and weaknesses of the framework from each stakeholder's perspective.

4.3.2.1 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 achieves 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 increase players' energy literacy and reduce their energy consumption during (and, hopefully, after) the game. A serious game for language learning would have a very different desired effect.

4.3.2.1.1 Pre-Post effectiveness study

We use a quasi-experimental pre-post study to assess the question of the effectiveness of a serious game framework.

This approach requires users of SGSEAM to first determine a set of domain-specific questions to assess the desired effects of their serious game. For example, a set of questionnaires on sustainability literacy, such as knowledge of power and energy, is used to assess the effectiveness of a serious game for sustainability education.

Once the domain-specific questionnaires are determined and designed, present this questionnaires as a survey to a random selection of the players before the game starts. After the game ends, present the same survey to the same players again. Compare the two sets of survey response data to study if the game has an impact on the players regarding the survey subjects. The extent of the changes reflected in the survey result indicates the degree of effectiveness of the serious game for this subject.

Serious games often engage players with resources of various types (energy, water, waste, etc.). Collect these measurements before, during, and after the game in order to acquire evidence regarding the potential impact upon player use of these resources.

4.3.2.1.2 Self-reported usability survey

This approach interviews players about player's self-reported experience with the game. We can administrate the interview through online surveys or face-to-face conversations, although online surveys are typically more cost effective than face-to-face conversation. If possible, implement the online survey as an activity inside the game. For example, the Makahiki serious game framework implements an online survey activity which incentivizes players to complete the survey by rewarding game points for the activity.

SGSEAM provides a generic set of usability questions outlined in Figure 4.2 that can be used in an usability survey:

1. What did you like most about the game?
2. What did you found confusing?
3. What issues did you have while using the game?
4. What was the thing you liked the least about the game?
5. What can we do to improve the game?
6. It was easy to find what I was looking for on the website.
   Strongly disagree - Disagree - Neutral - Agree - Strongly agree
7. The website was responsive.
   Strongly disagree - Disagree - Neutral - Agree - Strongly agree
8. The website provided adequate help in teaching me how to play.
   Strongly disagree - Disagree - Neutral - Agree - Strongly agree
9. I understood how to play.
   Strongly disagree - Disagree - Neutral - Agree - Strongly agree
10. this is something my friends should participate in.
    Strongly disagree - Disagree - Neutral - Agree - Strongly agree

Figure 4.2: Player self-reported usability metrics questionnaires

4.3.2.1.3 Engagement metrics

This approach calculates engagement metrics to assess the extent of engagement from players and the impact of the game. The more engaging the game is, the more potential impact it can have on the 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. On the other hand, 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 diffusion effect can be an interesting research area.

SGSEAM is designed to calculate the player engagement metrics described in Figure 4.3 by analyzing the data from system log or other channels provided by the framework. The more metrics obtained, the better understanding of the extent of player engagement.

The participation rate measures the percentage of users who use the game based on the total number of eligible players. In the serious game context, it indicates the level of involvement or

Metric	Definition	Mesure
participation	percentage of players who play the game	the level of involvement from players
player	number of players per day	the frequency of players interact with the game
play time	play time of a player per day	the frequency of players interact with the game
submission	submissions of all player per day	the rate of players' completion of game activities
social interaction	social interaction of all player per day	the rate of in-game social interactions between players
game error	game errors per day	the rate of errors encountered by players during the game

Figure 4.3: Player engagement metrics

awareness of the issues of interest. The number of players and play time per day measures 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 that happened in the game between the players. Finally, the website errors per day measures the rate of errors encountered by the players while using the game website.

With the exception of the game error metric, the higher value these metrics are, the higher engagement level the game has.

4.3.2.2 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, maintaining the database, backups, and so forth. The goal of system admin assessment is to determine to what extent the framework facilitates the system administration tasks from system admin's perspective. SGSEAM assesses how much time is required to install and maintain an instance of a serious game using the framework and the problems encountered during the system admin process.

SGSEAM proposes two assessment approaches.

4.3.2.2.1 Post-hoc admin interview

This approach assesses the system admin's experience using the post-hoc interview. The system admins are asked about their experience with the framework after they completed the installation and maintenance in the production system. The interview questions are described in Figure 4.4.

1. How much time did you require to install the system and the dependencies?
2. What problems did you encounter when installing the system and the dependencies?
3. How much time did you require to maintain the system?
4. What problems did you encounter when maintaining the system?
5. Did you find it difficult to admin the system? What was difficult?

Figure 4.4: System admin interview questionnaires

The interview should be tape-recorded. Once the interview is completed, qualitative data analysis is performed against the interview data by doing: (1) transcribing the recordings; (2) coding (categorizing) the time and problems or difficulties encountered. These data reveal the strengths, weaknesses and the areas of improvement for the framework.

4.3.2.2.2 In-lab system admin study

This approach assesses the system admin's experience using the in-lab experimental study. First identify a group of participants who have some level of system administration experience. Second, provide instruction on each installation step, ask the participants to install the system according to the instructions, and ask them to record the time spent and problems encountered as they complete each step.

Once the experiment data is collected, categorize the reported problems and correlate with the reported time data to identify the areas of strength (less time spent) and weakness (more time spent and problems or difficulties).

The level of confidence of the above two assessment approaches varies. The experimental study approach is more rigorous 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.

4.3.2.3 Game designer assessment

A game designer uses the serious game framework to design and create a serious game. A serious game framework normally provides tools or interfaces for game designers to facilitate the design of a game. For example, the framework provides interface to configure the game period, set up players, and tools to design individual game elements.

The goal of SGSEAM game designer assessment is to determine the strengths and weaknesses of the framework regarding the game design process. 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 two approaches for game designer assessment:

4.3.2.3.1 Post-hoc designer interview

This approach interviews the game designer(s) after they complete the design of a serious game using the framework in a production system. The interview includes the questions described in Figure 4.5.

1. How much time did you spend to complete each design task?
2. What problems did you encounter?
3. Did you find it difficult to configure? What was difficult?
4. Did you find it difficult to design a specific game? Which one, and what was difficult?

Figure 4.5: Game designer interview questionnaires

The interview should be tape-recorded. After the interview, transcribe the recordings, code and categorize the reported time and problems to identify the strengths and weaknesses.

In addition, if possible, collect system log data related to the game designing tasks, and analyze the logs to find out the time spent and the errors encountered during the game designing tasks. Use the log data to verify the findings from the interview data.

4.3.2.3.2 In-lab game design study

This approach assesses the game designer experience using an in-lab experimental study. First identify a group of participants who are somewhat familiar with the subject domain of the game. Second, provide instructions on each design step, ask the participants to design the game according to the instructions, ask them to record the time spent and problems encountered as they complete each step.

Once the experimental data is collected, categorize the reported problems and correlated with the reported time data to identify the areas of strength (less time spent) and weakness (more time spent and problems or difficulties).

4.3.2.3.3 Game design log data analysis

This approach collects the system log data related to the game designing tasks. When available, the time spent and errors encountered can be queried from the system logs. Although this system generated data might be easier to gather in some systems, it might not provide the same depth of insight than the other two approaches where the experiences are provided by the participants directly. On the other hand, this system data can be supplemental to the other approaches. They can be correlated with the data gathered from the other assessment approaches to increase the confidence of the assessment.

4.3.2.4 Game manager assessment

A game manager uses the serious game framework interface to manage the serious game that the game designers created. It is possible that a game manager is also the game designer. The examples of game management tasks includes managing player submissions, monitoring the game state, entering manual resource data, notifying winners of the game, etc.

The goal of SGSEAM game manager assessment is to determine the strengths and weakness of the framework regarding the game management process. Similar to the assessment of the game designer, SGSEAM assesses the game manager stakeholder regarding the time it required to manage an instance of a serious game using the framework and the problems encountered during the

managing process.

SGSEAM proposes two approaches for assessing the game manager's experience.

4.3.2.4.1 Post-hoc manager interview

This approach interviews the game manager(s) after they have finished managing a serious game using the framework in a production environment. The interview questions are described in Figure 4.6.

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

Figure 4.6: Game manager interview questionnaires

The interview should be tape-recorded. After the interview, transcribe the recordings, code and categorize the reported time and problems to identify the strengths and weaknesses.

In addition, if possible, collect the system log data related to the game managing tasks, analyze the logs to find out the time spent and errors encountered during the game managing tasks. Use the log data to verify the findings from the interview data.

4.3.2.4.2 In-lab game management study

This approach assess the game manager's experience using the in-lab game management study. First identify a group of participants who are somewhat familiar with the subject domain of the game. Second, provide instructions on each managing tasks, ask the participants to complete the tasks following the instructions, ask them to record the time spent and problems encountered as they complete each task.

Once the experiment data is collected, categorize the reported problems and correlate with the reported time data to identify the areas of strength (less time spent) and weakness (more time spent and problems or difficulties).

4.3.2.4.3 Game management log data analysis

This approach collects and analyzes the system log data related to the game managing tasks. The time spent and error encountered can be deducted from the system log and reveals strengths and weaknesses of the game managing interface.

4.3.2.5 Game developer assessment

The game 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 game 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 development process.

4.3.2.5.1 Post-hoc developer interview

This approach interviews the game developer(s) to assess their experiences of developing the game using the framework. The interview questions are described in Figure 4.7.

1. How much time did you spend developing a customization using the game framework?
2. What problem(s) did you encounter?
3. Did you find it difficult to understand, extend and debug the system? What was difficult?

Figure 4.7: Game developer interview questionnaires

4.3.2.5.2 In-lab game development study

This approach assess the game developer's experience using an in-lab game development study. First identify the general development skills that the framework requires, such as the programming language. Second, identify a group of participants who have satisfied the required development skills. Third, provide requirements specification or instructions on how to develop a new enhance-

ment to the system, ask the participants to complete the task, record the time spent and problems encountered as they works on the task.

Once the experimental data is collected, categorize the reported problems and correlate with the reported time data to identify the areas of strength (less time spent) and weakness (more time spent and problems or difficulties).

4.3.3 Choose participants

Once the assessment approaches are determined for each stakeholder class, the next step is to choose participants. Identify the people from the each stakeholder class that may be willing to participate in the assessment, contact them and get consent for their participation.

For example, in the case of pre-post effectiveness study approach for player assessment, this step randomly chooses a group of players and present a consent form before the online survey. In the case of post-hoc game designer interview approach, the game designer of a real world game instance of the framework should be identified, contacted and consent for the participation in the assessment. When the in-lab game development experiment study is chosen, a group of game developers that meet the required development skills of the framework should be identified and contacted.

4.3.4 Create assessment schedule

Once decide what the assessment approaches are and who the participants are, the next step is to create the assessment schedule. The document should include a detailed assessment plan for each stakeholder class.

Depending on the assessment approach, the actual tasks of the assessment are different. The player pre-post effectiveness study requires the administration of an online survey before and after the game. The game designer post-hoc interviews requires administration of interviews to the real world game designers of a production system. Table 4.3 shows an example of the assessment schedule broken down by the tasks in the plan document.

Game design assessment approach: in-lab experiment study		
Task	**Estimated Start date**	**Estimated End date**
Design the in-lab experiment instruction		
Ask participants to follow the instruction		
Collect response data from participants		
Obtain log data		
Analyze the data		
Interpret strength and weakness		
Produce action document		

Table 4.3: Assessment schedule in the plan document

4.4 Gather Data

Once the plan has been finalized, the next step is to carry out the assessment, record the data, obtain log data, and (if necessary) refine the assessment plan. The output of this step is a data repository containing all the assessment data that can be analyzed in the next step.

4.4.1 Carry out the assessment

For each assessment approach, complete the tasks outlined in the assessment plan and gather the data when carrying out the assessment. In the case of the game designer post-hoc interview approach, record the interview and take notes if necessary. Store all the data in a central data repository.

In the example of the in-lab game design experiment study, a google form can be used to give detailed step by step instructions for the participants to design games using the framework. Participants can be asked to record the time they spent completing each step and the problems they encountered. They can also be asked to provide feedback about their design experiences in the form of written article.

4.4.2 Obtain log data

Talk to the technical staff of the framework to find out what kind of log data is available. Obtain the log data in a format that is easy to analyze. For example, if the log data is in a database table, ask for the access to the table, or the CSV export of the table data. If the log data is in a log file, ask for

the access to the file. Store the log data into the central data repository.

4.5 Produce Assessment Report

In this step, analyze the data gathered from previous steps, create an analysis of the strengths and weakness of the framework, and produce an action report with your recommendations as to framework improvements.

4.5.1 Analyze Data

This step performs the data analysis from the data repository obtained from the previous step. For the game designer assessment, perform queries from designer interaction log data to find out the completion time for each design task, for instance, the time for a game designer to complete the configuration of global game settings. For player assessment, calculate the engagement metrics from the game log. For post-hoc interview assessment approach, first transcribe the interview recording into text, code and categorize the responses from the interview questions.

In the example of the in-lab game design experiment study described previously, the assessment data is generalized into 7 tasks corresponding to distinct types of game design tasks. The time for each task is calculated from the Google form responses. The problems reported from the participants are coded and aggregated into the the problems areas.

4.5.2 Determine strength and weakness

This step determines the most important problem areas from our data and summarizes them, as well as the areas where the framework appears to be most successful.

In the example of the in-lab design experiment study, there may be a problem area that had been reported by the most numbers of participants, and if this problem happened in one of the tasks that took the longest time to complete, we can identify a weakness area of the framework from the perspective of game designer. If there were no problems reported in a game design task and the time to complete is short, we can consider those areas are the strengths of the framework.

4.5.3 Produce Report with Actionable Steps

Once the strengths and weaknesses of the framework are identified, an action report should be produced. This report includes the weakness areas that can be improved and actionable steps on how to improve from each stakeholder's perspective. It also includes strengths that the framework needs to maintain.

By producing the report with actionable steps to improve the framework, the SGSEAM assessment is completed.

CHAPTER 5
MAKAHIKI AND SGSEAM EVALUATION

This chapter describes the way I evaluated the Makahiki framework described in Chapter 3 and the SGSEAM method described in Chapter 4. First, I describe the Real-world case studies of Makahiki instances realized in the Kukui Cup Challenges at the different organizations, followed by the detailed assessment of applying SGSEAM to Makahiki framework. The evaluation is to address: (a) obtain insights about the strength and weakness of the Makahiki serious game framework, (b) obtain insights about the strength and weakness of SGSEAM serious game framework assessment method.

5.1 Real-world Makahiki Instances Case Studies

Makahiki, as a serious game framework for sustainability, had been used by different organizations to create multiple serious game instances targeting to educate and foster sustainable behavior among the communities. The first Kukui Cup Energy challenges at the University of Hawaii at Manoa (UHM) were held in 2011 for 3 weeks for over 1,000 first year students living in the residence halls. UHM subsequently held the second and third Kukui Cup Energy challenges in 2012 and 2014 for different first year students and different durations, for 9 months and 2 weeks respectively. Hawaii Pacific University (HPU) held their Kukui Cup Energy challenge in Fall 2012 and 2013 for about 200 students each year. An international organization called the East-West Center (EWC) held a Kukui Cup Energy and Water challenge for the international residents living in the residence halls. An Hawaii private school called Holy Nativity School (HNS) held a pilot Kukui Cup challenge for the elementary school students.

Table Table 5.1 lists these instances and their different requirements. The major requirements are differed in the duration of the challenge, population that could participate in the challenge, the type of resource such as energy or water, whether they have smarter meters installed, and type of web server hosting. Additional difference in requirements includes the type of the authentication for the participation, the differences in the game mechanics implementation. These differences will

be described in the result chapter in more details.

Instances	Duration	Populations	Resource	Smart meters	Hosting
UHM 2011	3 weeks	1038	Energy	✓	Local
UHM 2012	9 months	1067	Energy	✓	Cloud
UHM 2014	2 weeks	1056	Energy	✓	Cloud
HPU 2012	3 weeks	198	Energy	✓	Local
HPU 2013	3 weeks	197	Energy	✓	Local
EWC 2012	2 weeks	129	Energy & Water	×	Cloud
HNS 2013	4 weeks	10	Energy	×	Cloud

Table 5.1: Makahiki Serious Game Instances

The Makahiki instances deployed at these organizations have to meet these different requirements. The goal of the Makahiki framework is to minimize the effort in supporting the different requirements in various organizations. The case study evaluation approach of Makahiki is to look at the different requirements of these organizations, and the corresponding different configurations in the Makahiki framework to support such requirements. A more formal assessment of the strength and weakness of the Makahiki framework is described in the next section, by applying SGSEAM to Makahiki, which assessing the experiences of various stakeholders of the Makahiki framework.

5.2 Applying SGSEAM to Makahiki

This section describes in details the application of SGSEAM to assess the Makahiki framework in order to identified the strengths and weaknesses of both the Makahiki and the SGSEAM itself.

5.2.1 SGSEAM Stakeholders in Makahiki

The first step in SGSEAM assessment method is to identify the stakeholders in Makahiki. Table 5.2 listed the identified stakeholders who use the Makahiki framework.

5.2.2 SGSEAM Approach for Makahiki

The second step in SGSEAM is to determine the assessment approach. As described in SGSEAM, The assessment approaches is categorized into in-vivo and in-vitro assessments. The in-vivo ap-

Stakeholder class	Tasks	Role
Player	Participate in the Makahiki games	Students living in the residential halls
System admin	Install Makahiki software, monitor and scale the system, backup, patch maintenance	IT staffs
Game designer	Design the content, configure suitable games and mechanics	Challenge organizers
Game manager	Manage the game during the period of game play.	Challenge organizers
Game developer	Develop customization, extend and enhance the game and framework.	Makahiki developers

Table 5.2: SGSEAM Stakeholders

proaches, such as pre-post test, in-game surveys and post-hoc interviews, assess the real world instance of the game. The in-vitro approaches use in-lab experiments in a simulated environment. Different assessment approaches will have different levels of rigor or validity. When applying SGSEAM in Makahiki, I used the real world Makahiki instances as the in-vivo approaches which includes pre-post effectiveness study for player assessment, post-hoc interview for game administrator and game designer.

In addition to real world instances assessment, I also implemented the in-vitro assessment approach using the in-lab experiments. 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 were seniors or graduate students majoring in computer science related fields. During the course, the students installed Makahiki, designed a serious game instance with Makahiki, and developed an enhancement to the Makahiki system. The participation is voluntary. This is considered as an in-lab experiment since they are evaluating Makahiki in a class setting and using Makahiki in the development environments.

Table 5.3 lists the SGSEAM approaches that are used to assess the strengths and weaknesses of Makahiki from different stakeholders' view.

The following sections describe the assessment approaches in details.

Stakeholder	Assessment approaches	Expected Outcomes
Player	Pre-post effectiveness study	Determine effectiveness in energy literacy and resource usage reduction
	Self-reported effectiveness survey	determine self-reported effectiveness in behavior change and awareness
	Self-reported usability survey	Identify problem areas in game interface
	Engagement metrics	Determine the extent of engagement
System admin	Post-hoc admin interview	Determine strengths and weaknesses in system install and maintenance
	In-lab system admin study	
Game designer	Post-hoc designer interview & log data analysis	Determine strengths and weaknesses in facilitating the game design process
	In-lab game design study	
Game manager	Post-hoc manager interview & log data analysis	Determine strengths and weaknesses in managing the game
	In-lab game management study	
Game developer	In-lab game development study	Determine strengths and weaknesses in developing system enhancement

Table 5.3: SGSEAM approaches

5.2.2.1 Player assessment

I applied 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 the 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. We also conducted the in-game self-reported behavior changes survey. The survey asked the questions about their interests in sustainability prior to and after the game, as well as any perceived behavior changes when playing the game.

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 is calculated based on the log data to assess the engagement level of the instance:

- participation rate
- number of players per day
- Play time per day
- Submissions per day
- Social interactions per day
- Website errors per day

5.2.2.2 System admin assessment

There are two approaches described in SGSEAM to assess the system admin's experience: One is 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 C includes the complete google form.

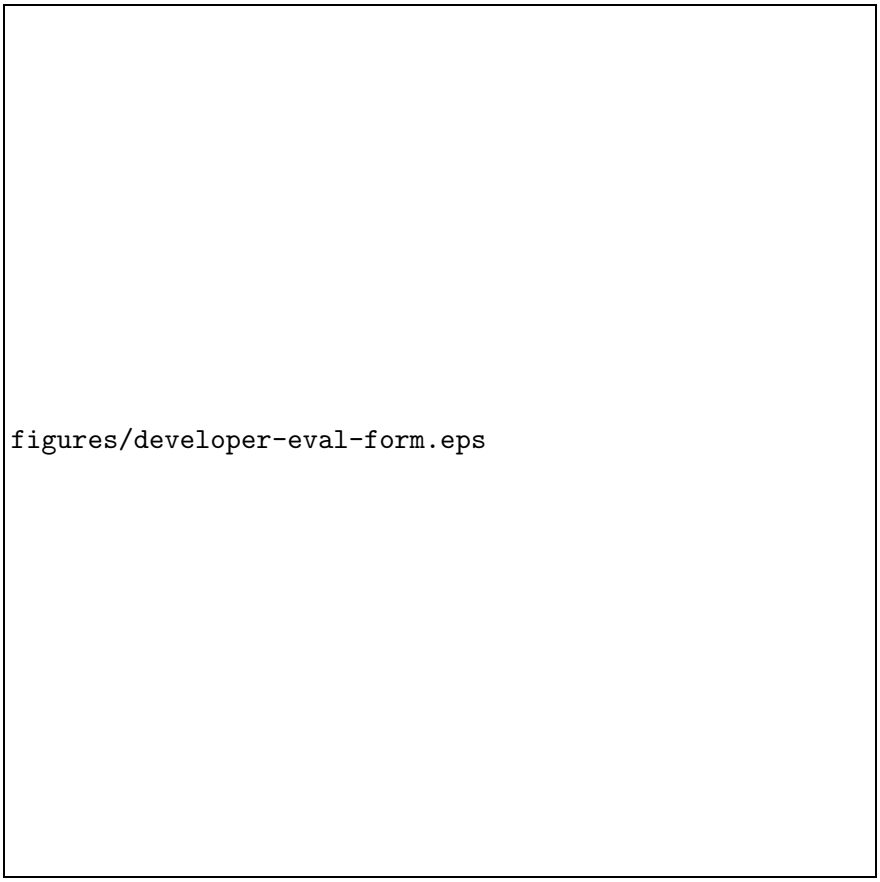


Figure 5.1: Makahiki Developer assessment Form

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 performed interviews to the system admins of the 2012 Hawaii Pacific University (HPU) challenges.

I analyzed 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

5.2.2.3 Game designer assessment

There are also two approaches described in SGSEAM to assess the game designer's experience: One is 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 C 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 performed interviews to the real world game designers of the 2012 Hawaii Pacific University challenges. We asked him about his game designing experiences using the Makahiki admin interface.

I analyzed 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

5.2.2.4 Game manager assessment

I performed interviews to the real world game managers of the 2012 Hawaii Pacific University challenges to study the experience of the game management using Makahiki.

I analyzed 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

5.2.2.5 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 reviewed 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.

5.2.3 Assessment Participants

After the assessment approaches are determined, the next step in SGSEAM is to identify the assessment participants for the different stakeholders. Table Table 5.4 lists the participants for assessing the Makahiki framework using SGSEAM.

Stakeholder class	Person(s)	Organization
Player	All eligible players in the UH KC instance	UHM
System admin	ICS691 students, system admin for HPU instance	UHM, HPU
Game designer	ICS691 students, game designer for HPU & EWC instance	UHM, HPU, EWC
Game manager	ICS691 students, game manager for HPU & EWC instance	UHM, HPU, EWC
Game developer	ICS691 students	UHM

Table 5.4: SGSEAM Stakeholders

5.2.4 Assessment Data Collection and Analysis

The SGSEAM assessment process for Makahiki is carried out by implementing the different assessment approaches for the stakeholder participants, both in real world Makahiki instances and in-lab experiments. The data collected from all the different assessment approaches includes:

- pre-post surveys from players
- in-game usability survey from players
- interviews audio recordings from system admin, game designers, game managers
- email communications from system admin, game designers, game managers
- website logs and errors
- google forms results reported from in-lab experiment evaluation

The data is analyzed according to the assessment approach to determine the strengths and weaknesses of the Makahiki framework with the respects of the different stakeholders in questions.

5.2.5 Consents from Human Research Study Subjects

This research interviewed and studied the behaviors of several human subjects including:

- First year students who played the real world UHM Kukui Cup instances for 2011, 2012 and 2014

- Students who participated in the UHM ICS691 in-lab experiment study
- Administrators who used Makahiki to install, design, and manage the real world Kukui Cup instances in HPU and EWC

We had obtained their consents to participate into this research from all the above human subjects. The study is also approved by Office of Research Compliance at the University of Hawaii Human Studies Program under the CHS #20451.

I

CHAPTER 6
RESULTS

This chapter reports the results of several real world instances of Makahiki implemented in different organizations, as well as the the application of SGSEAM to the Makahiki framework.

6.1 Real World Case Studies

We have used Makahiki to create totally seven (7) Kukui Cup Energy Challenges in four different organizations. The following sections describes the Makahiki instances for the four organizations and the different configurations between these instances.

6.1.1 University of Hawaii at Manoa

There are three instances of Kukui Cup Challenges implemented by using the Makahiki framework in the university of Hawaii at Manoa (UHMM). They are held in 2011, 2012, and 2014 respectively for over 1000 first year students living in the residence halls on campus. The three instances have different competition durations, which are 3 weeks, 9 months and 2 weeks respectively. The residence halls where the students living in have energy smart meters installed for collecting the real time energy data consumed by the students.

Figure 6.1: UHM Kukui Cup Challenge Home Page

6.1.2 Hawaii Pacific University

There are two instances of Kukui Cup Challenges implemented by using the Makahiki framework in the Hawaii Pacific University (HPU). They are held in 2012 and 2013 respectively for about 200 students living in the residence halls at the Hawaii Loa Campus. Energy smart meters were installed in the residence halls.

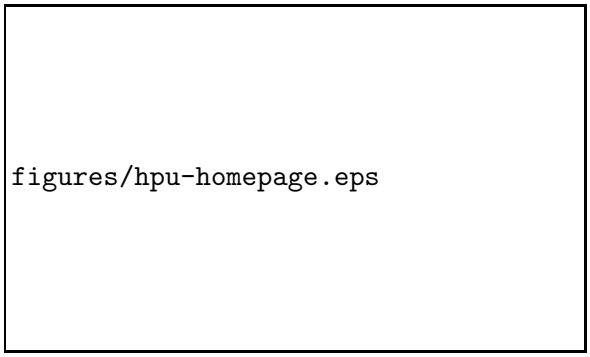


Figure 6.2: HPU Kukui Cup Challenge Home Page

6.1.3 East-West Center

The EWC Kukui Cup Energy and Water challenge was implemented by an international organization called the East-West Center (EWC) using the Makahiki framework. It was held in 2013 for approximately 600 international students living in their residence halls in Hawaii. The challenge lasts for 2 weeks and includes energy and water saving competition between two residence halls. The residence halls did not have internet-enabled smart meters.

6.1.4 Holy Nativity School

A pilot instance of Kukui Cup challenge implemented by using the Makahiki framework was held at the Holy Nativity School (HNS), a private elementary school in Hawaii, in 2013. The pilot instance was organized by the school with the partnership with Project Learning Tree (PLT) GreenSchool! program[78]. The nationwide environmental service-learning program helps improve students academic performance in STEM subjects by engaging students in STEM as they solve environmental issues at their school.

Figure 6.3: EWC Kukui Cup Challenge Home Page

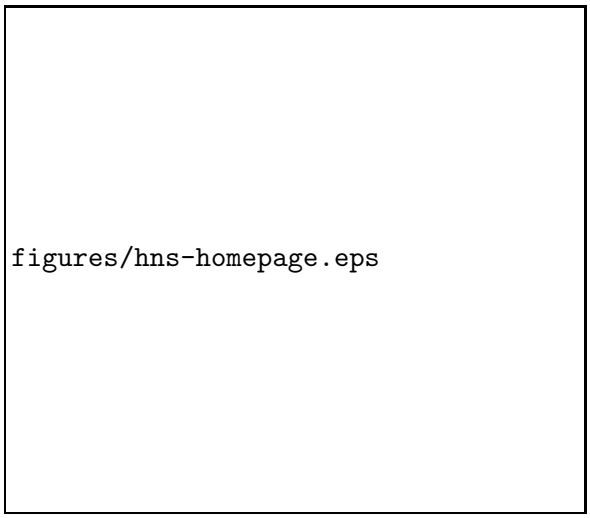


Figure 6.4: HNS Kukui Cup Challenge Home Page

6.1.5 Customization of the Makahiki Instances

The following sections describe the different customizations that were done to the above Makahiki instances according to the different organizations' needs.

6.1.5.1 Configuration Customization

The challenge configuration includes the duration of the challenge, the participant accounts, resource such as energy and water settings, learning action configurations, prize and other game mechanics settings.

Table 6.1 lists the different configurations between the seven real world instances of Makahiki.

Instances	Participants	Teams	Duration	Rounds	Game Element			
					Energy	Water	Prize	Quest
UHM2011	1000	20	3 weeks	3	✓	×	✓	✓
UHM2012	1086	20	9 months	4	✓	×	✓	✓
UHM2014	1093	20	2 weeks	2	✓	×	✓	✓
HPU2012	190	6	3 weeks	3	✓	×	✓	✓
HPU2013	190	6	3 weeks	3	✓	×	✓	✓
EWC2012	130	2	2 weeks	1	✓	✓	×	×
HNS2013	10	2	4 weeks	1	×	×	✓	✓

Table 6.1: Challenge Configuration Differences

As we can see from the Table 6.1, the Makahiki framework can be customized to support different size of the team competition with different duration, with energy, water and both competition, as well as the different education contents of the sponsoring organizations. For example, while UHM and HPU challenges involved only energy consumption data, the EWC challenge involved both energy and water consumption data.

6.1.5.2 Content Customization

Because the different organizations have different sustainability educational needs, they used the Makahiki framework to customize the content, which is shown to student players via the SmartGrid Game mechanics. They can re-use or modify the existing contents came with the Makahiki framework or create new content to be included in the system. The Table 6.2 shows the difference in the type and layout of the educational contents. UHM had the most number of the learning actions while HNS has the least.

Instances	Levels	Activities	Commitments	Events	Total Actions
UHM2011	1	51	21	21	93
UHM2012	7	68	23	35	126
UHM2014	4	60	21	20	101
HPU2012	3	24	11	4	39
HPU2013	3	29	11	4	44
EWC2012	4	21	1	19	41
HNS2013	2	22	6	4	32

Table 6.2: Content Differences

The layout of the educational content represented in the SmartGrid game is also highly customizable to include different levels, rows and columns. The figures Figure 6.5, Figure 6.6, Figure 6.7, Figure 6.8 illustrate the content and layout of the educational SmartGrid game in the different Makahiki instances.

6.1.5.3 Branding Customization

The look and feel of the challenges website are difference between the different organizations, which is customized using the customization feature of the Makahiki framework. The user interface was customized to "brand" each challenge. The list of customizable branding are:

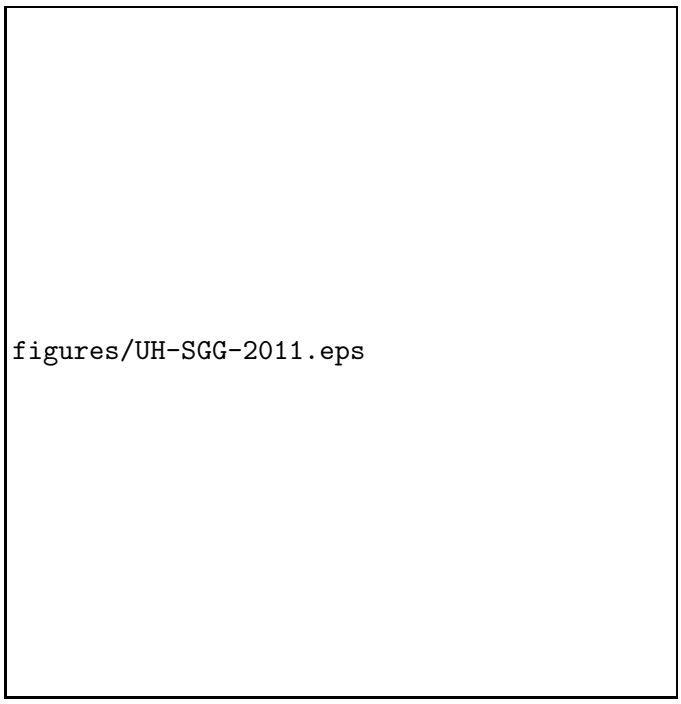
- logo
- size name
- challenge name
- team label
- landing page text
- about page text
- sponsor text and logo
- theme

6.1.5.4 System Configuration

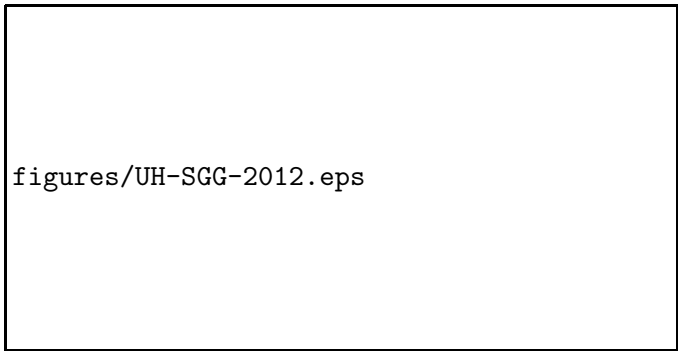
The system configuration includes the infrastructure hosting, user authentication, and smart meter connections.

Table 6.3 lists the different configurations between the seven real world instances of Makahiki.

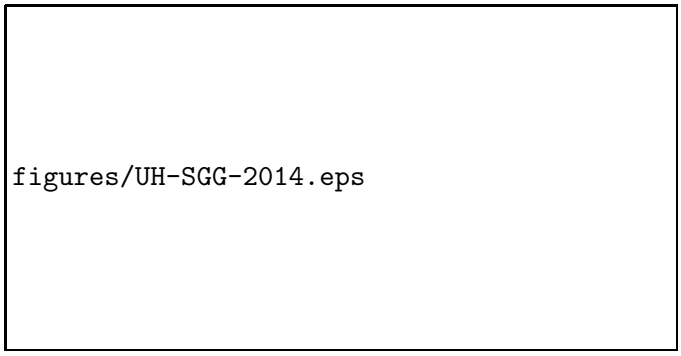
UH and HPU used different metering infrastructure, and EWC collected their resource data manually. Since the halls did not have internet-enabled meters, resource consumption data had to be entered by the game managers manually.



(a) UHM 2011 Kukui Cup SmartGrid Game

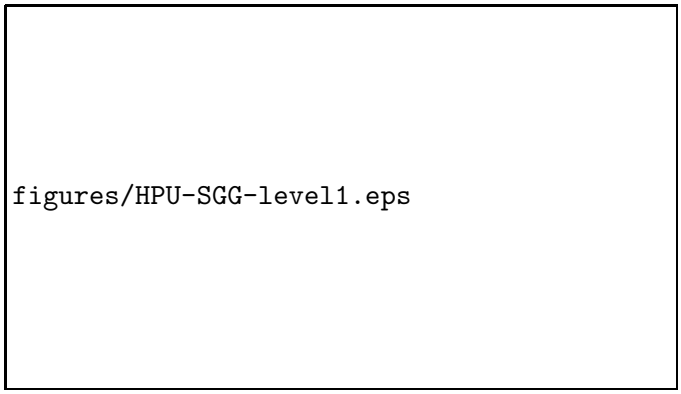


(b) UHM 2012 Kukui Cup SmartGrid Game

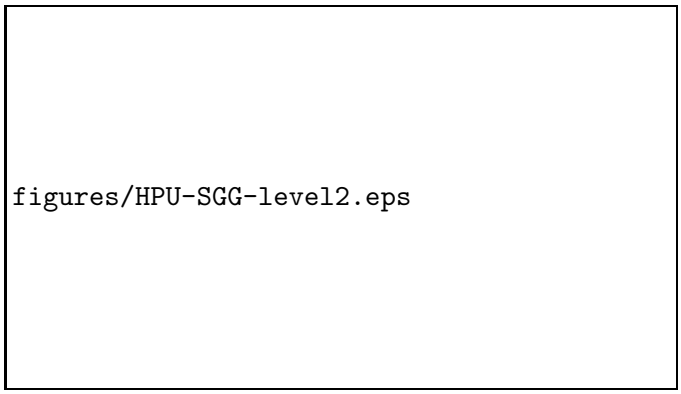


(c) UHM 2014 Kukui Cup SmartGrid Game

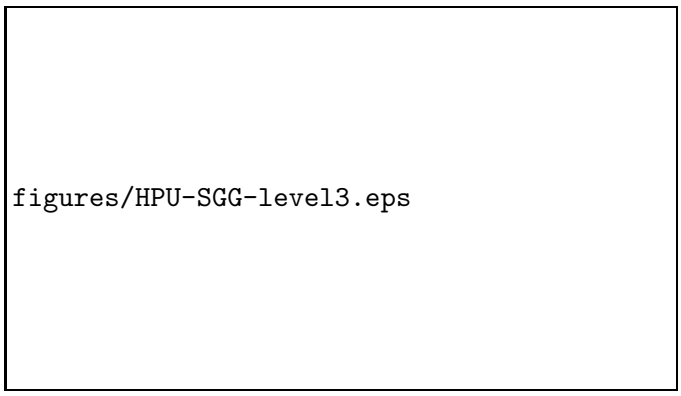
Figure 6.5: UHM SmartGrid Game Layouts



(a) HPU SmartGrid Game Level1



(b) HPU SmartGrid Game Level2



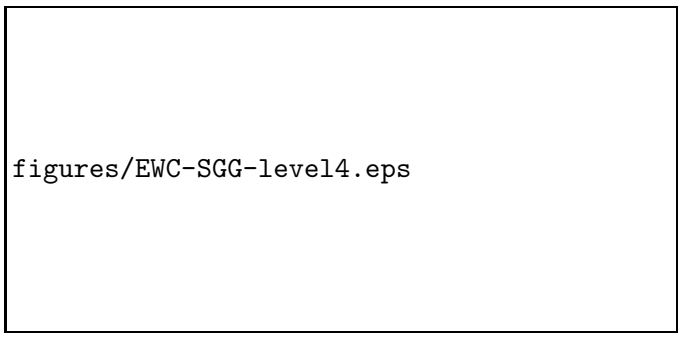
(c) HPU SmartGrid Game Level3

Figure 6.6: HPU SmartGrid Game Layouts

(a) EWC SmartGrid Game Level1

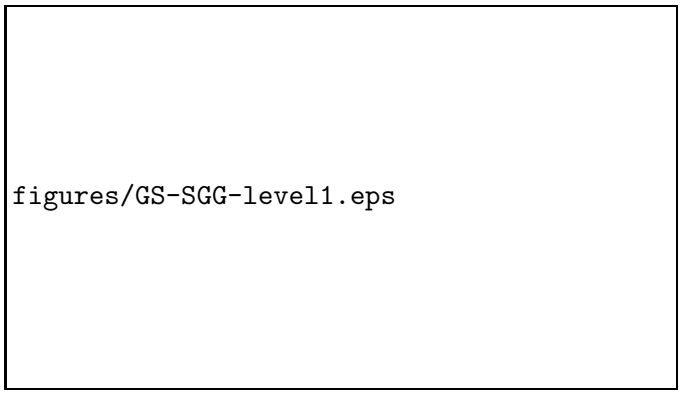
(b) EWC SmartGrid Game Level2

(c) EWC SmartGrid Game Level3

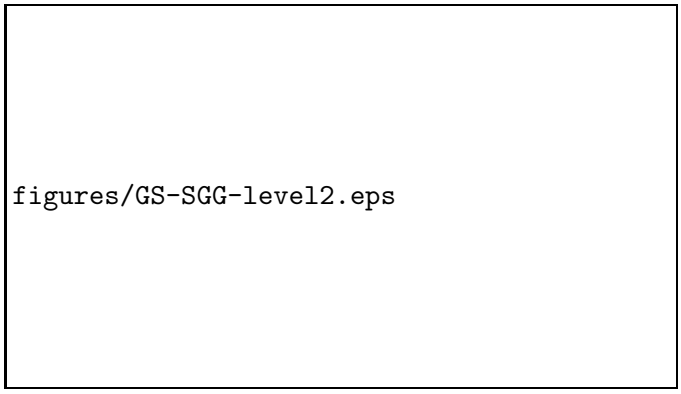


(d) EWC SmartGrid Game Level4

Figure 6.7: EWC SmartGrid Game Layouts



(a) HNS SmartGrid Game Level1



(b) HNS SmartGrid Game Level2

Figure 6.8: HNS SmartGrid Game Layouts

Instances	Hosting	Authentication	Smart meters
UHM2011	Local	CAS	✓
UHM2012	Cloud	CAS	✓
UHM2014	Cloud	CAS	✓
HPU2012	Local	LDAP	✓
HPU2013	Local	LDAP	✓
EWC2012	Cloud	CAS & Internal	×
HNS2013	Cloud	Internal	×

Table 6.3: System Configuration Differences

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.

6.2 SGSEAM assessment

The successful creation of serious game challenges by four different organizations provides evidence that Makahiki can be successfully tailored to the needs of different organizations. This section describes the result of applying a formal assessment method of SGSEAM to the Makahiki framework to assess the strengths and weaknesses of the Makahiki as a serious game framework.

The Table 6.4 provides the overview of applying SGSEAM to Makahiki.

Stakeholder	Assessment Approach	Experiments
Players	Pre Post effectiveness study	UHM KC
	Self-reported effectiveness survey	
	Self-reported usability survey	
	Engagement metrics	
System admins	In-lab installation study	ICS691
	Post-hoc system admin interview	HPU KC
Game designers	In-lab game design study	ICS691
	Post-hoc game designer interview	HPU & EWC KC
Game managers	In-lab game management study	ICS691
	Post-hoc game manager interview	HPU & EWC KC
Developers	In-lab game development study	ICS691

Table 6.4: SGSEAM assessments for Makahiki

6.2.1 Makahiki Player Assessment

We used four approaches to assess the player experience for the Makahiki framework. They are pre-post effectiveness study, self-report effectiveness survey, self-report usability survey, and engagement metrics. The real world Makahiki instances of UHM Kukui Cup challenge were used for the Makahiki player assessments.

6.2.1.1 Pre Post effectiveness study

In 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 5 resident halls. The challenge was designed to lasted for 3 weeks and the student players are divided into 20 teams based on the dorm locations where they resided, each team's energy consumption is measured a smart meter installed in the various locations inside the resident hall. Makahiki recorded the energy consumption for the players before, during and after the challenge. Makahiki also 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, two energy literacy surveys were conducted, one before the challenge (pre-game) and one after the challenge (post-game).

Robert Brewer designed and conducted the survey. The results are reported in his dissertation [11]. 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. Non-players as a control condition were also surveyed. The result is shown in the Figure 6.9. According to Brewer [11], "Based on the questionnaire results, it appears that the energy knowledge of challenge participants increased modestly compared to those that did not participate in the challenge.".

To assess the effectiveness of the framework for designing games that produce positive change in sustainability behaviors, The energy consumption data that collected before, during and after the challenge were used to compare the differences. Before the challenge, an energy usage baseline was

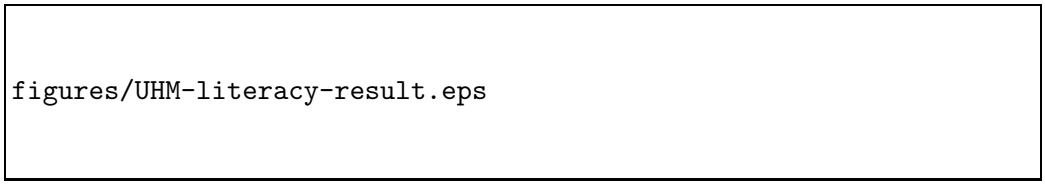


Figure 6.9: Literacy Survey Result of UHM 2011 KC from Robert Brewer 's Dissertation [11]

established.

Robert Brewer calculated the energy consumption data before and after the UHM 2011 Kukui Cup challenge. According to his dissertation [11], 12 out of the total 20 teams reduced their energy consumption compared to the baseline. 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 approximately 2%. The result is shown in the Figure 6.10.

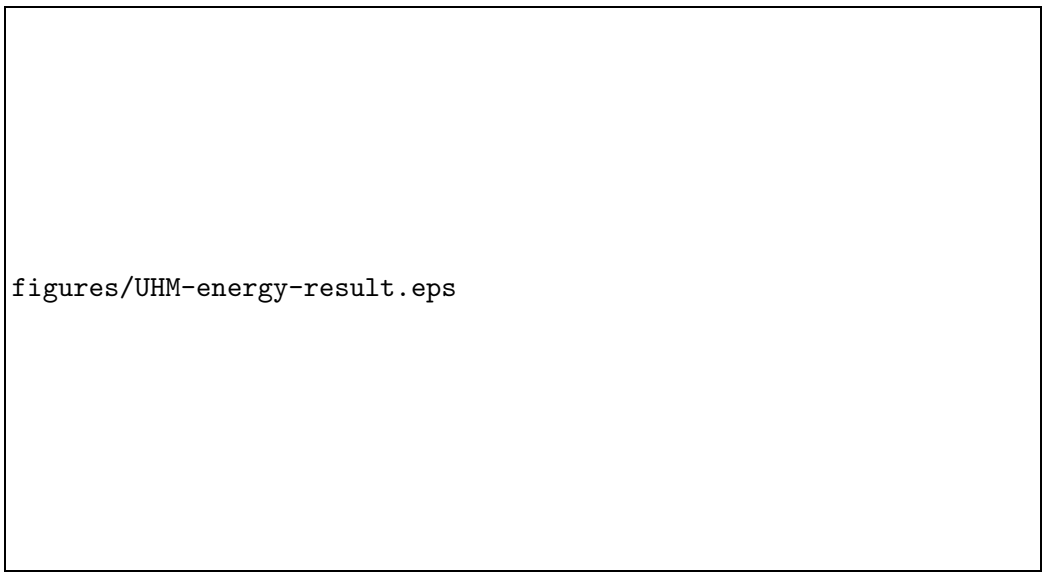


Figure 6.10: Energy Consumption Result of UHM 2011 KC from Robert Brewer's Dissertation [11]

Sara Cobble [17] from Hawaii Pacific University conducted the similar energy consumption study on the 2012 HPU Kukui Cup instance. Her result, as shown in Figure 6.11, shows that one team met the energy reduction goal (which is 5%) for 14 days out of the 3 weeks competition, with an average 11.3% energy reduction. The average numbers of days meeting the reduction goal for all the teams is 6.5 days, with an average energy reduction of 5.1%.

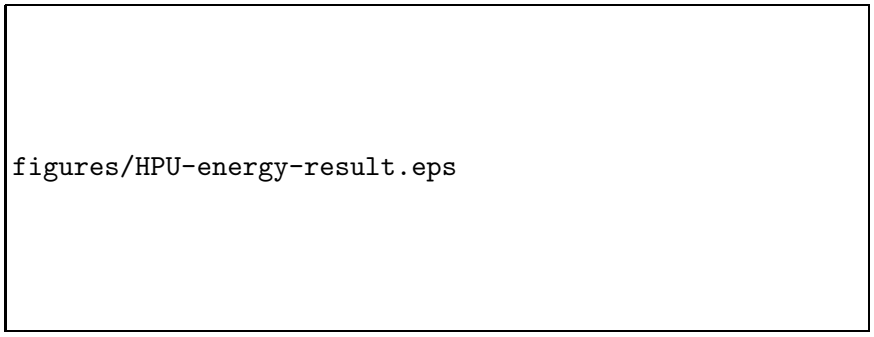


Figure 6.11: Energy Reduction Result of HPU 2012 KC from Sara Cobble's Report [17]

In summary, the SGSEAM can provide evidences of the Makahiki achieving literacy improvement and some positive change in behavior.

6.2.1.2 Self-reported effectiveness survey

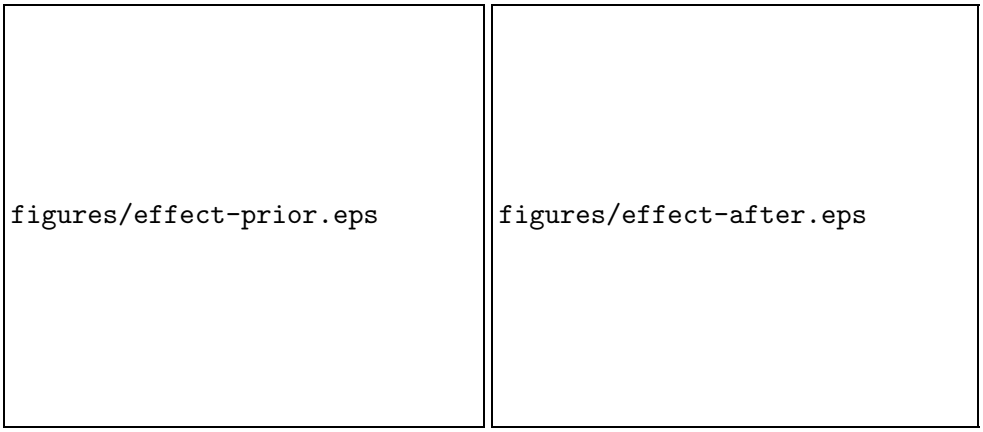
A survey to gather the opinions of participants regarding the effect of the challenge to their sustainability behavior was included at the last round of the challenge. Two survey questions was used to assess the self-reported perception of the players regarding the interests in energy conservation and sustainability prior and after playing the Kukui Cup.

In the 2011 UHM Kukui Cup challenge, 43 players completed the survey. The responses to the survey are in free text. We analyzed the free text responses and coded them into three categories: "Yes", "No", and "Somewhat". Table 6.5 lists results of the responses. Figure 6.12 illustrates the percentages of self-reported interests in the sustainability prior to the KuKui Cup and the effect after playing the Kukui Cup.

Question	**Number of Responses**		
	Yes	**No**	**Somewhat**
Prior to playing the Kukui Cup, were you interested in energy conservation?	24	8	11
Has the Kukui Cup increased your interest in energy conservation and sustainability?	37	0	6

Table 6.5: Interests in sustainability prior and after the KC (2011 UHM, n=43)

The self-reported responses indicates that there are a small percentage (19%) of players were not interested in the sustainability prior to the Kukui Cup. After playing the Kukui Cup, 100% of



(a) interests in sustainability prior (b) increased interests in sustainability after

Figure 6.12: Interests in sustainability prior and after the UHM 2011 KC

responses reported an affirmative or somewhat increase of interests in sustainability.

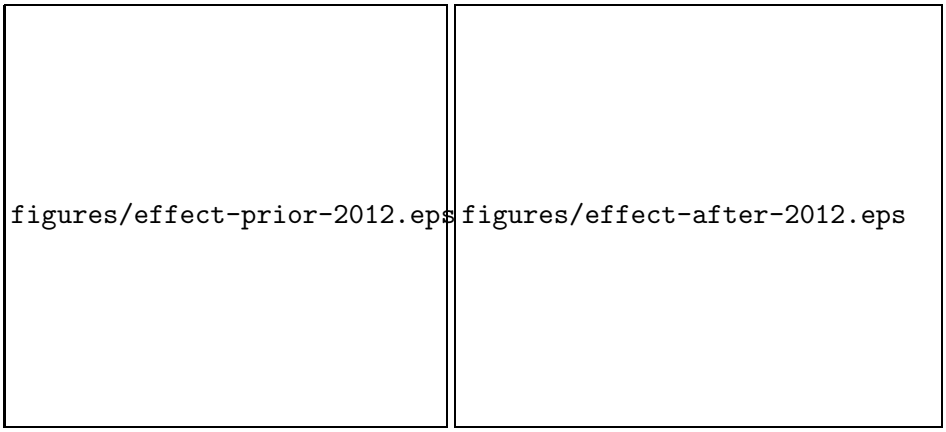
In 2012 UHM Kukui Cup challenge, the similar survey questions were included the last round. 44 players completed both the two questions. Table 6.6 lists results of the responses. Figure 6.13 illustrates the percentages of self-reported interests.

Question	**Number of Responses**		
	Yes	**No**	**Somewhat**
Prior to playing the Kukui Cup, were you interested in energy conservation?	28	4	12
Has the Kukui Cup increased your interest in energy conservation and sustainability?	37	5	2

Table 6.6: Interests in sustainability prior and after the KC (2012 UHM, n=44)

The self-reported responses from 2012 KC indicates that there are a smaller percentage (9%) of players than 2011 KC that were not interested in the sustainability prior to the Kukui Cup. After playing the Kukui Cup, 89% of responses reported an affirmative or somewhat increase of interests in sustainability. There are 5 players (11%) reported that there is no changes of interests in sustainability. A closer look at the data indicates that the 5 players that reported no changes of interests also answered "Yes" or "Somewhat" interested to the sustainability prior to the Kukui Cup. The 4 players that reported no interests in sustainability also reported that playing KC had increased their interests.

The followings are some sample responses from the students who considered the Kukui Cup



(a) interests in sustainability prior (b) increased interests in sustainability after

Figure 6.13: Interests in sustainability prior and after the 2012 UHM KC

had increased their interests in sustainability:

- Yes. I'm more aware of everything I am using.
- I've been interested, but the Kukui Cup has expanded and broadened my mind on what else I can be doing to help with conservation and sustainability. I think people are genuinely concerned, they just don't know how to exactly conduct them, or what other ways they can do it.
- Yes, it made me realize that you can save a lot of money by turning off and unplugging a few things. (Hopefully lower tuition? =D)
- It has increased my interest since I didn't know much about how much energy were using.
- Some workshops made me think differently of how I use energy. Makes alternatives more interesting for me.
- It taught me some new interesting facts about renewable energy and made me more aware.

There was a question in the 2011 KC survey tasking about the players' perception about how would they describe the Kukui Cup. The players were asked to check all that applies to their agreement to the following descriptions of the Kukui Cup: Educational, Fun, Addictive, So-so,

Difficult, Boring, Not useful, and Other where they will type in their free text response. There were 43 responses from the 2011 KC survey. The number of responses and their percentage are listed in the Table 6.7.

Question: How would you describe the Kukui Cup?	Number of Responses	Percentage
Educational	41	95%
Fun	39	91%
Addictive	19	44%
So-so	9	21%
difficult	3	7%
Boring	1	2%
not useful	0	0
Other	5	12%

Table 6.7: Self-reported Perception of the Kukui Cup in 2011 UHM KC (n=43)

Majority of the responses indicated the players perceived the Kukui Cup as "Educational" (95%) and "Fun" (91%). There are 44% players perceived Kukui Cup as "Addictive". On the other hand, there are 1 player (2%) considered the Kukui Cup as"Boring". The "Other" responses are: "AWSOME-NESS"(1), "engaging"(1), "fun competition"(1), "Great way to bond with others"(1), "impressive"(1).

A survey question was also asked about the players' self reported behavior change during the challenge in the 2012 UHM Kukui Cup. The question is "Did you change your behavior during the competition based on the commitment(s) you made? if so, how?". It is a free response question. 45 players completed the survey in the 2012 UHM KC. I categorized the free text responses into three categories: "Yes", 'already a habit", and "no". The results are listed in Table 6.8.

Question: Did you change your behavior during the competition based on the commitment(s) you made?	Number of Responses	Percentage
Yes	39	87%
Already a habit	4	9%
No	2	4%

Table 6.8: Self-reported Behavior Changes in 2012 UHM KC (n=45)

The examples of a "Yes" response are:

- "I changed my behavior during the commitments but found myself doing the same things i

did before after they were over."

- "Yes, because knowing the facts of how much energy we use has helped me realize that I have been wasting money and energy."
- "yes, my behavior has changed during the competition. I'm more aware of the things i do such as turning off appliances when not in use, as well as using more natural energy such as sunlight, rather than electricity."

A "Already a habit" response is that the commitments already become part of the daily habit. The examples are:

- "Most of the commitments I made I already did."
- "I always turn off my lights when I leave the room, use cold water to wash my clothes, and I lessen my meat intake. "

The self-reported survey results indicate in general, the players of Makahiki considered their experiences are positive and there had some self-reported impacts to their sustainability behaviors.

6.2.1.3 Self-reported usability survey

A survey to gather the opinions of players regarding the usability of the website was added during the last round of the challenge.

The players were asked to rate how much you agree with the following 4 usability statements in a likert scale (Strongly disagree, Disagree, Neutral, Agree, Strongly agree):

1. "It was easy to find what I was looking for in the website."
2. "The website was responsive. I did not wait too long after I clicked on something."
3. "The website provided adequate help in teaching me how to play the game."
4. "I understood the rules of the game and how to play."

The questions were asked in both the 2011 and 2014 Kukui Cup in the University of Hawaii at Manoa, 43 players completed the survey in the 2011 KC while 18 players completed in the 2014 KC.

Table 6.9 and Table 6.10 lists the results of the self-reported usability responses for both 2011 and 2014 Kukui Cup at UHM.

Usability statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
It was easy to find what I was looking for in the website.	2	1	2	14	24
The website was responsive. I did not wait too long after I clicked on something.	2	1	1	19	20
The website provided adequate help in teaching me how to play the game.	1	1	1	16	24
I understood the rules of the game and how to play	1	1	0	12	29

Table 6.9: Self-reported Usability in 2011 UHM KC (n=43)

Usability statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
It was easy to find what I was looking for in the website.	0	0	1	9	8
The website was responsive. I did not wait too long after I clicked on something.	0	4	2	10	2
The website provided adequate help in teaching me how to play the game.	0	0	2	10	6
I understood the rules of the game and how to play.	0	0	1	10	7

Table 6.10: Self-reported Usability in 2014 UHM KC (n=18)

Figure 6.14 illustrates the self-reported usability measurements in both 2011 KC and 2014 KC. Majority of players reported that they agreed that the usability of the website is good with one exception of responsiveness from the 2014 responses. 4 out of 18 players (22%) of 2014 KC reported that they considered the website is not very responsive. Comparing to the result of the 2011 KC, this indicates that there may be a perceived performance downgrade in the 2014 KC website.

Another question was asked in the 2014 UHM KC survey regarding the issues encountered when playing using the website. There are 3 out of 18 responses (17%) reported that the loading of

(a) 2011 Self-reported Usability Measurements(n=43)

(b) 2014 Self-reported Usability Measurements(n=18)

Figure 6.14: Self-reported Usability Measurements in 2011 KC and 2014 KC

the website page were slow. This confirms the responsiveness issues discovered in the self-reported usability measurements described above. Another issues reported in the responses to the survey question is the confusion of the scoreboard display in the website. 3 out of 18 responses (17%) reported that scoreboard's display keep changing so it is not easy to see their rankings. There are also 2 responses reported that some of the videos were not displayed which is due to the links to the

videos were outdated.

In summary , the self-reported usability survey is a good tool to get feedback from the players of Makahiki to reveal the strengths and weaknesses regarding the usability of the game.

6.2.1.4 Engagement metrics

Based on the engagement metrics 4.3.2.1.3 proposed in the SGSEAM, we calculated a variety of engagement metrics to assess the player's engagement level in the Kukui Cup challenge created by the Makahiki framework. The metrics are calculated by analyzing the website logs and the data collected by the website. The results shown in Table 6.11 are the engagement metrics for the 2011 Kukui Cup challenge at the University of Hawaii at Manoa.

Measurement	**2011 KC**			**2012 KC**		
	MIN	**AVG**	**MAX**	**MIN**	**AVG**	**MAX**
Participation rate	13%	37%	74%	19%	34%	64%
Number of players per day	43	85	147	0	12	130
Play time per day	1 min	27.7 mins	8.5 hours	0	6.2 mins	8.8 hours
Submissions per day	32	266	1110	0	30	953
Social interactions per day	51	208	468	0	31	502
Website errors per day	0	0.6	4	0	2	458

Table 6.11: Engagement Metrics for 2011 and 2012 UHM Kukui Cup

The participation rate is the percentage of players who played the game. The 2011 UHM KC had a 37% average participation rate, while the 2012 KC had 34%. Both are good compared to other sustainability challenges.

Over the 3 weeks course of the challenge in the 2011 KC, an average player spent about 27.7 minutes per day on the website, while in the 24 weeks challenge in 2012 KC, an average player spent about 6.2 minutes per day. Both instances had one player spent over 8 hours (8.5 and 8.8 respectively) on one day, which is quite significant amount of time for a student to spent in this kind of game. The daily minimum time spent on the 2011 KC is 1 minute which indicates that for every day during the challenge, there are at least one player who played at least 1 minute. The daily minimum time spent on the 2012 KC is 0 minutes. This indicates that there are at least one day when no player use the website.

In order to investigate the engagement in a more details, we looked at the engagement measurement in a time series format. Figure 6.15 shows the timed measurements graph during the 2011 and 2012 Kukui Cup.

Figure 6.15: Engagement Measurements during the 2011 and 2012 UHM Kukui Cup

The divided line in the graphs indicates the division of the rounds for the 2011 and 2012 KC. In the 2011 KC, there are 3 rounds, each round lasted 1 week. In the 2012 KC, there are 4 rounds, the first and second round lasted 2 weeks each, and the third round lasted about 8 weeks, while the last round lasted about 12 weeks, with the total of 24 weeks for the 2012 KC.

In addition to the daily number of players and daily play time which indicate the level of visits to the website or game, the daily submission and daily social interaction measurement indicate the level of deeper interactions with the game. We can see that during the 3 short weeks of the 2011 KC, the engagement patterns are similar in each week. The first few days has higher level of interactions then decreased later into the week. There is a spike on the last day of the round, which may be due to the urge of the players to check the winning results of the round.

We can also see that in the 2012 KC, the engagement level significantly dropped after the second round, which is 4 weeks after the beginning of the game. There are still some numbers of players spent times on the game but the number of submissions and social interactions had decreased sig-

nificantly. Over the time, the number of players decreased in the third round and even less in the last round. It is interesting to see that there are still some amounts of play time during the third and fourth round. A closer look at the data indicated that they are time spent from the the several top players who may be winning the game.

Although the website error in the 2012 KC shown in the Table 6.11 seems high, the detailed graph in Figure 6.15 shows that the errors mostly happened during in one day which is the day after the start of the last round. The investigation of the error in the log file revealed that they are due to a content configuration error in a newly available event in the last round. The error caused the players not able to submit the completion of the event to claim their points so they kept trying and encountered the error repeatedly. The error was corrected 2 hours later after the first such error occurred.

In summary, SGSEAM indicates that Makahiki can be successful in achieving player engagement.

6.2.2 Makahiki System Admin Assessment

We used two approaches to assess the system administrators' experience with the Makahiki framework. They are in-lab installation study and post-hoc system admin interview.

6.2.2.1 In-lab installation study

In the in-lab installation study, the participants are the students in a serious game class (ICS691) in the Spring 2012 in the computer science department at the University of Hawaii at Manoa. The students were tasked with installing the Makahiki system into their local computers as well as deploying to the Heroku cloud environment. A Google Form was used to ask the students to record the time they spent completing each step and the problems they encountered. The students also provided feedback about their installation experiences in the form of blog posts.

There were a total of 8 students who voluntarily participated in the experiments. The participants were either senior undergraduates or graduate students majoring in Computer Science. 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 6.16 shows the average time for each installation step.

Figure 6.16: 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. Table 6.12 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

Table 6.12: 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.

6.2.2.2 Post-hoc System Admin Interview

In order to gain insights on the experience of a real world system admin who uses the Makahiki, I performed interviews to the system admins of the Hawaii Pacific University (HPU) Kukui Cup challenges and analyzed the problems encountered during the software installation and system administration. The HPU KC server software was installed by the system administrator from the HPU IT department with the assistances from us. The installation was performed in the HPU local IT infrastructure with the integration to the HPU LDAP server and their email server. During the installation, issues encountered during the installation were communicated through emails and phone calls between the administrator and us. The interview took place after the challenge. The questions are outlined in the system admin assessment section of the SGSEAM.

The data about the system admin experience was compiled and listed in Table 6.13 and Table 6.14 for the HPU KC instances for 2012 and 2013 respectively. The time to complete is the working days for the HPU system admin to complete the tasks reflected by the announcement in the email exchange and the conversation during the interview. During those working days, the system admin might have other work responsibilities not related to the Makahiki software installation. So the actual time to complete might be less.

The data shows that the the configuration to use HPU's LDAP server and email server are the most difficult tasks. It took a comparable large amount of time to install the ldap libraries, create the ldap account, testing the correct configuration and eventually discovered that the Makahiki software need to modify to support HPU's special server settings.

Once the integration with the HPU's local infrastructure was completed in 2012, the 2013 experience is much easier, the LDAP and email server configuration changes was able to completed shortly in 2013.

When asked about the experience in maintaining the Makahiki server, such as backup and monitoring, the system admin answered that it is fairly straightforward to perform the backup. Since the

Installation Task	Time to Complete	Problem Encountered
Install and startup	5 days	error in installing the runtime environment virtualenvwrapper
Install image library	1 day	error in displaying JPG image during testing
Use HPU LDAP server	20 days	need to install ldap libraries; need to create a special bind user to connect to the ldap server; use the correct ldap DN; HPU ldap server use non-standard way to identify user so the Makahiki software need to update to support HPU's server settings
Use HPU Email Server	2 days	need to create a special email account for KC admin; HPU email server reported error if the "from" parameter is not the same as the email account so the Makahiki software need to fix to support HPU's email.
Update the software	1 day	none
Use SSL	not complete	need to procure the SSL certificate; the SSL certificate acquired by HPU does not have a trusted CA, it is decided that the competition will start without SSL
Total	29 days	

Table 6.13: Installation Issues in HPU 2012 KC

Installation Task	Time to Complete	Problem Encountered
Startup from last year's Vmware image	1 day	none
Use HPU LDAP server	1 day	not able to login because the HPU LDAP server changed to use a new directory structure
Makahiki software upgrade	1 day	need to recreated database migration script due to HPU still use older Postgresql DB version.
Use the new LDAP server	1 day	need to reconfigure to use the new LDAP server
Use HPU Email Server	2 days	not able to send email because the HPU email server configuration change.
Total	6 days	

Table 6.14: Installation Issues in HPU 2013 KC

server was built on the VMWare virtual machine, he used the built-in VMWare snapshot function to perform the daily backup. The backed up image was successfully used in 2013 as the starting point for the 2013 KC instance without the need to re-install the software. The system admin did not do any monitoring and relied on the game designer and manager to report any issues to him. During

the running period of the two challenges, there is no report on the performance issues. Only one issue reported by the game designer during the testing is related to the system installation, that is the JPG image support library not being installed.

6.2.3 Makahiki Game Designer Assessment

6.2.3.1 In-lab game design study

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. [90] 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.

There were a total of 8 students who voluntarily participated in the experiments. 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 6.17 shows the average time for each design tasks:

We aggregated the problems reported in the feedback of the 8 students that participated in the experiment. Table 6.15 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 process-

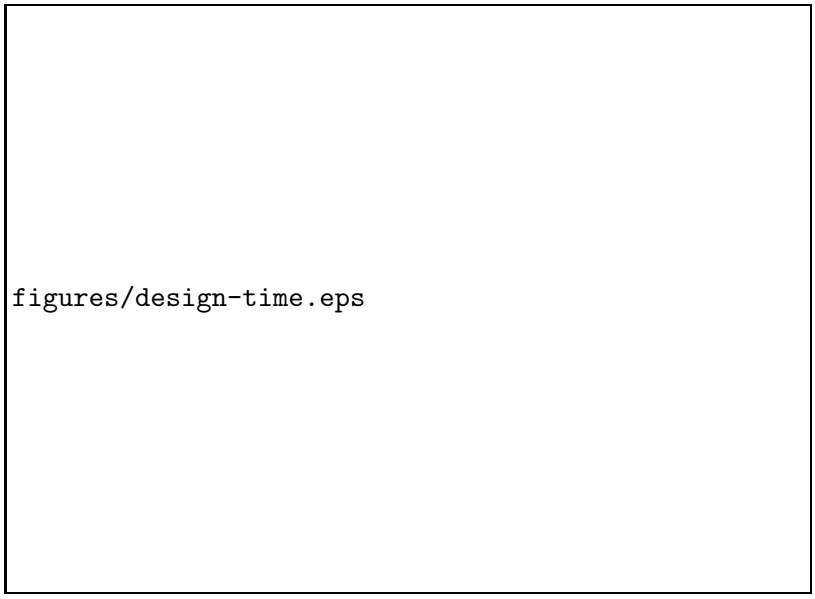


Figure 6.17: Average time (minutes) for design tasks (n=8)

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

Table 6.15: Makahiki Game Design Analysis, (n=8)

ing 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.

6.2.3.2 Post-hoc Game Designer Interview

In order to gain insights on the experience of a real world game designer who uses the Makahiki software to design the serious game, I performed interviews to the game designer of the two Kukui Cup challenges in Hawaii Pacific University (HPU) and East West Center (EWC) in the year of 2012. The game designer for HPU is the sustainability coordinator for the Hawaii Pacific University; while the game designers for EWC are two sustainability coordinator for the East-West Center Participant Association. We asked them about their game designing experiences using the Makahiki game design interface. The interview questions are outlined in the game design section of the

SGSEAM. In addition to the interview data, Makahiki system log file and email exchanges were analyzed to identify the problems encountered during the game design process.

Table 6.16 and Table 6.17 lists the game design experience with Makahiki for the 2012 HPU and 2012 EWC Kukui Cup instances respectively.

Problem encountered	Cause
Error displaying the prize page after adding a prize	Makahiki software did not validate the prize parameter inputted
The introduction video referenced to previous year	The introduction video should be made generic so it could be reused over years
Error when users save their profile in the profile page	Python Image Library is not installed correctly
Confusion of the event code generation	The admin interface to generate the event code is not intuitive
Don't know how to creating external link in Kukui Cup Activities description	The markup language for activity description is not WYSIWYG
Smartgrid layout not change immediately after the settings changed	The cache is not clear automatically when setting changed

Table 6.16: Makahiki Game Design Experiences in 2012 HPU Kukui Cup

Problem encountered	Cause
confusing in generating the confirmation code	the admin interface is not intuitive
don't know how to use video other than youtube	Makahiki software only support youtube video id
forget to change the default commitment period	the default is meant for testing and not typical
not able to delete the FAQ widget from help page	the admin interface to find the name of the widget on a page is not intuitive

Table 6.17: Makahiki Game Design Experiences in 2012 EWC Kukui Cup

One EWC designer responded that "It is easy to create the smartgrid game, putting the video etc. The interface is easy to use.". She also mentioned that "Just a little bit time consuming."

6.2.4 Makahiki Game Manager Assessment

In order to gain insights on the experience of a real world game designer who uses the Makahiki software to design the serious game, I performed interviews to the game manager of the two Kukui Cup challenges in Hawaii Pacific University (HPU) and East West Center (EWC) in the year of

2012. The game manager for HPU is the sustainability coordinator for the Hawaii Pacific University; while the game managers for EWC are two sustainability coordinator for the East-West Center Participant Association. They are also the game designers for their Kukui Cup instances. We asked them about their game management experiences using the Makahiki admin interface. The interview questions are outlined in the game manager section of the SGSEAM. We also analyzed the Makahiki instance log file and email exchanges between the game managers and us to identify the problems encountered during the game management process.

Table 6.18 lists the game management experience with Makahiki for the 2012 HPU and 2012 EWC Kukui Cup instances.

Problem encountered	**Cause**	**Reporting Instance**
not easy to find the event confirmation code	the admin interface to view the event confirmation code is not intuitive	HPU and EWC
error when click on the ”save and add another” button in the approval admin interface, the ”save” button is ok	the approval admin interface should remove the ”save and add another” button	HPU and EWC
some status data disappear after the competition ended	Makahiki software bug	HPU
missing two days worth of energy and water data	did not enter the manual energy and water data in time	EWC
Intermittently unable to access the website	there was an DNS problem with the domain name registrar	EWC

Table 6.18: Makahiki Game Managing Experiences in 2012 HPU and EWC Kukui Cup

When asked if it was easy to approve the player's submissions, HPU manager responded that it was “very easy”.

About the approval process, HPU game manager responded that he made sure that player submissions were either approved or rejected within 12 hours. He also discovered a useful feature in the approval interface without help from the Makahiki support team.

EWC game managers responded with more issues during the game managing process, as discussed in the followings:

- participation game does not make sense since the total number of residences are different
- a hassle to manually enter the data;

- have to manually sign up user before and during the game
- hard to choose the appropriate points for various competing elements
- Adjusting the point system in the middle of the game cause potential unfairness
- need to make the game site available to player after the competition over. software not support yet, EWC admin worked around it by extending the game for one more week
- did not support sending out email daily to inform the progress or current status of the game. software not support yet. EWC admin worked around by manually sending out the status email

In summary, SGSEAM uncovered few problems with Makahiki game management using the interview approach. We realized that the confident level of this assessment approach is low because of availability of only one data point. An experimental study approach or perform interviews to multiple game managers will increase the confidence level of the assessment.

6.2.5 Makahiki Developer Assessment

We assessed developer experience using an in-lab experiment. In the ICS691 serious game development class, the participating students were asked to complete the assignment 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 enhancements to extend the functionality of Makahiki which include 5 required development tasks. 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 and experiences in completing the development activities. The estimated completion time is 10 to 30 hours. The students were told to complete as much as possible and if not complete, they should report in the blog post that what part is not complete. The blog posting should also discuss the parts of the enhancement exercise that they found easy to complete, the parts they found hard to complete, and their recommendations for how the Makahiki framework could be improved to support such enhancement activities more easily in the future.

The Table 6.19 lists the results of the development status after analyzing the blog posts and the source codes they submitted to GitHub.

Development Task	**Number of completion**	**Reported Difficulty**
Setup development env	8	easy
Create the “Hello World” widget	8	easy
Update score_mgr class to support groups.	7	easy
Create a group scoreboard widget.	7	a little hard
Create a group resource widget.	4	hard
Create a group prize widget.	2	hard
Create two group statistics widgets for the status page	1	hard

Table 6.19: Makahiki Game Development Experience, (n=8)

All 8 students reported that the first three tasks of setting up the environment, creating the “Hello world” widget and extending the score_mgr class was easy, while the rest of the enhancements was hard. Only one student was able to successfully completed all required enhancement developments, while the most of them was able to successfully completed the reported easy tasks.

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. All students reported that they spent at least 10 hours working on the assignment. 5 students stated that they had spent more than the required hours and had to move on and not completing the assignment.

The followings are the list of comments and suggestions for ways to enhance the Makahiki support to developing enhancements to the framework:

- better documentation, add type hierarchy diagram
- wished for a bit more of a high-level overview of how widgets should work
- no documentation on ”subclassing” a widget, mostly have to find out by looking at the source code
- had some trouble getting the templates to redirect to the right place ;

- lots of files in the original Prizes folder, and I wasnt sure what was needed and what wasnt.
- documentation is lacking and confusing, not consistent, the screenshot does not match; The exercise was also rather difficult as some of the documentation is vague or incorrect.
- help topic is hard to change
- hard to add widgets to the pages on my Heroku version, how to develop with the heroku instance is not document; this guide could use more specifics, and updating to adhere to changes in the program.
- Sometimes a method returned a dictionary, but the documentation didnt give the dictionary keys
- It also requires reading and understanding each model; have a database model diagram;
- use stackoverflow to get answer for env and Django issues
- confusion with INSTALLED_APPS instead of INSTALLED_WIDGET_APPS,
- learning the code base, a lot to digest,, Django, template, aggregation is an advanced topic

In summary, SGSEAM reveals significant problems with developer efficiency. The problems reported in this assessment are very helpful to address the areas of improvement that the Makahiki framework should provided to support the development activities.

CHAPTER 7
CONCLUSION

This dissertation investigated the design, implementation, and evaluation of the serious game framework for sustainability called Makahiki and a stakeholder experience based assessment method for serious game framework. This chapter summarizes the results of the research, the contributions of the research, and possible future directions.

7.1 Research Summary

This research investigates 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 assessment method accessing the effectiveness and efficiency of the IT infrastructure for serious games for sustainability with regarding the most important stakeholder's perspective.

7.2 Contributions

The contributions of this research are:

- Makahiki: open source information technology for development of serious games for sustainability.
- SGSEAM: an assessment method for assessing serious game framework.
- 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 a second system (BuildingOS) as a framework for development of serious games for sustainability.
- Insights into the strengths and weaknesses of the assessment method.

7.3 Future Directions

There are a variety of directions that can be pursued once this research is complete. One of them is the evaluation of the SGSEAM itself. The design of SGSEAM creates a research question of what are the strengths and weaknesses of this assessment method. To better answer this question, SGSEAM should be applied to another serious game development environment. BuildingOS[52] by Lucid Design Group is such a serious game framework that is suitable for SGSEAM evaluation. Our research lab had made the effort to contact Lucid Design group for the collaboration. I created the assessment plan for them which hope to minimize the effort spent from their side. But due to the workload of the Lucid design group, which is still a newly found startup company, the collaboration did not continue. A further evaluation of SGSEAM by applying to another serious game framework is still an ongoing research direction.

Other future direction of this research includes:

- Evaluate the other stakeholders experiences
- Build a community to expand content and game library for Makahiki
- Scale and expand Makahiki to support other geographical and cultural different locations.

This chapter describes some enhancement projects for Makahiki that we believe would be interesting and useful for the framework.

3.11.1. Real-time player awareness It is not possible in Makahiki to know who is currently on line and playing the game. Creating this awareness opens up new social gaming opportunities (performing tasks together), new opportunities for communication (chat windows), and potentially entirely new games (play against another online player).

The goal of this enhancement is to extend the framework with a general purpose API that provides the identities of those who are online, and then the development of one or more user interface enhancements to exploit this capability.

3.11.2. Deep Facebook integration Makahiki currently supports a shallow form of Facebook integration: you can request that your Facebook photo be used as your Makahiki profile picture, and

you are given an oppportunity to post to Facebook when the system notifies you of an accomplishment.

For this task, expand the current Facebook integration. One way is to deepen the connection between user Facebook pages and their game play. This might involve more automated forms of notification (i.e. the same way Spotify playlists are posted to your Facebook wall), or ways in which your activities on Facebook could impact on your Makahiki challenge status (for example, posting a sustainability video to Facebook, or liking a Sustainability organization could earn you points.)

A different type of enhancement is to allow challenge designers to specify a Facebook page as the official Challenge Facebook information portal, and have the system automatically post information to that Facebook page as the challenge progresses.

3.11.3. Action Library Management System Makahiki currently ships with over 100 possible actions already developed for the Smart Grid Game. However, the current implementation suffers from a number of problems:

There is no convenient way to display and peruse the current set of actions. This has led to a duplicate representation of the smart grid game, implemented using a Google Docs spreadsheet linked to Google Sites pages. This approach has a lot of problems: it duplicates content, it does not provide a way to edit or manage content, it is already out of date. The content is intimately tied to the Smart Grid Game implementation. The SGG is just one of many ways that the sustainability content could be presented to players. By separating content from the presentation, more games can be developed using this content. For this task, you will enhance Makahiki to provide a content management system for actions. This involves the following changes to the current system:

A new set of database tables must be defined to hold Library actions. Library actions can be instantiated (i.e. copied) into the Smart Grid Game. At that point they are assigned a category and a row within the Smart Grid Game. An editor is provided to create action content and preview it in a formatted manner. A new set of pages can be (optionally) made available to allow others to peruse Library content. Library content can be exported and imported into systems in order to support sharing. A public repository can be provided on GitHub. The format is likely JSON.

APPENDIX A
PUBLICATION LIST

These are the publications that have come out of this research that I have authored or co-authored:

A.1 Journal Paper

- Robert S. Brewer, **Yongwen Xu**, George E. Lee, Michelle Katchuck, Carleton A. Moore, Philip M. Johnson. Three Principles for the Design of Energy Feedback Visualizations. In *International Journal On Advances in Intelligent Systems*, Vol. 3 & 4, No. 6. (2013), pp. 188-198

A.2 Conference Papers

- **Yongwen Xu**, Philip M. Johnson, George E. Lee, Carleton A. Moore, Robert S. Brewer. Makahiki: An open source serious game framework for sustainability education and conservation. In *Proceedings of the the 2014 International Conference on Sustainability, Technology, and Education (STE 2014)*, Taiwan, December 2014

- **Yongwen Xu**, Philip M. Johnson, Carleton A. Moore, Robert S. Brewer, Jordan Takayama. SGSEAM: Assessing serious game frameworks from a stakeholder experience perspective. In *Proceedings of the First International Conference on Gameful Design, Research, and Applications (Gamification 2013)*, Ontario, Canada, October 2013

- Robert S. Brewer, **Yongwen Xu**, George E. Lee, Michelle Katchuck, Carleton A. Moore, and Philip M. Johnson. Energy feedback for smart grid consumers: Lessons learned from the Kukui Cup. In *Proceedings of the Third International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies (ENERGY 2013)*, Lisbon, Portugal,

  March 2013.

- Philip M. Johnson, **Yongwen Xu**, Robert S. Brewer, Carleton A. Moore, George E. Lee, and Andrea Connell. Makahiki+WattDepot: An open source software stack for next generation energy research and education. In *Proceedings of the 2013 Conference on Information and Communication Technologies for Sustainability (ICT4S)*, Zurich, Switzerland, February 2013.

- Philip M. Johnson, **Yongwen Xu**, Robert S. Brewer, George E. Lee, Michelle Katchuck, and Carleton A. Moore. Beyond kWh: Myths and fixes for energy competition game design. In *Proceedings of Meaningful Play 2012*, October 2012.

A.3 Workshop

- Robert S. Brewer, George E. Lee, **Yongwen Xu**, Caterina Desiato, Michelle Katchuck, and Philip M. Johnson. Lights Off. Game On. The Kukui Cup: A dorm energy competition. In *Proceedings of the CHI 2011 Workshop on Gamification*, Vancouver, Canada, May 2011.

- **Yongwen Xu**. Designing a Serious Game Framework for Sustainability. In *PhD Students Workshop on ICT4S 2013*, Zurich, Switzerland, February 2013.

A.4 Poster

- Robert S. Brewer, Philip M. Johnson, Michelle Katchuck, George E. Lee, **Yongwen Xu**. Lights Off. Game On. The 2011 Kukui Cup. In *The Behavior, Energy and Climate Change Conference (BECC) 2011*, Washington DC, November 2011.

APPENDIX B
IN-GAME SURVEY QUESTIONNAIRE

This appendix details the contents of the questionnaire made available to participants via the in-game questionnaire during the UHM Makahiki challenge. Participants filled out the questionnaire via the SurveyGizmo [77] website. The survey started with the informed consent via inputing the email address.

The questions were prefaced with the following instructions: "The goal of this survey is to learn about your experiences during the Kukui Cup. Please answer honestly, we want to know how you really feel."

This appendix only lists the questions that are related to the Makahiki framework.

B.1 UHM 2011 in-game survey questionnaire

1. Prior to playing the Kukui Cup, were you interested in energy conservation?
2. Has the Kukui Cup increased your interest in energy conservation and sustainability?
3. Have you made any commitments through the website during the game?

○ Yes

○ No

[If Yes] Did you change your behavior during the competition based on the commitment(s) you made?

○ Yes

○ No

○ Not sure

4. How much time do you usually spend on the following activities? [Options for each activity:]

    1. 3 or more hours a day

2. about 1 hour a day

3. about 1 hour a week

4. 1 hour a month or less

5. never

List of activities:

- Playing games on a laptop computer
- Playing games on a game console (Xbox, PS3, Wii)
- Playing games on a handheld game device (DS3, PSP)
- Playing games on a mobile phone
- Checking Facebook
- Checking Twitter

5. Rate how much you agree with each statement below: [Each statement was ranked on the following Likert-type scale:]

1. Strongly disagree

2. Disagree

3. Neutral

4. Agree

5. Strongly agree

6. Not Applicable

Statements:

- It was easy to find what I was looking for in the website.

- The website was responsive. I did not wait too long after I clicked on something.
- The website provided adequate help in teaching me how to play the game.
- I understood the rules of the game and how to play.

6. What did you like about the website?
7. What did you find confusing about the website?
8. If you could add or change something in the website, what would that be?
9. How would you describe the Kukui Cup? (check all that apply)

□ Fun

□ Educational

□ So-so

□ Boring

□ Not useful

□ Difficult

□ Addictive

□ Other: _____

10. The Kukui Cup website shows energy data updated every 15 seconds. Did you find this helpful in conserving energy?

○ not really, updating the data daily would be enough

○ not really, updating the data hourly would be enough

○ not really, I only care about the final result of the competition

○ yes, it is helpful to see the energy usage changing in real time

11. Which of the following do you wish there were more of in the game? (choose all that apply)

□ events

□ excursions

□ commitments

□ videos

□ social activities

□ physical activities

□ online activities

12. On average, how many minutes a day did you spend on the Kukui Cup website?

13. If you were able to play the Kukui Cup next year, would you?

○ Yes

○ I enjoyed it, but I wouldn't play again

○ I didn't enjoy it, and I wouldn't play again

○ No, because: _____

14. How likely would you be to recommend playing the Kukui Cup to a first year student in Fall 2012?

○ Very Likely

○ Likely

○ Neutral

○ Unlikely

○ Very Unlikely

○ Not Applicable

15. Is there anything else you would like to tell us about your experience playing the Kukui Cup that this survey didn't ask?

B.2 UHM 2012 in-game survey questionnaire

1. Prior to playing the Kukui Cup, were you interested in energy conservation? Please answer with a number in a Likert scale from 1 to 7, where 1 is “Very Interested” and 7 is “Not at all Interested”.

Very Interested 1 2 3 4 5 6 7 Not at all Interested

2. Has the Kukui Cup increased your interest in energy conservation and sustainability? If so, how?

3. Did you change your behavior during the competition based on the commitment(s) you made? If so, how?

4. The Kukui Cup website shows real-time energy data for your team. Did you find this helpful in conserving energy?

5. Do you find the Kukui Cup website responsive? In other words, did pages load quickly?

- ○ Extremely quickly
- ○ Quickly
- ○ OK
- ○ Slow
- ○ Very slow

6. Was it easy to understand how to unlock new activities and levels?

- ○ Yes
- ○ No

7. What was the thing you liked most about the Kukui Cup so far?

8. What was the thing you liked the least about the Kukui Cup so far?

9. If you were able to play the Kukui Cup next year, would you? Please answer with a number in a Likert scale from 1 to 7, where 1 is “Absolutely I would” and 7 is “Definitely Not”.

Absolutely I would 1 2 3 4 5 6 7 Definitely Not

10. Did you try accessing the application from a smart phone? If so, please tell us what kind of phone you used and whether or not you encountered any problems.

11. How likely would you be to recommend playing the Kukui Cup to a first year student in Fall 2013? Please answer with a number in a Likert scale from 1 to 7, where 1 is "Likely" and 7 is "Unlikely'.

Likely 1 2 3 4 5 6 7 Unlikely

12. What did you find confusing about the website (if anything)?

13. What do you consider to be the single most important thing for us to improve in the website?

14. Is there anything else you would like to tell us about your experience playing the Kukui Cup that this survey didn't ask?

B.3 UHM 2014 in-game survey questionnaire

1. It was easy to find what I was looking for in the website.

- ○ Strongly disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly agree
- ○ Not Applicable

2. The website was responsive. In other words, did pages load quickly?

- ○ Strongly disagree
- ○ Disagree
- ○ Neutral
- ○ Agree

○ Strongly agree

○ Not Applicable

3. The website provided adequate help in teaching me how to play.

○ Strongly disagree

○ Disagree

○ Neutral

○ Agree

○ Strongly agree

○ Not Applicable

4.If you were able to play the Kukui Cup next year, would you?

○ Strongly disagree

○ Disagree

○ Neutral

○ Agree

○ Strongly agree

○ Not Applicable

5. This is something my friends should participate in.

○ Strongly disagree

○ Disagree

○ Neutral

○ Agree

○ Strongly agree

○ Not Applicable

6. I understood how to play

○ Strongly disagree

○ Disagree

○ Neutral

○ Agree

○ Strongly agree

○ Not Applicable

7. What did you like the most about the game?

8. What did you found confusing about the website?

9. What issues did you have while using the game?

10. What was the thing you liked the least about the game?

11. What can we do to improve the game?

12. When you logged in for the first time, you are prompted with a series of screens to set up your profile. What did you think of this ”first login sequence”?

13. After finishing the first login sequence, the application took you to the home page. Did you know what to do next?

14. Is there anything else you would like to tell us about your experience playing the Kukui Cup that this survey didn't ask?

APPENDIX C
SURVEY FOR IN-LAB EVALUATION EXPERIMENTS

This appendix lists the survey that are used by the students in the ICS 691 class at the University of Hawaii at Manoa in Spring 2013. The surveys were administered as a Google Forms documents. The students were voluntarily participated in the in-lab assessment experiments for system admin and game designer experiences.

C.1 System admin Assessment

There are two google form surveys to assess the system admin's experience with the Makahiki framework regarding the installation of Makahiki and its software dependencies, based on Makahiki documentation provided online. One google form is the Local installation log survey to assess the local installation of Makahiki on their personal computers or on a virtual machine created on their personal computers, the other is the Heroku installation log survey to assess the cloud installation of Makahiki on the Heroku environment.

C.1.1 Makahiki Local Installation Survey

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:

○ 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/latest/installation-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/installation-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/installation-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.readthedocs.org/en/latest/installation-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/en/latest/installation-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/latest/installation-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.readthedocs.org/en/latest/installation-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/latest/installation-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.org/en/latest/installation-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.readthedocs.org/en/latest/installation-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/en/latest/installation-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/latest/installation-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: * _____

C.1.2 Makahiki Heroku 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/latest/installation-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/en/latest/installation-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.readthedocs.org/en/latest/installation-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.org/en/latest/installation-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/en/latest/installation-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: * _____

C.2 Game designer Assessment

There is one google form survey to assess the game designer's experience with the Makahiki framework regarding the game design process using Makahiki, based on Makahiki documentation provided online.

C.2.1 Makahiki Configuration Log Survey

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/installation-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/latest/challenge-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/challenge-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.org/en/latest/challenge-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/latest/challenge-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/challenge-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/challenge-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/challenge-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/latest/challenge-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/execution-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 D

SGSEAM ASSESSMENT GUIDE FOR LUCID BUILDINGOS AND BUILDINGDASHBOARD

This appendix includes the SGSEAM assessment guide written specifically for BuildingOS and BuildingDashboard, with the intension of administrating SGSEAM assessment to the Lucid Design Group's serious game framework. Although the assessment was not actually carried out, this guide illustrates an example for SGSEAM assessment to a similar serious game framework.

D.1 Overview

This document describes how to assess the Lucid BuildingOS and BuildingDashboard using the Serious Game Stakeholder Experience Assessment Method (SGSEAM).

The goal of this assessment is to identify the major strengths and shortcomings of the software framework using the perspectives of major stakeholders.

The cost of this assessment to Lucid is the requirement for various stakeholders to be available to me for approximately one 30 minute interview.

The benefit of this assessment is the identification of actionable improvements to Lucid BuildingOS and BuildingDashboard.

The SGSEAM assessment method is being developed as part of my Ph.D. research at the University of Hawaii. The assessment of Lucid BuildingOS and BuildingDashboard will help me to identify strengths and weaknesses in SGSEAM. All data about the LucidBuildingOS or BuildingDashboard systems revealed through this assessment will be kept confidential and will not be presented in my research findings.

Table D.1 outlines the steps of the process of applying SGSEAM to a framework.

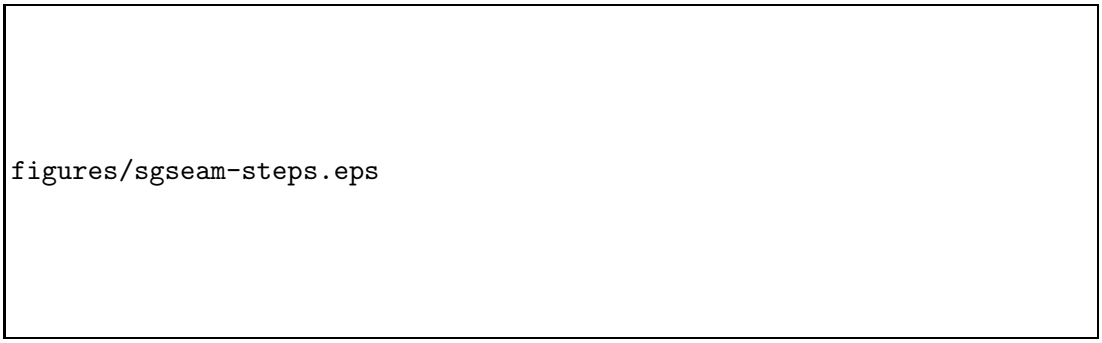


Table D.1: Applying SGSEAM to a framework

1. Step one is to **Plan the assessment**, including identifying the stakeholders, determining assessment approaches, and creating the assessment schedule. The deliverable for this step is the ***assessment plan*** document.

2. Step two is to **Gather data** by carrying out the assessment, recording and obtaining related data. The deliverable for this step is the assessment ***data repository***.

3. Step three is to **Produce the assessment report** by analyzing the data and interpreting strengths and weaknesses. The deliverable for this step is the ***improvement action*** document.

The following chapters describe the steps in detail. The Appendix provides additional background material. Each chapter concludes with an "Action Item" shade box, which indicates what you need to do. For example:

Action Item: Read the next three chapters of this document, and determine if this proposed evaluation is feasible. If you identify obstacles, please note them in the spreadsheet so that we can discuss them in an upcoming phone call.

D.2 Step 1: Plan the Assessment

D.2.1 Identify Stakeholders

The first step is to identify the SGSEAM stakeholders and their tasks for the Lucid BuildingOS and BuildingDashboard framework.

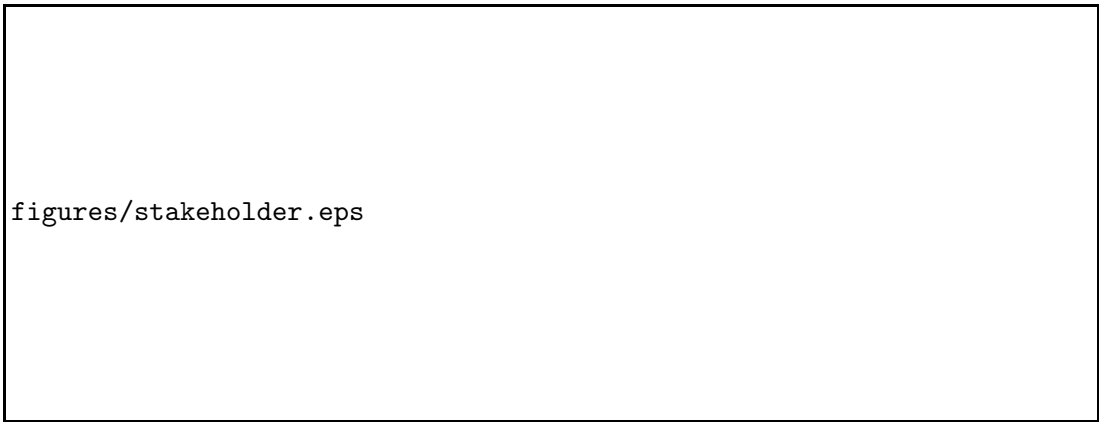


Table D.2: BuildingOS Stakeholders

According to Campus Conservation Nationals (CCN) Competition Planning Guide, a Competition Organizing Team (COT) will plan and execute the competition. Besides being residents of buildings participating in the competition, they are also users and stakeholders of the BuildingOS framework.

We have converted COT roles into SGSEAM stakeholders and identified their tasks related to BuildingOS and BuildingDashboard, as shown in Table D.2.

Action Item: Review the "Stakeholders" tab in the attached spreadsheet, and provide comments if you believe the set of stakeholders or the mapping needs modification.

D.2.2 Determine Assessment Approach

There are several possible assessment approaches for each stakeholder. Different assessment approaches have different levels of rigor which impacts upon the quality the assessment result. They

also require different levels of implementation costs or efforts. Table 4.2 describes the SGSEAM assessment approaches we have developed for each stakeholder category.

While an in-lab experiment has the most rigor, we believe it is too expensive for this assessment. We therefore recommend an interview approach for all stakeholders except players. Table D.3 shows the approaches we recommend for each stakeholder in the case of Lucid BuildingOS and BuildingDashboard.

figures/approach.eps

Table D.3: BuildingOS Assessment Approaches

The following sections describe in detailed the assessment approaches for each stakeholder. description of the recommended approaches.

Action Item: Review the "Approach" tab in the attached spreadsheet. Provide a comment if you believe an approach should be modified, deleted, or added.

D.2.2.1 Assess Player Stakeholder Experience

The goal of player assessment is to determine the effectiveness of the game framework from player's perspective as well as the usability of the game interface and the engagement level of the game.

We recommend three approaches for player assessment: pre-post effectiveness, usability survey and engagement metrics. The attached spreadsheet outlines the planned goals and survey questionnaires for these assessment approaches, as shown in Table D.4.

Table D.4: Player Assessment

The first approach is **Pre-post Effectiveness Study**. One of the goals of the competition is (but not limited to) the reduction of resource such as energy and water consumption. To assess the effectiveness of this goal, we need to determine the metrics that may be measured before and after the competition (pre-post). Lucid BuildingOS and Dashboard calculates the percentage of reduction of energy and water consumption for each participated building, based on the baseline usage of the previous two weeks. We will use this metrics to measure the effect of the competition. The maximum, minimum and average percentage of reduction of all the buildings are calculated to determine the most, the least and average reduction of the resource usage. This assessment approach reveals the extend of effectiveness of the game produced by the framework, regarding to the resource consumption reduction.

The second approach is **Usability Survey**. We will conduct a player usability survey at the final

week or right after the competition to understand the strengths and weaknesses of the game user interface perceived by players. Minimum of 20 players (the more the better) are randomly selected to participate in this survey. The survey is administrated online via survey monkey or other survey tools. We design the survey questionnaire as shown in the section 2 of Table D.4. Once the survey is created online, the survey administrator will email the selected players with the link and instruction to the online survey. After we received all the survey responses, we will code and analyze the response to understand the areas of usability problems in the game interface as well as the areas of strengths. This assessment approach reveals the strengths and weaknesses of the framework regarding the usability of the game interface.

Finally, the third approach is **Engagement Metrics**. This approach calculates the engagement metrics to assess the extent of engagement from players and the impact of the game. The more engaging the game is, the more potential impact could be to the players. We will first obtain the detailed logs of user interaction with the game. These logging includes http web server logs and user action logs which identify every user click on the web page. Once the log data are available, we will calculate the engagement metrics as described in section 3 of Table D.4. With the exception of the game error metric, the higher value these metrics are, the higher engagement level the game has. Distribution of the above metrics across of the period of the competition also provides insights on the extent of engagement in different time of the competition. For example, it may be typical that the first few days of the competition may have higher number of player and play time metrics because of the launch, or due to the announcement of an interesting real-world event. This assessment reveals the extent of engagement of the players in the game.

Action Item: Review the Player tab in the attached spreadsheet. Provide comments for any Player assessment items that you believe might need to be changed.

D.2.2.2 Assess System Admin Stakeholder Experience

The goal of system admin assessment is to determine to what extent the framework facilitates the system administration tasks from system admin's perspective. SGSEAM assesses how much time is

required to install and maintain an instance of a serious game using the framework and the problems encountered during the system admin process.

We consider the tasks of system admin interacting with Lucid's framework are:

1. install the software
2. configure smart meter connectivity
3. backup data
4. monitor performance
5. scaling the system
6. patching

We recommend the post-hoc interview approach for system admin assessment. Once we identify the contact information of the system admins, the interview will be administrated by using an online questionnaire form followed by an optional phone interview if needed. We design the interview with the following questionnaire that is tailored to the specific tasks of the system admins of Lucid's framework. The attached spreadsheet outlines the planned interview questionnaires, as shown in Table D.5.

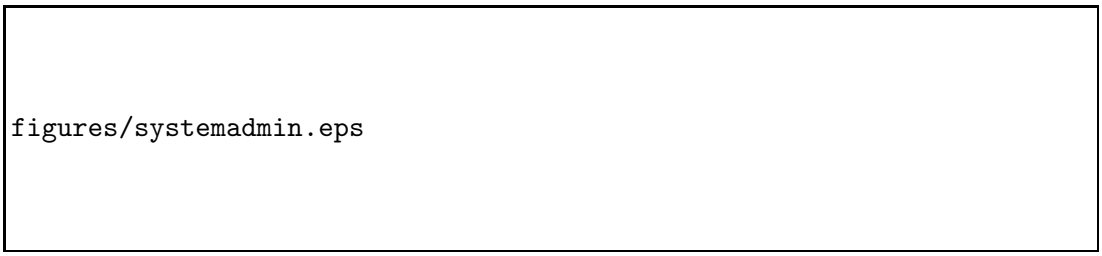


Table D.5: System Admin Assessment

Once we receive the responses from the system admin, we will code (categorize) the time and problems encountered to find out what are the problem areas if there is any. if we need further explanation to the response, we will administrate a quick phone interview to address the specific response.

These assessment reveals the strengths, weaknesses and the areas of improvement regarding the

system admin process for the framework.

> **Action Item:** Review the System Admin tab in the attached spreadsheet. Provide comments for any System Admin interview questionnaires that you believe might need to be changed.

D.2.2.3 Assess Game Designer Stakeholder Experience

The goal of SGSEAM game designer assessment is to determine the strengths and weaknesses of the framework regarding to the game design process. SGSEAM assesses how much time is required to design an instance of a serious game using the framework and the problems encountered during the design process.

We consider the tasks of game designer interacting with Lucid's framework are:

1. decide competition period
2. set up building occupancy, manual or automated meters
3. decide baseline period
4. monitor competition status during the competition

We recommend the post-hoc game designer interview approach for assessing game designer stakeholder experiences. The interview is administrated by using an online questionnaire form followed by an optional phone interview if needed. We will interview several game designers of different competitions. The more data we collect, the more insights we get. The interview is designed with the following questionnaire that is tailored to the specific tasks of the game designers of Lucid's framework. The attached spreadsheet outlines the planned interview questionnaires for game designer, as shown in Table D.6.

After the interview, code and categorize the reported time and problems to identify the strengths and weaknesses. In addition, if possible, collect the system log data related to the game designing tasks, analyze the logs to find out the time spent and error encountered during the game designing

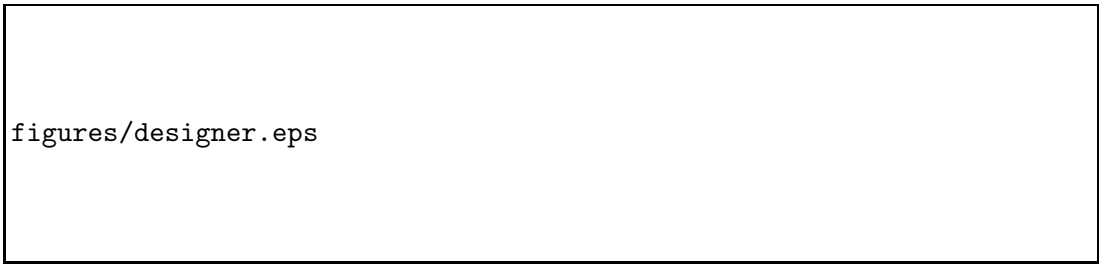


Table D.6: Game Designer Assessment

tasks. Use the log data to verify the findings from the interview data.

These assessment reveals the strengths, weaknesses and the areas of improvement regarding the game design process for the framework.

Action Item: Review the Game Designer tab in the attached spreadsheet. Provide comments for any Game Designer interview questionnaires that you believe might need to be changed.

D.2.2.4 Assess Game Manager Stakeholder Experience

The goal of SGSEAM game manager assessment is to determine the strengths and weakness of the framework regarding to the game management process. Similar to the assessment of the game designer, SGSEAM assesses how much time it is required to manage an instance of a serious game using the framework and the problems encountered during the managing process.

We consider the tasks of game manager interacting with Lucid's framework are:

1. input data manually
2. manage events, marketing, handing out prizes
3. monitor competition status

We recommend the post-hoc interview approach for game manager assessment. The interview is administrated by using an online questionnaire form followed by an optional phone interview if needed. We will interview several game managers of different competitions. The more data we

collect, the more insights we get. The interview is designed with the following questionnaire that is tailored to the specific tasks of the game managers of Lucid's framework. The attached spreadsheet outlines the planned interview questionnaires, as shown in Table D.7.

figures/manager.eps

Table D.7: Game Manager Assessment

After the interview, code and categorize the reported time and problems to identify the strengths and weaknesses in the game managing process. In addition, if possible, collect the system log data related to the game managing tasks, analyze the logs to find out the time spent and error encountered during the game managing tasks. Use the log data to verify the findings from the interview data.

These assessment reveals the strengths, weaknesses and the areas of improvement regarding the game managing process for the framework.

Action Item: Review the Game Manager tab in the attached spreadsheet. Provide comments for any Game Manager interview questionnaires that you believe might need to be changed.

D.2.2.5 Assess Game Developer Stakeholder Experience

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 development process.

We consider the tasks of game manager interacting with Lucid's framework are:

1. use API to get data in and/or out of the system
2. customize the interface
3. extend the system to support new meters

4. enhancement

We recommend the post-hoc game developer interview approach for assessing game developer stakeholder experiences.

BuildingOS and Dashboard have APIs for developing apps to tie into the framework. We will use the API to develop an extension or customization of the system. Here are the development tasks we proposed to perform using Lucid's API to extend the framework:

1. create a new widget to be available in the home page.
2. support the automated energy data collection from a new type of meter.

We will ask the identified game developers to perform the above development tasks using Lucid's framework. The developer could be Lucid internal developers or some one outside of Lucid. After the development tasks are completed, we will interview the developers to assess his experience for these development tasks. The attached spreadsheet outlines the planned questionnaires for game developer interview, as shown in Table D.8.

figures/developer.eps

Table D.8: Game Developer Assessment

Once the interview data is collected, categorize the reported problems and correlated with the reported time data to identify the areas of strength (less time spent) and weakness (more time spent and problems or difficulties) in the process of development.

These assessment reveals the strengths, weaknesses and the areas of improvement regarding the game development process for the framework.

Action Item: Review the Game Developer tab in the attached spreadsheet. Provide comments for any Game Developer interview questionnaires that you believe might need to be changed.

D.2.3 Choose Assessment Participants

Once the stakeholder categories are defined, the next step is to find individuals fitting those categories who will be willing to participate in the evaluation process.

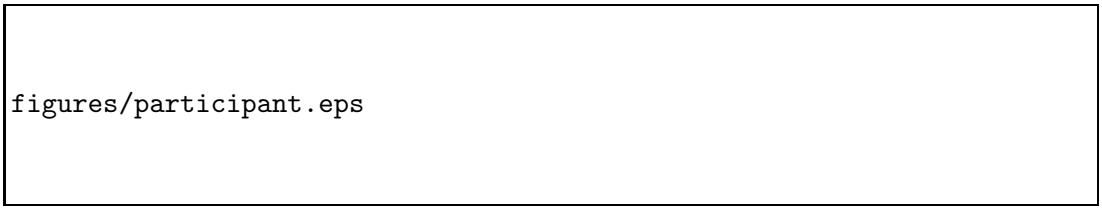


Table D.9: Choose Participants

Table D.9 shows a sample of the ***Participants*** worksheet.

For each stakeholder, identify the name(s), organization and contact info. It is important to be able to contact the stakeholders in some way, either via email or phone, to get the feedback from their experiences with the framework.

Action Item: Review the Participants tab in the attached spreadsheet, and provide any individuals that you believe might be able to participate at this point in the planning process.

D.2.4 Create Assessment Schedule

Once we know what the assessment approaches and who the participants are, the next step is to create the assessment schedule. We have created a sample schedule based on the sample planning timeline in the CCN Competition Planning Guide, as shown in Table D.10.

Action Item: Review the Schedule tab in the attached spreadsheet. Provide comments for any schedule items or dates that you believe might need to be changed.

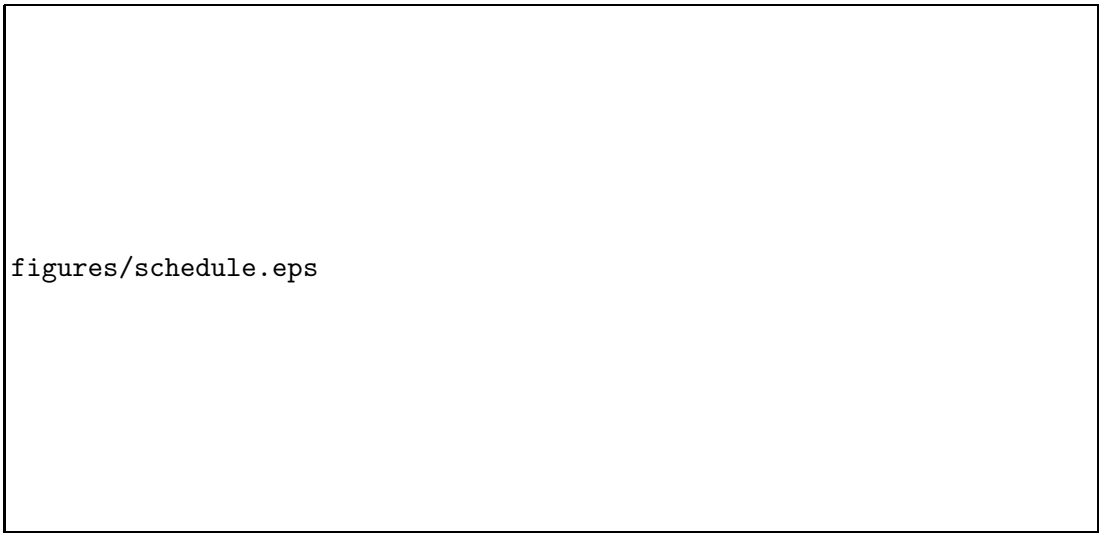


Table D.10: Assessment Schedule

D.3 Step 2: Gather Data

Once the plan has been finalized, the next step is to carry out the assessment, record the data, obtain log data, and (if necessary) refine the assessment plan. The output of this step is a data repository contains all the assessment data that can be analyzed in the next step.

D.3.1 Carry Out Assessments

For each stakeholder group, we will complete the tasks outlined in the assessment plan, gathering the data.

D.3.2 Obtain log data

Certain assessments (such as player engagement) depend upon access to certain kinds of log data. We will confer with technical staff as to how to obtain this data.

D.4 Step 3: Produce Assessment Report

In this step, we will analyze the data gathered from previous steps, create an analysis of the strengths and weakness of the framework, and produce an action report with our recommendations as to framework improvements.

D.4.1 Analyze Data

Our analysis will include qualitative analysis of questionnaire data as well as quantitative analysis of log data. For example, for player assessment, we will calculate the engagement metrics from the game log; for game designer assessment, we will analyze interaction log data to find out the completion time for a certain game design tasks.

D.4.2 Determine Strength and Weakness

We will attempt to determine the most important problem areas from our data and summarize them, as well as the areas where the framework appears to be most successful.

D.4.3 Produce Report with Actionable Steps

Once the strengths and weaknesses of the framework are identified from the data analysis, an action report should be produced. This report includes the weakness areas that can be improved and actionable steps on how to improve from each stakeholder's perspective. It also includes strengths that the framework needs to maintain.

This concludes the SGSEAM assessment for Lucid BuildingOS and BuildingDashboard.

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