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

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAI‘I IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

COMPUTER SCIENCE

AUGUST 2014

By
Yongwen Xu

Dissertation Committee:

Philip M. Johnson, Chairperson
David Chin
Scott Robertson
Lipyeow Lim
Daniel Port

©Copyright 2014

by

Yongwen Xu

♢ 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 appre-
ciated.
♢

Acknowledgments

This research project could not have been completed without the help of a number of people. My deeply thanks go to Prof. Philip Johnson, who has been my most respectful advisor and mentor for my four fruitful years in the Collaborative Software Development Lab.

I'd also like to thank past and present members of CSDL in chronological order: Robert Brewer, George Lee, Michelle Katchuck, Carleton Moore and Jordan Takayama. Special thanks go to George Lee, who developed the initial version of Makahiki. The Makahiki research project would not have happened without your long hours and hard work.

I would like to thank my committee members Prof. David Chin, Prof. Scott Robertson, Prof. Lipyeow Lim, and Prof. Daniel Port for taking the time to read and evaluate this dissertation.

This research is supported in part by grant IIS-1017126 from the National Science Foundation and the funding from the Center for Renewable Energy and Island Sustainability (REIS).

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 [24] 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 [38]); (b) out-source to a commercial provider (as was done at the University of British Columbia in 2011); or (c) use a minimal tech solution such as a web page and manual posting of data and results (as was done at Harvard in 2012).

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

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

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

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

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

Table of Contents

Acknowledgments . . . iv
Abstract . . . v
List of Tables . . . xi
List of Figures . . . xii
1 Introduction . . . 1
1.1 Sustainability Education and Behavior Change . . . 1
1.2 Collegiate dormitory sustainability competition . . . 2
1.3 Serious games and Gamification . . . 2
1.4 Serious game assessment . . . 3
1.5 Research Description . . . 3
1.5.1 Makahiki . . . 4
1.5.2 SGSEAM . . . 4
1.5.3 Evaluation . . . 5
1.6 Outline . . . 5
2 Related Work . . . 6
2.1 Serious Games and Gamification . . . 6
2.2 Serious Games for Sustainability . . . 12
2.3 Serious Game Frameworks . . . 15
2.4 Serious Game Framework Assessment . . . 18
3 Makahiki Design . . . 22
3.1 Overview and Architecture . . . 22
3.2 Configurable Game Elements . . . 22
3.2.1 Smart Grid Game . . . 24
3.2.2 Power Meter . . . 25
3.2.3 Daily Energy Goal Game . . . 27
3.2.4 Raffle Game . . . 28
3.2.5 Social and Referral Bonuses Game Mechanics . . . 29
3.2.6 Quest Game Mechanics . . . 29
3.2.7 Badge Game Mechanics . . . 30
3.3 Real-time Analytics . . . 31
3.4 Configurable resource . . . 31
3.5 Responsive mobile support . . . 31
3.6 Cloud deployment support . . . 32
4 SGSEAM Design . . . 35
4.1 Overview of SGSEAM . . . 35

4.2 Assessment Methodology . . . 36
4.3 Stakeholder Experience Assessment . . . 37
4.3.1 Player Assessment . . . 39
4.3.1.1 Pre-Post effectiveness study . . . 39
4.3.1.2 Self-reported usability metrics . . . 39
4.3.1.3 Engagement metrics . . . 40
4.3.2 System Admin Assessment . . . 41
4.3.2.1 Post-hoc system admin interview . . . 41
4.3.2.2 In-lab installation study . . . 42
4.3.3 Game Designer Assessment . . . 42
4.3.3.1 Post-hoc game designer interview . . . 42
4.3.3.2 In-lab game design study . . . 43
4.3.3.3 Game design log data analysis . . . 43
4.3.4 Game Manager Assessment . . . 43
4.3.4.1 Post-hoc game manager interview . . . 44
4.3.4.2 In-lab game management study . . . 44
4.3.4.3 Game management log data analysis . . . 44
4.3.5 Game Developer Assessment . . . 44
4.3.5.1 Post-hoc game developer interview . . . 44
4.3.5.2 In-lab game development study . . . 45
5 Makahiki and SGSEAM Evaluation . . . 46
5.1 Makahiki Assessment Overview . . . 46
5.1.1 Real-world Makahiki Instances Case Studies . . . 46
5.1.2 In-lab Makahiki Experiment Case Studies . . . 47
5.2 Makahiki Assessment . . . 47
5.2.1 Player assessment . . . 47
5.2.2 System admin assessment . . . 48
5.2.3 Game designer assessment . . . 50
5.2.4 Game manager assessment . . . 51
5.2.5 Developer assessment . . . 52
6 Results . . . 53
6.1 Makahiki Player Assessment . . . 55
6.2 Makahiki System Admin Assessment . . . 56
6.3 Makahiki Game Designer Assessment . . . 57
6.4 Makahiki Developer Assessment . . . 59
7 Conclusion . . . 60
7.1 Research Summary . . . 60
7.2 Contributions . . . 60
7.3 Future Directions . . . 61
A Publication List . . . 62
A.1 Journal Paper . . . 62
A.2 Conference Papers . . . 62
A.3 Workshop Papers . . . 63
B Serious Game Stakeholder Experience Assessment Method (SGSEAM) User Guide . . . 64
B.1 SGSEAM Overview . . . 64

B.2 Plan Assessment . . . 65
B.2.1 Identify stakeholders . . . 65
B.2.2 Determine assessment approach . . . 65
B.2.3 Choose participants . . . 67
B.2.4 Create assessment plan . . . 68
B.3 Gather Data . . . 68
B.3.1 Carry out the assessment . . . 68
B.3.2 Obtain log data . . . 69
B.4 Produce Strength and Weakness Report . . . 69
B.5 Analyze data . . . 69
B.5.1 Interpret strength and weakness . . . 70
B.5.2 Produce reports with actionable steps . . . 70
C In-Game Questionnaire . . . 71
C.1 Gamification . . . 71
C.2 General Feedback . . . 74
D Google Forms for In-lab Evaluation Experiments . . . 75
D.1 System admin Assessment . . . 75
D.1.1 Makahiki Local Installation Log . . . 75
D.1.2 Makahiki Local Installation Log . . . 81
D.2 Game designer Assessment . . . 85
D.2.1 Makahiki Configuration and Management Log . . . 85
E SGSEAM Assessment Guide for Lucid BuildingOS and BuildingDashboard . . . 94
E.1 Overview . . . 94
E.2 Step 1: Plan Assessment . . . 96
E.2.1 Identify Stakeholders . . . 96
E.2.2 Determine Assessment Approach . . . 96
E.2.3 Choose Assessment Participants . . . 97
E.2.4 Create Assessment Schedule . . . 98
E.2.5 Assess Player Stakeholder Experience . . . 98
E.2.6 Assess System Admin Stakeholder Experience . . . 99
E.2.7 Assess Game Designer Stakeholder Experience . . . 100
E.2.8 Assess Game Manager Stakeholder Experience . . . 100
E.2.9 Assess Game Developer Stakeholder Experience . . . 101
E.3 Step 2: Gather Data . . . 101
E.3.1 Carry Out Assessments . . . 101
E.3.2 Obtain log data . . . 102
E.4 Step 3: Produce Assessment Report . . . 102
E.4.1 Analyze Data . . . 102
E.4.2 Determine Strength and Weakness . . . 102
E.4.3 Produce Report with Actionable Steps . . . 102
E.5 SGSEAM Assessment Approaches for BuildingOS . . . 103
E.6 Player Assessment . . . 104
E.6.1 Player Assessment Approach: Pre-post Effectiveness Study . . . 104
E.6.2 Player Assessment Approach: Self-reported Usability Survey . . . 104
E.6.3 Player Assessment Approach: Engagement Metrics . . . 105

E.7 System Admin Assessment 106
E.7.1 System Admin Assessment Approach: Post-loc System Admin Interview . 107
E.7.2 System admin assessment approach: In-lab system admin study (Not Recommended for Lucid) 10
E.8 Game Designer Assessment 108
E.8.1 Game Designer Assessment Approach: Post-hoc Game Designer Interview 109
E.8.2 Game designer assessment approach: In-lab game design study (Not Recommended for Lucid) 109
E.9 Game Manager Assessment 110
E.9.1 Game Manager Assessment Approach: Post-hoc Game Manager Interview 110
E.9.2 Game manager assessment approach: In-lab game management study (Not Recommended for Luc
E.10 Game Developer Assessment 112
E.10.1 Game Developer Assessment Approach: Post-hoc Game Developer Interview 112
E.10.2 Game developer assessment approach: In-lab game development study (Not Recommended for Lu
Bibliography 114

List of Tables

Table		Page
4.1	Overview of SGSEAM	38
B.1	SGSEAM Stakeholders	66
B.2	SGSEAM approaches	67
E.1	Applying SGSEAM to a framework	95
E.2	BuildingOS Stakeholders	96
E.3	BuildingOS Assessment Approaches	97
E.4	Choose Participants	97
E.5	Assessment Schedule	98
E.6	Player Assessment	99
E.7	System Admin Assessment	100
E.8	Game Designer Assessment	100
E.9	Game Manager Assessment	101
E.10	Game Developer Assessment	101
E.11	SGSEAM approaches	103
E.12	Player self-reported usability survey questionnaires	105
E.13	Player engagement metrics	106
E.14	System admin interview questionnaires	107
E.15	Game designer interview questionnaires	109
E.16	Game manager interview questionnaires	111
E.17	Game developer interview questionnaires	113

List of Figures

Figure		Page
2.1	Foldit is solving a serious problem	7
2.2	Foursquare makes modern badges popular	8
2.3	Nike+ makes fitness run	9
2.4	RibbonHero Helps to Learn Office	9
2.5	Ancient Games Shown in British Museum	10
2.6	Serious Game and Gamification (source: Deterding [14])	11
2.7	Power House Game to Save Energy(source: Reeves [42])	12
2.8	RecycleBank - Gaming for Good	13
2.9	Gameful Design for Sustainability	14
2.10	Energy Competition for Sustainability	15
2.11	Building Dashboard (source: Lucid [30])	16
2.12	Stanford Energy Services Platform (source: Stanford [1])	17
2.13	Four Dimensional Framework for Evaluating Educational Games [13]	18
2.14	Triadic Game Evaluation (TGE) [23]	19
2.15	Technology Acceptance Model (TAM) [12]	20
2.16	Game Engagement Questionnaire (GEQ) items [6]	20
3.1	Architecture of Makahiki	23
3.2	*Smart Grid Game widget*	24
3.3	*Power Meter widget*	26
3.4	*Daily Energy Goal Game widget*	27
3.5	*Raffle Game widget*	28
3.6	Badge widget	30
3.7	Game analytic widgets: User Stats and Energy Goal Status	32
3.8	Configurable resource	33
3.9	Responsive design supports both desktop and mobile	33
3.10	Heroku cloud deployment	34
5.1	Makahiki Developer assessment Form	49
6.1	Status of Makahiki assessment	54
6.2	Makahiki Engagement Metrics	56
6.3	Average time (minutes) for installation steps (n=8)	57
6.4	Makahiki Installation Analysis (n=8)	57

6.5 Average time (minutes) for design tasks (n=8) 58
6.6 Makahiki Game Design Analysis, (n=8) 58

B.1 Applying SGSEAM to a framework 65
B.2 Assessment schedule in the plan document 68

Chapter 1

Introduction

1.1 Sustainability Education and Behavior Change

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

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

On the other hand, changing people's behavior with respect to energy holds significant promise in reducing energy use. Darby's survey of energy consumption research found that identical homes could differ in energy use by a factor of two or more [11]. Data from a military housing community on Oahu show energy usage for similar homes can differ by a factor of 4 [36].

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. 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 [38]. 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 [30], 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 [31]. 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 [33, 41]. Priebatsch attempts to build a game layer on top of the world with his location-based service startup [39]. 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" [14] 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 [42].

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 [21]. 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 [32] [23]. 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)[6], QUIS (Questionnaire for User Interaction Satisfaction)[22]. 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" [25]. 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, as well as another serious game framework, Lucid BuildingOS[30], to gather evidences of the effectiveness and efficiency of Makahiki and BuildingOS, and to gain insight into the strenghths and weakness of 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 implemention 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.
- **??** lists our research questions and explains the plan to evaluate them.
- Chapter 7 concludes the dissertation with a list of contributions and future directions.
- **??** contains the questionnaire to be administered to various roles in the evaluation.
- Appendix D contains the google forms to be used in the in-lab evaluation experiments.

Chapter 2

Related Work

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

2.1 Serious Games and Gamification

A Serious game is "a game designed for a primary purpose other than pure entertainment" [52]. It includes categories such as educational games and advergames (advertising), political games, and training game (also known as game-learning). Zyda [57] defines serious game is "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, etc".

One prominent example is Foldit [27], 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 2.1 shows a screen shot of the Foldit game.

Serious Alternative Reality Game (ARG) is one type of serious game that blends the real and virtual worlds activities in the serious gaming context. Jane McGonigal designed the award winning serious ARG games "World Without Oil" [15] and "Evoke" [53] with the goal to empower people to come up with creative solutions to our most urgent real-world problems.

ARGs have also been used to support learning. Connolly et al. [9] discuss the development of an educational ARG to motivate secondary school students across Europe to learn foreign languages . 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 limita-

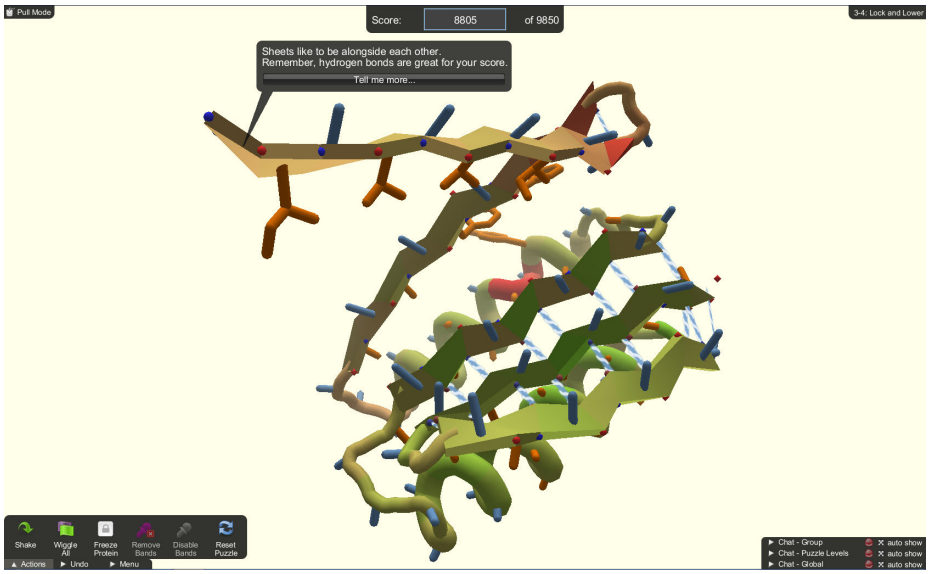


Figure 2.1. Foldit is solving a serious problem

tion of Moodle platform the game is based on and there are potentials to improve the effectiveness of the game.

The report of the ARGOSI project [51] provides insights to the use of ARGs in game based learning and the challenges in the field of higher education. The pilot was run at the University of Bolton with the aim to provide an engaging alternative to traditional methods of introducing students to university life. The overall up-take of the game was fairly low with 173 players and 23 (13%) of whom were active. The project identifies a number of questions surrounding educational ARGs, such as motivation, relationship to curriculum, marketing and timing. The report suggests that a complete ARG model may not be appropriate for wholesale learning, but there is certainly potential in using game elements.

While “Serious Games” has been an active research topic for decades, “Gamification”, on the other hand, is a fairly new subject. Deterding et al. [14] defines gamification is “the use of game design elements in non-game contexts”. The term only came into widespread use starting in the recent year of 2010 [44]. Gartner [20] predicts that by 2015, more than half of companies managing innovation processes will employ gamification, a process of applying game mechanics to application areas including productivity, finance, health, sustainability, news, user-generated content and e-learning.

FourSquare [19] is probably the most recognized example of applying game mechanics to location-based networking application. It is a location-based game-like service where players

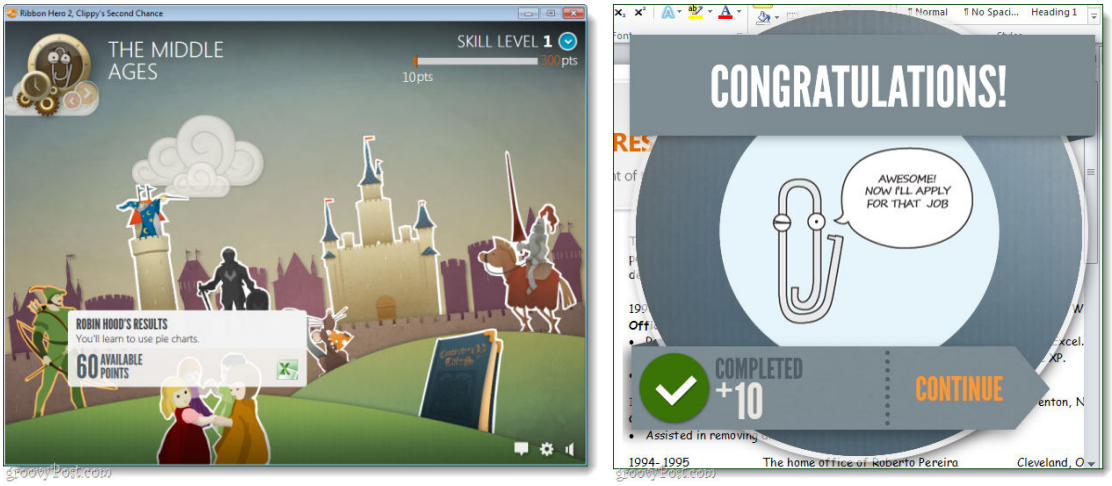
check-in to locations for virtual points and rewards. By employing gamification elements such as points, badges, levels and leader boards, it engages users to revisit a location such as restaurant or pub and become a loyal customer and finally the "mayor" of the place. Certain virtual rewards such as the "mayors" of Starbucks and badges 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.

Figure 2.2. Foursquare makes modern badges popular

Nike+ [35], as another gamification example, 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 to solve the main problem of most fitness programs: motivation. Nike+ makes it easy for runners to upload their exercise data to its web site, and start challenging themselves and their friends. They can also get supports from their friends through the web site. The game makes running and exercise fun, which eventually serve the "serious" purpose of making players healthy.

RibbonHero [43] is a game that helps users discover new Microsoft Office features in a fun and motivating way. The goal is to have users build familiarity and expose them to the Office UI, so that they understand what kind of features are available. According to the creator of the game, Office "has a lot of powerful features that users might not know but can be really useful". The game gives users a chance to learn those features in a fun and engaging way, rather than reading the software manuals or watching the typically dry IT training videos.

Figure 2.3. Nike+ makes fitness run



(a) Quest to earn points

(b) Competing a task

Figure 2.4. RibbonHero Helps to Learn Office

Why games? Results of a study published in the May 1998 issue of Nature [28] demonstrated that video game players experienced regular releases of dopamine during game play. Dopamine is a neurotransmitter that signals pleasure rewards for food, sex and addictive drugs, such as cocaine.

A favorite subject of the 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 2.5. It is noteworthy that both Ajax and Achilles have the full armor on while playing the game. According to Arthur A. Krentz [29], 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. "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 2.5. Ancient Games Shown in British Museum

In modern day, World of Warcraft (WoW) is a massively multiplayer online role-playing game (MMORPG) with 11.1 million subscribers, currently the world's most popular MMORPG. Nick Yee [56] pointed out that the shared experience, the collaborative nature of most activities makes MMORPG unique. "It's the people that are addictive, not the game". "Most importantly, it is the reward of being socialized into a community of gamers and acquiring a reputation within it" . He claimed [55] 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" [34] and in her book "Reality is Broken" [33], researcher and game designer Jane McGonigal illustrated why good games make us better, and how they can help us change the world. She notes that currently more than 3 billion hours a week is spent in playing video game by our society, for good reasons. She says that the average gamer plays 10,000 hours of games by age 21. That's about the same number of hours that students spent in high school and middle school. There are 500 million gamers today, playing on all sorts of platforms from the iPhone to the game consoles. Instead of the common conception that gaming is a waste of time, she argues that "playing games is the single most productive thing we can do with our time" and is the solution to the "Broken Reality".

Deterding et al. [14] describes the distinctions between gamification, serious games and other related concepts, as shown in Figure 2.6. According to Deterding, a) Gamification is about game. It is different than playful interaction, playful design. b) Gamification uses game elements. It is not the complete game such as a serious game. c) Gamification applies to non-game context. Similar to serious game, it uses game for other purposed than game's normal expected use for entertainment. d) Gamification focuses on design. It is not game-based technology or practice of wider game ecology.

Figure 2.6. Serious Game and Gamification (source: Deterding [14])

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 [3] considered the serious game Foldit as a victorious example of gamification in science.

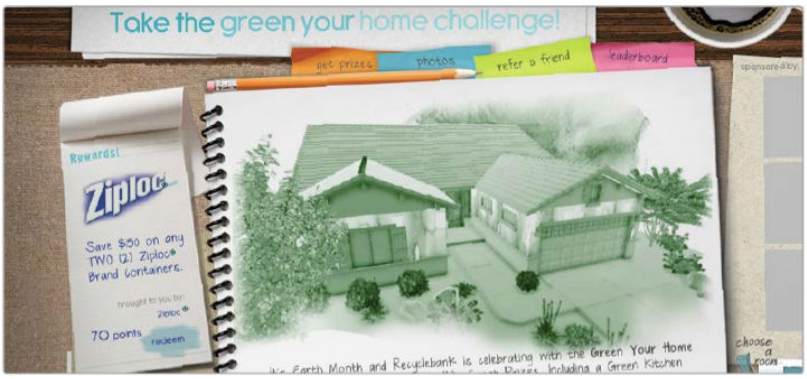
2.2 Serious Games for Sustainability

Serious games for sustainability is the games designed to achieve the serious goal of sustainability development. Reeves et al. [42] 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. In the game, the real world energy data are transformed into a "more palatable and relevant form of feedback", and players may be incentivized by the in-game rewards to complete more energy-friendly real-world behaviors.

Figure 2.7. Power House Game to Save Energy(source: Reeves [42])

RecycleBank [40] introduced a series of "Green Challenges" that used gaming techniques online to motivate participants to learn about green living and to take small green actions to live more sustainable lives offline. According to this report [21], 49,000 individuals participated in the "Green Your Home Challenges". Partnered with Google Analytics and ROI research, they found that:

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



(a) Green Your Home Challenge

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

(b) Game Change Behavior

Figure 2.8. RecycleBank - Gaming for Good

Interactive design also applies game elements in their design to achieve sustainability goal. The "SmartGauge" dashboard [26] for Ford's hybrid cars, where a digital plant is responding 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, thus promotes a more environmental behavior. Similarly, The design of "Piano Staircase" [49], 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 2.9. Gameful Design for Sustainability

Energy competitions or challenges have been introduced to college dormitories and residential homes as ways to facilitate and incentivize energy reduction. Petersen et al. [38] describe their experiences deploying a real-time feedback system in an Oberlin College dorm energy com-

petition in 2005 that includes 22 dormitories over a 2-week period. 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. There has been little analysis on energy usage after competitions finish, or how positive behavior changes could be sustained.

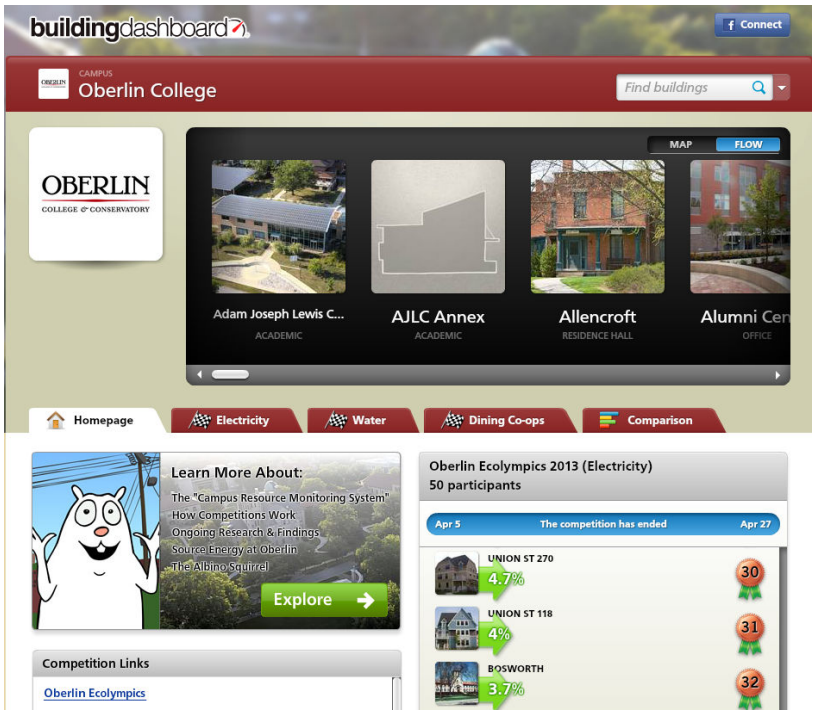


Figure 2.10. Energy Competition for Sustainability

2.3 Serious Game Frameworks

Game frameworks (also known as game engines) [45] 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". The examples of game frameworks include:

- Unreal [48]: 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 [37]: 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 [16]: 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 [17]: 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 lovel 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 [30], developed by Lucid Design Group, as shown in Figure 2.11.

Figure 2.11. Building Dashboard (source: Lucid [30])

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 support the Campus Conservation Nationals (CCN) [31], a nationwide electricity and water use reduction competition on college campuses. In CCN 2014, the framework was used by 109 schools in north american to display the energy and water consumption to the competition participants. It enables viewing, comparing and sharing building energy and water use information on the web in compelling visual interface, but the cost of the commercial system creates the barrier for wider adoptions. In addition, the building dashboard solutions focus on providing energy information as a passive media. Besides a scoreboard, There is little interaction between participants and the system.

Another framework that is related to sustainability development is the Stanford Energy Services Platform [1], as shown in Figure 2.12. It provides services to benefit the creations of energy efficiency program and research. The services include data storage, recommendation system, user registration and participation assignment, surveys and analytics. It had been utilized to support the implementation of several Stanford's energy saving projects and energy related serious games, such as 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 2.12. Stanford Energy Services Platform (source: Stanford [1])

2.4 Serious Game Framework Assessment

This section examines the assessment of serious game frameworks. It starts with looking at the assessment of serious games, then looks at the assessment of game frameworks in general, finally examines the assessment of serious game frameworks in particular.

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 [46]. In the field of serious games, there is an increasing focus on the methodology of game evaluation [32].

De Freitas and Oliver [13] pointed out that there are few frameworks to support the evaluation of education games. They introduced the four dimensional framework for evaluating educational games and simulations. The framework consisting of: the context, the pedagogy, the representation, and the learner (or player). Figure 2.13 illustrates the evaluation framework.

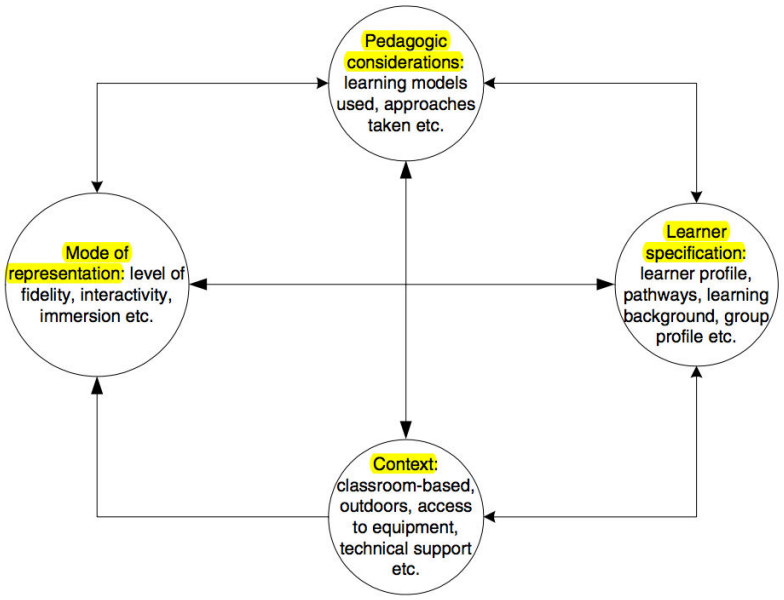


Figure 2.13. Four Dimensional Framework for Evaluating Educational Games [13]

Harteveld [23] 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 2.14.

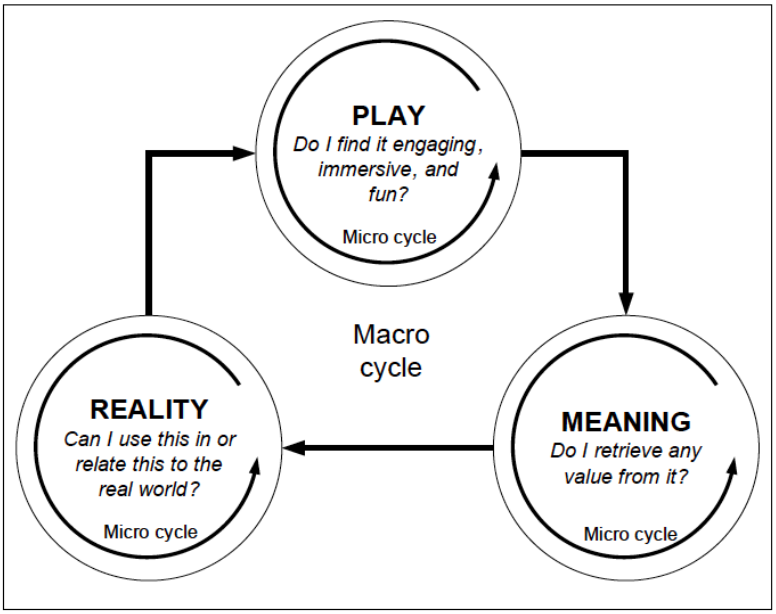


Figure 2.14. Triadic Game Evaluation (TGE) [23]

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 [2] described their approach of using the Technology Acceptance Model (TAM) to evaluate the custom game engine Fabula [17]. Technology Acceptance Model [12] 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 predicated by user motivation, which is influenced by an external stimulus of the system's features and capabilities. Figure 2.15 illustrates the original Davis model. X1, X2 and X3 in the figure represent the system features.

As Chuttur [8] pointed out in his review of TAM that there are skepticisms among some researchers regarding the rigor and limitations of the model. There exists some other assessment tools such as Game Engagement Questionnaire (GEQ) and Questionnaire for User Interaction Satisfaction (QUIS).

Game Engagement Questionnaire (GEQ) [6] was developed by Brockmyer et al. and published in the Journal of Experimental Social Psychology. The questionnaire provides a "psycho-

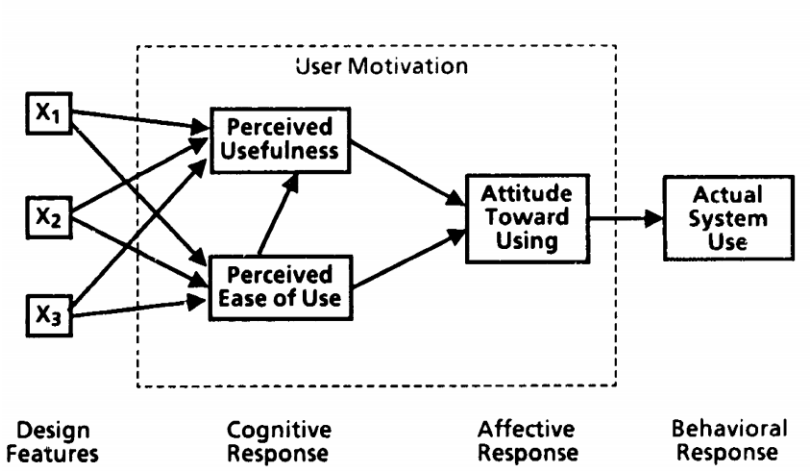


Figure 2.15. Technology Acceptance Model (TAM) [12]

metrically" strong measure of levels of engagement specifically while playing video games. While the GEQ could measure the engagement level of positive game experience, the orignal intent of the research is to "examine risk and protective factors for negative game impact". Figure 2.16 shows the questionnaire items.

1	I lose track of time
2	Things seem to happen automatically
3	I feel different
4	I feel scared
5	The game feels real
6	If someone talks to me, I don't hear them
7	I get wound up
8	Time seems to kind of stand still or stop
9	I feel spaced out
10	I don't answer when someone talks to me
11	I can't tell that I'm getting tired
12	Playing seems automatic
13	My thoughts go fast
14	I lose track of where I am
15	I play without thinking about how to play
16	Playing makes me feel calm
17	I play longer than I meant to
18	I really get into the game
19	I feel like I just can't stop playing

Figure 2.16. Game Engagement Questionnaire (GEQ) items [6]

Questionnaire for User Interaction Satisfaction (QUIS) [22] 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.

The above assessment framework or tools are for general purpose. 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.

Chapter 3

Makahiki Design

This chapter describes the design of the Makahiki, a serious game framework for sustainability. It starts with the overview and architecture of Makahiki, followed by the distinctive features that make Makahiki an innovated serious game framework.

3.1 Overview and Architecture

Makahiki represents research intended to create synergy between the need to create knowledge and engagement regarding energy and the ability of so-called "serious game" techniques and energy feedback to create participation and engagement [14, 11, 18, 38]. In Makahiki, online game mechanics are employed with the goal of affecting real-world energy behaviors [5]. The ultimate goal is not just to affect energy behaviors during the course of the game, but also to produce long lasting, sustained change in energy behaviors and outlooks by participants. Figure 3.1 illustrates the architecture of Makahiki.

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

3.2 Configurable Game Elements

Makahiki builds in a set of configurable game elements and mechanics that can be turned on or off, or customized by the game designers to the needs of different organizations.

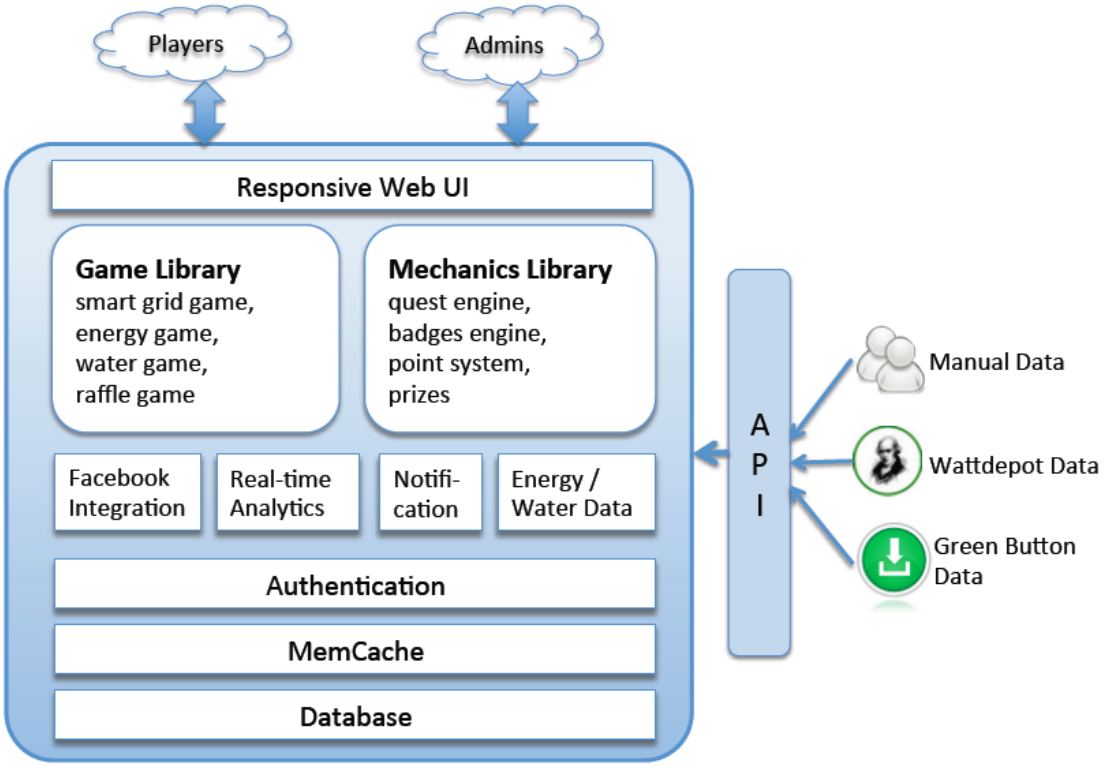


Figure 3.1. Architecture of Makahiki

3.2.1 Smart Grid Game

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

Figure 3.2. *Smart Grid Game widget*

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

description by the administrator of why it was rejected. The player can change and resubmit their response and still earn the full point value for that activity.

Commitments are pledges that the player will do something related to energy or sustainability for a period of five days. Examples include: reducing shower time, taking the stairs, and turning off the lights when leaving a room. Although these commitments are not verifiable, they are public and visible to other players in the same team and worth fewer points than activities. Furthermore, a player is limited to five active commitments at any given time. After the five day period is up, the player can then declare that they completed the commitment and immediately earn their points. They can then sign up for another commitment, including the one they just completed.

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

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

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

3.2.2 Power Meter

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

The Power Meter widget provides basic feedback on energy consumption via a display of the team's power consumption, updated every few seconds. The visualization can normalized

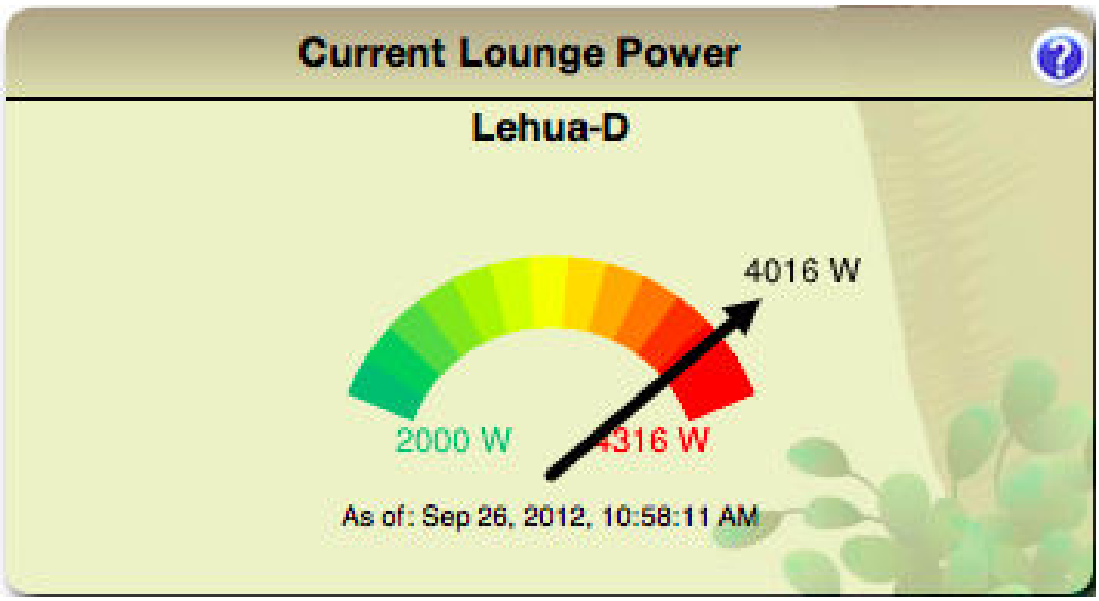


Figure 3.3. *Power Meter widget*

using baseline values so that when the needle is pointing straight up, the power consumption is the average for that team during that specific hour of that specific day of the week. Thus, if the needle leans left toward the green side, the team's power consumption at that moment in time is below average, while if the needle leans right toward the red side, the team's power consumption at that moment in time is above average.

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

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

3.2.3 Daily Energy Goal Game

The Daily Energy Goal Game widget provides a way for players to earn points by reducing their current energy consumption from a baseline. This baseline can be calculated using historical data or dynamically throughout the competition. Both the baseline data and the current consumption is typically provided by API calls from Makahiki to an underlying WattDepot server. Figure 3.4 illustrates this widget.

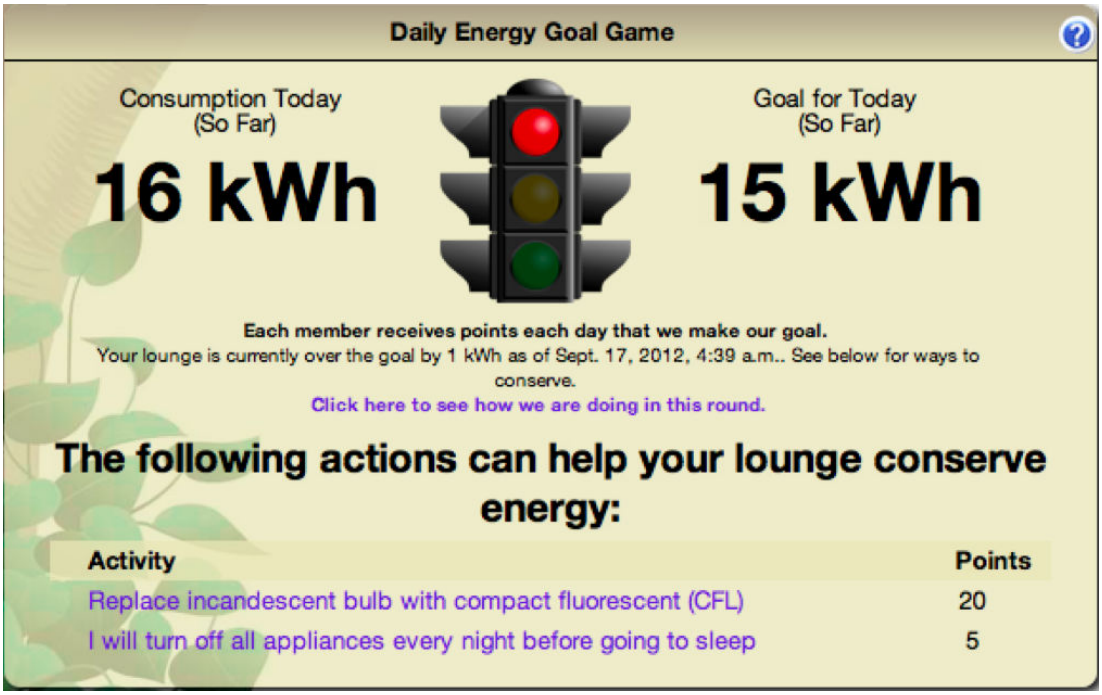


Figure 3.4. *Daily Energy Goal Game widget*

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

The Daily Energy Goal display shows both their current progress and their goal so far. We have noticed that our participants use more energy at night rather than during the day. Thus, it

is easy to be under their actual energy goal for most of the day and then jump over the goal at the very end. Displaying their progress toward the goal so far provides a pace for players to follow.

3.2.4 Raffle Game

The Raffle Game widget provides a way to incentivize participation from all individuals, even those who are not in the running for a top prize. For every 25 points a player earns, they receive one virtual raffle ticket. Players can dynamically allocate their tickets to any raffle prizes they are interested in at any time, up to the end of the raffle. Figure 3.5 shows an example of the Raffle Game.

Figure 3.5. *Raffle Game widget*

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

3.2.5 Social and Referral Bonuses Game Mechanics

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

The social bonus is an configurable option when an action is created in the Smart Grid Game. Players earn extra points if they perform the action with another player. Examples of actions with a social bonus include attending an event, recording a song related to energy, or measuring a shower water flow rate. When a player submits a response for an action with a social bonus, the player can provide the email address of the person who jointly completed the action. Once the other player completes the action, the social bonus is awarded. Social bonuses are not bi-directional; if the second player doesn't provide the first player's email address, only the first player will get the social bonus.

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

3.2.6 Quest Game Mechanics

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

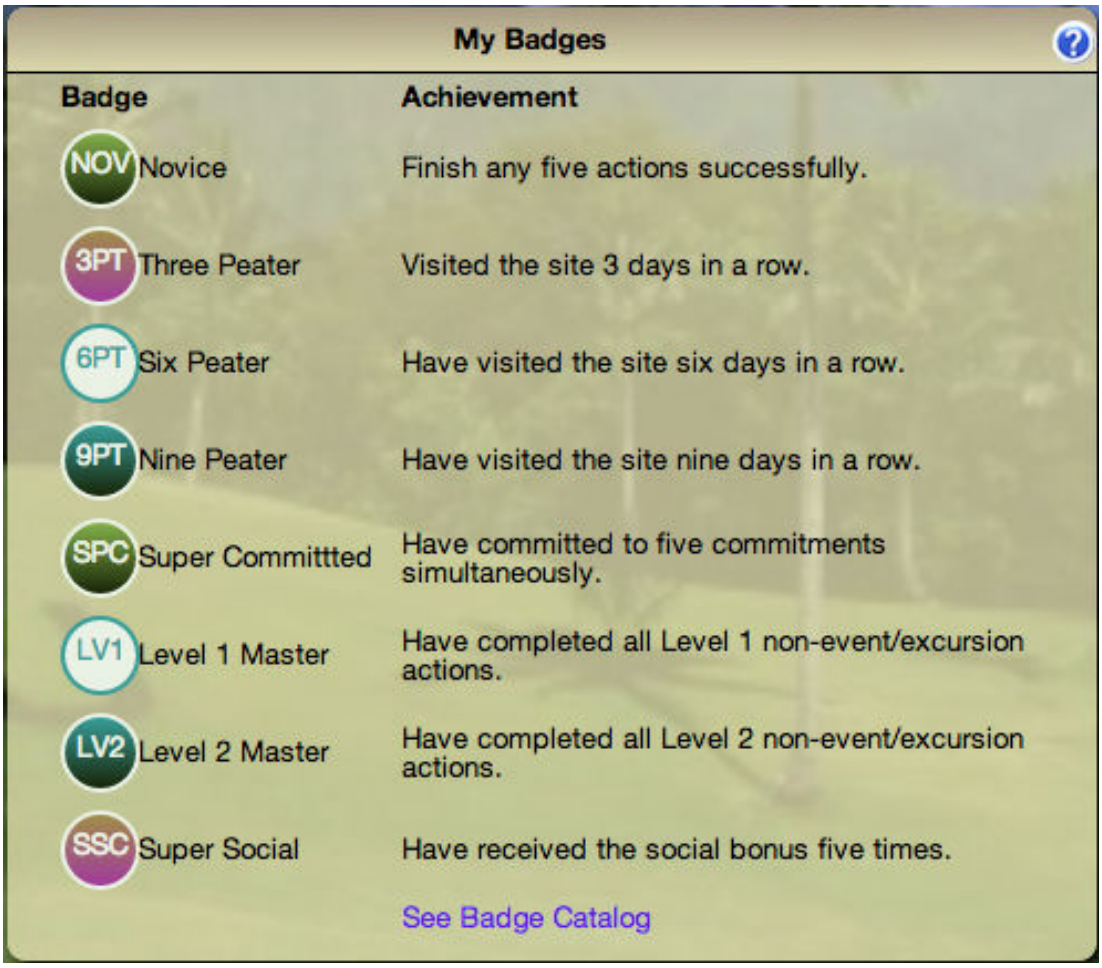


Figure 3.6. Badge widget

3.2.7 Badge Game Mechanics

Makahiki provides the popular badge game mechanics that could be used to motivate and engage players to interact with the game in different ways. The badge mechanics is implemented in a customizable way which game designers could create as many badges as they like. The badge could be triggered by certain award condition, which is defined by the flexible predicative system in Makahiki. Figure3.6 shows an example of the badges available in the Makahiki system:

3.3 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 3.7 shows an example of two game analytic widgets.

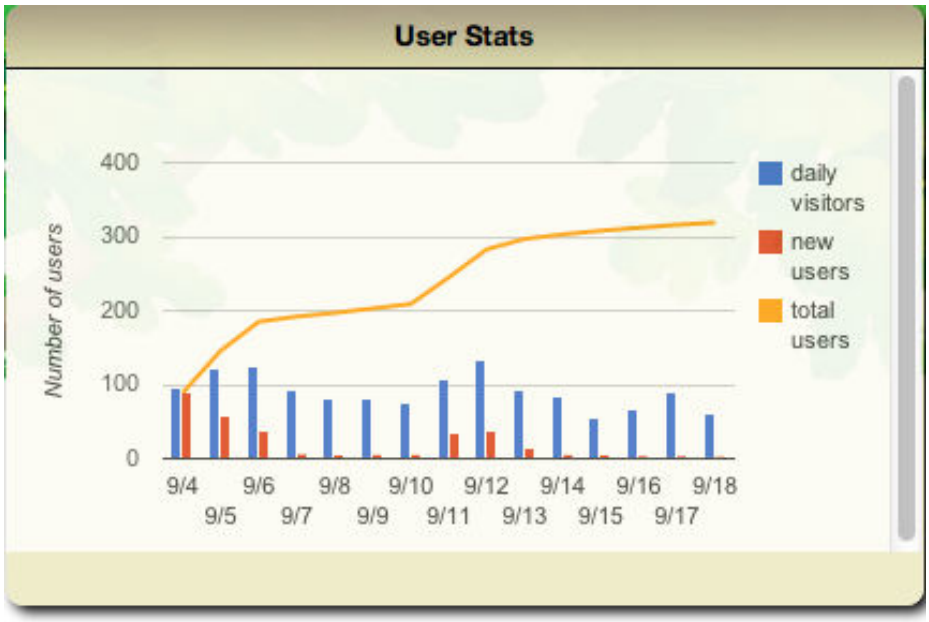
The top widget, User Stats, shows trends in the total number of players, the total number of new users, and the total number of players visiting the site each day. The bottom widget provides information on the ability of teams to achieve their daily energy goal each day and over time.

3.4 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 3.8 shows the Makahiki admin interface to configure the resources.

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 the responsive web design technology to support multiple devices, to enhance the players experience. Figure3.9 shows the responsive interface in Makahiki that supports both desktop view and mobile view with the same code base.



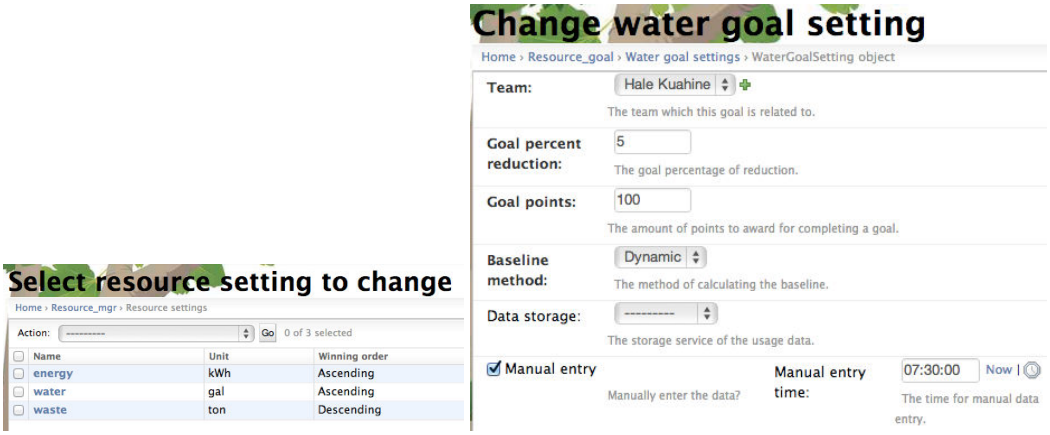
Energy Goal Status

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

Figure 3.7. Game analytic widgets: User Stats and Energy Goal Status

3.6 Cloud deployment support

Another feature we implement in Makahiki is the ability to deploy to the 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. Figure3.10 shows a screen shot of the Dashboard showing the 2012 East West center Kukui challenge deployed in



(a) Supported resource types (b) Manual resource

Figure 3.8. Configurable resource

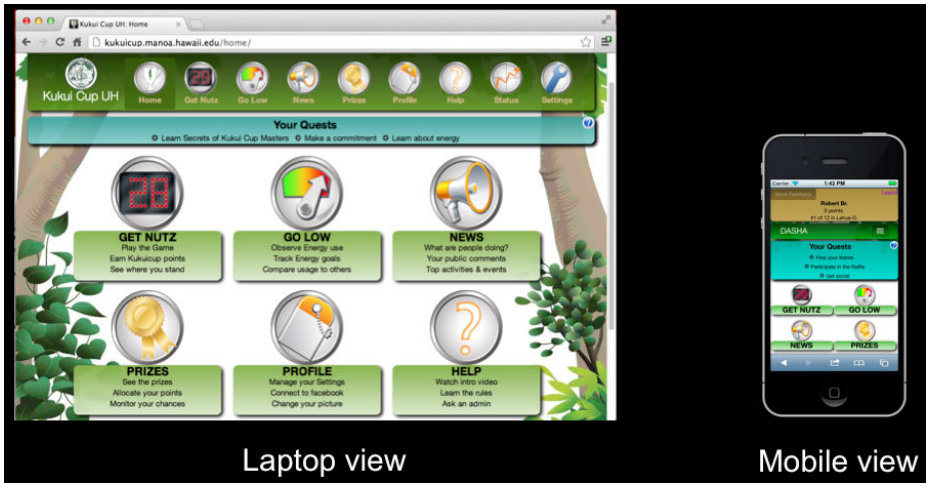


Figure 3.9. Responsive design supports both desktop and mobile

the Heroku, one of the cloud platform provider. The monthly cost for the IT infrastracture in this instance is fairly affordable.

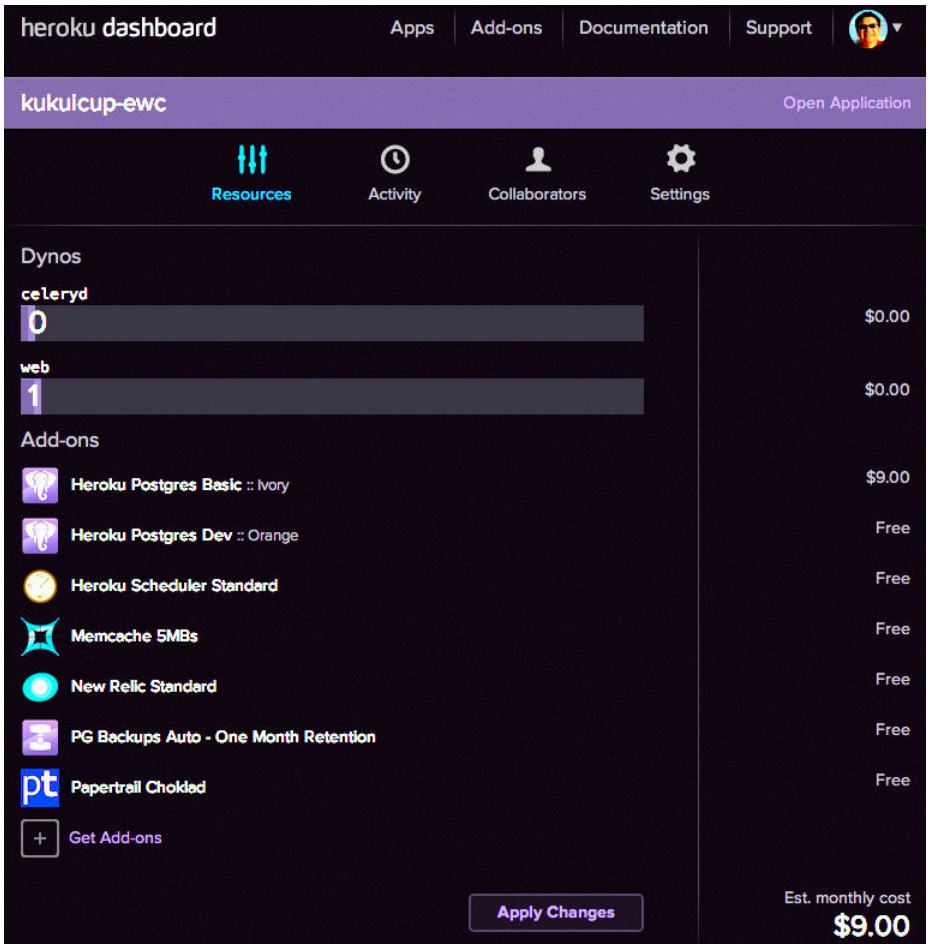


Figure 3.10. Heroku cloud deployment

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 the overview of SGSEAM, followed by the discussion of assessment methodology, and the details of the assessment method.

4.1 Overview of SGSEAM

The goal of SGSEAM is to identify (a) major strengths of a serious game framework, which aids the community by indicating features of the framework to emulate, and (b) major shortcomings of the framework, which aids the community by indicating features to avoid. The target audiences of SGSEAM are the developers of the serious game framework.

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 energy data collection if the serious game requires energy 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 assess the experiences of the players, system admins, game designers, game managers, and game developers, which are closely related to software infrastructure.

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

4.2 Assessment Methodology

Creswell [10] categorizes research methods into three approaches: quantitative, qualitative, and mixed methods, according to what knowledge claims are being made and how knowledge is acquired. Quantitative method reflects a post-positivist paradigm where hypotheses are specified *a priori* and tested by experimental design. Qualitative method reflects a constructivist or participatory paradigm where knowledge would be acquired by observation and open-ended design. SGSEAM employs the mixed methods approach which based on pragmatic knowledge claims and assumption that collecting diverse types of data provides better understanding of the research problem: assessing the strengths and shortcomings of a serious game framework.

In SGSEAM, the concurrent triangulation strategy 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).

4.3 Stakeholder Experience Assessment

SGSEAM follows closely with the "Goal-Question-Metric" (GQM) approach [7] 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. There are many metrics related to user experiences [50], SGSEAM focus on the metrics that is 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 is described.

The following describes the three steps in using SGSEAM to assess a serious game framework:

- ***Step 1: Identify all the potential stakeholders of the framework and categorize them as SGSEAM stakeholders.***

  For each stakeholder, identify the population, the name and contact if possible. For example, the player stakeholder could be identified as the users interact with the game interface, perform certain tasks given by the interface, or winning the prize. 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.

- ***Step 2: For each stakeholder, identify the important tasks which interact with the framework.***

  For example, the players interact with the game interface; the system admins install, backup, monitor the software system; the game designers create the content for the game and design what game mechanics to used; the game managers manage the game during the game period; and the game developers develop enhancement, customization using the framework.

- ***Step 3: Determine the appropriate assessment approaches for each stakeholder.***

  The appropriate assessment approaches should be determined according to the resource available. Sometimes it is impossible or really hard to implement a certain approach. The more approaches applied, the higher confidence of the assessment can be achieved. The following sections describe in detailed the different approaches for each stakeholder. Each assessment approach describes 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.

Table 4.1 provides the different approaches of the assessment method for each stakeholder:

Stakeholder	Assessment Goal	Assessment approaches
Players	To what extent does the framework affect players? To what extent does the framework engage players?	Pre-Post effectiveness study, Self-reported usability metrics, Player Assessment Approach: Engagement Metrics
System admins	How easy is it to install and maintain the system?	System Admin Assessment Approach: Post-loc Syste In-lab installation study
Game designer	How easy is it to design a game?	Game Designer Assessment Approach: Post-hoc Gan Game designer assessment approach: In-lab game de Game design log data analysis
Game managers	How easy is it to manage a game?	Game Manager Assessment Approach: Post-hoc Gan Game manager assessment approach: In-lab game ma Game management log data analysis
Game Developers	How easy is it to enhancing the system?	Game Developer Assessment Approach: Post-hoc Ga Game developer assessment approach: In-lab game d

Table 4.1. Overview of SGSEAM

There are usually multiple assessment approaches for a specific question. The approaches listed above can be generally categorized into in-vivo and in-vitro assessments. The in-vivo approaches, such as pre-post test, in-game surveys and 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. 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, while in-game surveys or interviews in the in-vivo

approach typically collect data from different settings but the data reflect the real world interaction between the stakeholders and the framework.

The details of the individual assessment approach for each stakeholder are described in the following sections. These approaches for each stakeholder can be additive. The more approaches applied, the higher confidence of the assessment for the stakeholder.

4.3.1 Player Assessment

The goal of player assessment is to determine the effectiveness of the game framework from player's perspective. It is essential that a game produced by a serious game framework could achieve its intended "serious" purpose. The intended purposes of serious games are always subject specific. For example, the desired effect of a serious game for energy education and conservation is to increases players' energy literacy and reduces their energy consumption during (and, hopefully, after) the game. A serious game for language learning would have a very different desired effect.

4.3.1.1 Pre-Post effectiveness study

Users of SGSEAM could use domain-specific questions to assess the desired effects of their serious game. For example, the following question could be used to assess a serious game for sustainability education: To what extent does the game increase player's literacy in sustainability?

One approach to assess the question of the effectiveness is a quasi-experimental pre-post study. A set of survey questionnaires can be presented to a random selection of the players before the game (pre-test). After the game ends, the same survey (post-test) is presented to the players who responded the pre-test survey. These two set of survey response data are compared to understand if the game has had an impact on the survey subjects. The extent of the changes reflected in the survey result could indicate the degree of effectiveness of the serious game for this subject.

Other measurements, for example, the energy consumption data in a energy challenge serious game, could be collected before and after the game to determine the extent of changes that may be caused by the participation in this serious game.

4.3.1.2 Self-reported usability metrics

Another approach for assess the players' experience is to interview players about their self-reported experience with the game. The interview could be administrated via a face-to-face conversation or through online survey. We found that the online survey is more cost effective than face-to-face

conversation. In additions, the online survey could be potentially implemented as part of an activity inside the game, as in the case of the Kukui Cup serious game.[4]. Some of the sample interview questions are included in the followings:

Open-ended questions:

- What did you like most about the website/game?
- What did you found confusing?
- What issues did you have while using the site/game?
- What was the thing you liked the least about the site/game?
- What can we do to improve the site/game?

Close-ended questions with Likert scale from ”Strong disagree” to ”Strongly agree”:

- It was easy to find what I was looking for on the website
- The website was responsive
- The website provided adequate help in teaching me how to play
- I understood how to play
- this is something my friends should participate in

4.3.1.3 Engagement metrics

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 could be an interesting research area.

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

- participation rate
- number of players per day
- play time of a player per day
- submissions of all player per day

- social interaction of all player per day
- website errors per day

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

4.3.2 System Admin Assessment

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

4.3.2.1 Post-hoc system admin interview

One approach to assess the question of how easy it is to install and maintain the system is a post-hoc interview. The actual system admin(s) are asked about their experience after their installation in the production system. The interview includes the following questions:

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

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

4.3.2.2 In-lab installation study

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

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

4.3.3 Game Designer Assessment

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

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

There are three approaches for game designer assessment:

4.3.3.1 Post-hoc game designer interview

One approach is to interview the actual game designer(s) after they had completed the design in a production system. The following questions will be asked:

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

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

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

4.3.3.2 In-lab game design study

Another approach is an in-lab experimental study, where a goup of participants is asked to use the system to perform a same set of design tasks. The time spent and problems encountered are recorded for each tasks. The assessor will triangulate the reported time data and the problem categories to identify the strengths and weaknesses.

4.3.3.3 Game design log data analysis

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

4.3.4 Game Manager Assessment

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

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

Similar to the assessment of game designer experience, SGSEAM includes three approaches.

4.3.4.1 Post-hoc game manager interview

The post-hoc interview approach gather data from the game manger(s) by asking the following questions:

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

4.3.4.2 In-lab game management study

The experimental study approach gather data from a group of participants about the time spent and problems encountered for each task of managing the serious game.

4.3.4.3 Game management log data analysis

The log data analysis collects 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.

4.3.5 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 process.

4.3.5.1 Post-hoc game developer interview

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

- How much time did you spend developing a customization using the game framework?

- What problem(s) did you encounter?
- Did you find it difficult to understand, extend and debug the system? What was difficult?

4.3.5.2 In-lab game development study

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

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

Chapter 5

Makahiki and SGSEAM Evaluation

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

5.1 Makahiki Assessment Overview

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

5.1.1 Real-world Makahiki Instances Case Studies

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

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

5.1.2 In-lab Makahiki Experiment Case Studies

In Spring 2012, Professor Philip Johnson at the Information and Computer Science Department of University of Hawaii used Makahiki to teach a course in serious game development. The students 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.

These students participated in the assessment experiments of Makahiki, in the aspects of system admin efficiency, game designer efficiency and developer efficiency. 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.

5.2 Makahiki Assessment

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

5.2.1 Player assessment

I 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 detailed logging data from every interaction between the players and the website.

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

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

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

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

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

5.2.2 System admin assessment

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

In the in-lab experiments, the students in the ICS691 Spring 2013 class were tasked with installing the Makahiki system into their local computers as well as the cloud environment. In order to understand how much time it takes to install the Makahiki and what problems might be

encountered, I design a Google form which details the steps of installing Makahiki both locally and in the cloud, and for each step, I ask the students to record the time they spent and the problems they encountered.

Figure 5.1 illustrates a partial google form used for Makahiki system admin assessment. Appendix D 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 will analyze qualitative data collected from the interviews and email changes. The data include:

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

5.2.3 Game designer assessment

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

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

5.2.4 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

5.2.5 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.

Chapter 6

Results

The following Figure 6.1 provides the overview of applying SGSEAM to Makahiki.

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

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

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

Besides the real world usage of Makahiki in the series of Kukui Cup challenges, we performed in-lab assessment experiments in 2013. Makahiki was used in a serious game development course in Spring semester of 2013 at the Information and Computer Sciences Department of the University of Hawaii at Manoa. There were a total of 8 students who participated in the experiments.

Stakeholder	Assessment	Completed	Proposed work
Players	Pre Post effectiveness study	UH KC 2011	
Players	Self-reported usability metrics		UH KC 2011, 2012, 2014
	Engagement metrics		UH KC 2011, 2012, 2014
System admins	In-lab installation study	ICS691 2013	
	Post-hoc system admin interview		HPU KC 2012, 2013
Game designers	In-lab game design study	ICS691 2013	
	Post-hoc game designer interview		HPU KC 2012, 2013
Game managers	In-lab game management study	ICS691 2013	
	Post-hoc game manager interview		HPU KC 2012,2013
Developers	In-lab game development study	ICS691 2013	
	Post-hoc game developer interview		UH 2014

Figure 6.1. Status of Makahiki assessment

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.

6.1 Makahiki Player Assessment

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

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

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

To assess player engagement of the game, we calculated a variety of engagement metrics. The results are shown in Figure 6.2:

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

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

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

Figure 6.2. Makahiki Engagement Metrics

6.2 Makahiki System Admin Assessment

System admin assessment was done using an in-lab experiment. Students in a serious game class were tasked with installing the Makahiki system into their local computers. In order to understand how much time it takes to install Makahiki and what problems might be encountered, we designed a Google Form explaining the steps required to install Makahiki. We asked the students to record the time they spent completing each step and the problems they encountered. We also asked the students to provide feedback about their installation experiences in the form of blog posts. [54] describes in detailed the Google Form that is used in this assessment.

The results from the Google Form responses show that the average total time to successfully install Makahiki was 1.4 hours, with a maximum time of 2 hours and the minimum time of 0.9 hour. Figure 6.3 shows the average time for each installation step.

We coded and categorized the descriptive problems reported by the students in both the Google Form and their blog posts. Figure 6.4 shows the result of the analysis from the feedback of the 8 students that participated in the experiment.

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.

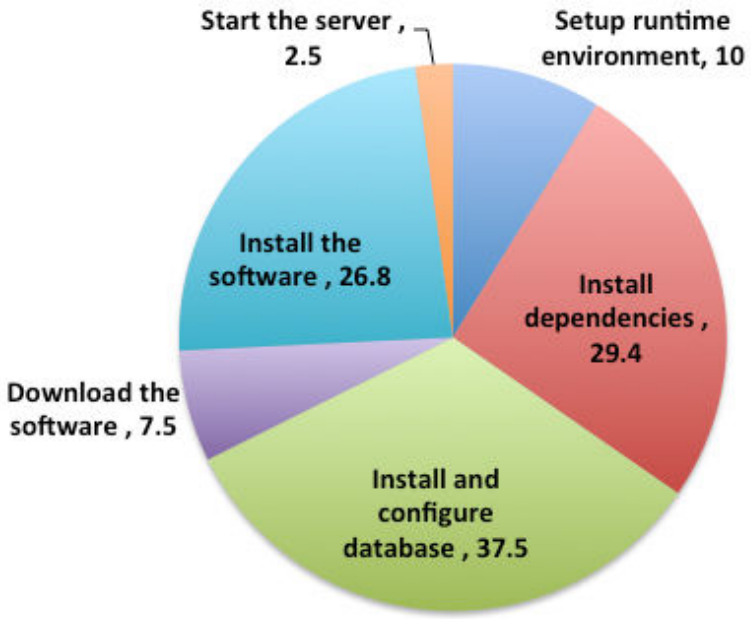


Figure 6.3. Average time (minutes) for installation steps (n=8)

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

Figure 6.4. Makahiki Installation Analysis (n=8)

6.3 Makahiki Game Designer Assessment

We also used the in-lab experiment to assess the game designer experience of Makahiki. One of the class assignments for the students in the experiment was to design a serious game using the Makahiki framework. We asked the students to follow specific design steps and record the time required and any problems encountered during their design process, using a Google Form similar to the one used for the system admin assessment. In addition, students were asked to provide feedback about their design experiences in the form of blog posts. [54] describes in detailed the Google Form that is used in this assessment.

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

Figure 6.5 shows the average time for each design tasks:

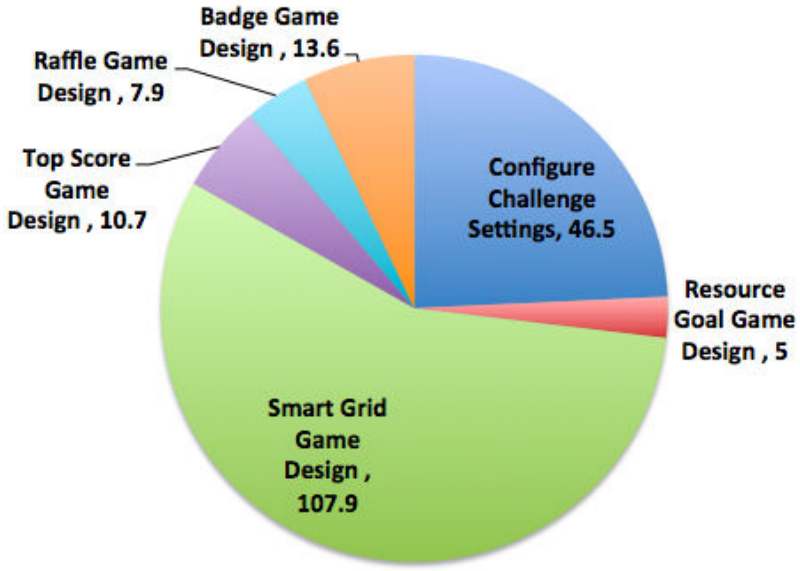


Figure 6.5. Average time (minutes) for design tasks (n=8)

We aggregated the problems reported in the feedback of the 7 students that participated in the experiment. Figure 6.6 shows the result of the analysis:

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

Figure 6.6. Makahiki Game Design Analysis, (n=8)

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

6.4 Makahiki Developer Assessment

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

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

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

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

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[30] 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.

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, 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)*, 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 Papers

- 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.

Appendix B

Serious Game Stakeholder Experience Assessment Method (SGSEAM) User Guide

This appendix includes the SGSEAM assessment user guide that can be used to guide an assessment to a serious game framework.

B.1 SGSEAM Overview

One of the benefits of using a serious game framework is that, if correctly designed, it will provide useful and reusable "building blocks" with which to develop a variety of serious games. Yet how are we to know if a serious game framework has been "correctly designed"?

Serious Game Stakeholder Experience Assessment Method (SGSEAM) describes a method for assessing serious game frameworks from the stakeholder experience perspectives. 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.

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.

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

Figure B.1. Applying SGSEAM to a framework

There are three steps in the process of applying SGSEAM. Step one is to plan the assessment, including identifying the stakeholder and participants and creating the assessment plan. The deliverable for this step is the assessment plan document. Step two is to gather data. The deliverable for this step is the assessment data repository. Step three is to produce the strength and weakness report. The deliverable for this step is the action document for framework improvement. The following chapters describe the steps in details.

B.2 Plan Assessment

B.2.1 Identify stakeholders

Identify the stakeholders in each SGSEAM stakeholder class, write down their names and roles.

SGSEAM assesses the experiences for the stakeholders listed in Table B.1. For each stakeholder, identify the population, the name and contact if possible. 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.

B.2.2 Determine assessment approach

Determine the appropriate assessment approaches for each stakeholder.

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

Table B.1. SGSEAM Stakeholders

There are usually multiple assessment approaches for each stakeholder. Table E.11 provides an overview of the assessment method and the approaches. The appropriate assessment approaches should be determined according to the resource available. The approaches for a stakeholder is additive. The more approaches applied, the higher confidence of the assessment can be achieved.

The assessment approaches is categorized into in-vivo and in-vitro assessments. The in-vivo approaches, 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. 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 rigor 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 less rigor. But the in-invo data reflect the real world interaction between the stakeholders and the framework, thus provides better insights in the real world settings.

The following sections describe in detailed 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.

Stakeholder	Assessment goal	Assessment approaches
Player	Determine the extent the framework affect and engage players.	Pre-post effectiveness study(E.6.1); Self-reported usability metrics(4.3.1.2); Engagement metrics(E.6.3)
System admin	Determine strengths and weaknesses in system install and maintenance.	Post-hoc admin interview(E.7.1); In-lab system admin study(E.7.2)
Game designer	Determine strengths and weaknesses in facilitating the game design process.	Post-hoc designer interview(E.8.1); In-lab game design study(E.8.2)
Game manager	Determine strengths and weaknesses in managing the game.	Post-hoc manager interview(E.9.1); In-lab game management study(E.9.2)
Game developer	Determine strengths and weaknesses in developing system enhancement.	Post-hoc developer interview(E.10.1); In-lab game development study(E.10.2)

Table B.2. SGSEAM approaches

B.2.3 Choose participants

Identify participants from each stakeholder class, Contact them and get consents for their participation.

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 consents 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.

B.2.4 Create assessment plan

Create a schedule for each assessment, produce the assessment plan document.

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

Depends on the assessment approach, the actual tasks of the assessment are different. The player pre-post effectiveness study requires the administration of 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. Figure B.2 shows an example of the assessment schedule broken down in 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		

Figure B.2. Assessment schedule in the plan document

B.3 Gather Data

This step carries out the assessment, record the data, obtain log data, and refine the assessment plan if necessary. The output of this step is a data repository contains all the assessment data that can be analyzed in the next step.

B.3.1 Carry out the assessment

Carry out the assessment as described in the assessment plan.

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

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

B.3.2 Obtain log data

Obtain the log data from the framework, including all the interaction log from the each stakeholder.

Talk to the technical staffs 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.

B.4 Produce Strength and Weakness Report

This step analyzes all the data gathered from previous steps, interpret the strengths and weakness of the framework, and produce the action report regarding to what areas of the framework needs to improve on.

B.5 Analyze data

Analyze the data from the data repository.

This step performs the data analysis from the data repository obtained from the previous step. For game designer assessment, perform queries from user interaction log data to find out the completion time for a certain user interaction 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.

B.5.1 Interpret strength and weakness

Interpret strengths and weaknesses of framework from the data analysis.

From the data analysis step, identified the problem areas which are indicated by having the most reported problems and the longest completion time.

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 this problem happened in one of the tasks that took the longest time to complete, we could identify a weakness area of the framework from the perspective of game designer. If there were no problem reported in some game design tasks and the time to complete is short, we could consider those areas are the strengths of the framework.

B.5.2 Produce reports with actionable steps

Produce the action reports for any improvement identified from the strength and weakness analysis.

Once the strength and weakness 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 the strength areas that the framework needs to maintain.

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

Appendix C

In-Game Questionnaire

This appendix details the contents of the questionnaire made available to participants via the in-game questionnaire during the challenge.

When participants filled out the questionnaire via the SurveyGizmo [47] website, the questions were broken into pages. Each page provided participants the ability to move forward to the next page in the questionnaire, but not back to previous pages.

C.1 Gamification

This section primarily covers questions about the game aspects of the challenge.

22. 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

23. Which of the followings Kukui Cup achievements would you want to share on Facebook? (choose all that apply)

- □ made a commitment
- □ participated in an activity
- □ attended an event or excursion
- □ earned a badge
- □ current leader in the scoreboard
- □ other

24. 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

25. How would you describe the Kukui Cup? (check all that apply)

- □ Fun

- □ Educational
- □ So-so
- □ Boring
- □ Not useful
- □ Difficult
- □ Addictive
- □ Other

26. 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

27. 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

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

29. On average, how many hours a week did you spend at Kukui Cup events?

C.2 General Feedback

This section covers feedback on the challenge overall.

30. What can we do to improve participation in the Kukui Cup website?

31. What was the best thing you liked about the Kukui Cup so far?

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

33. 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: _____

34. 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

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

Appendix D

Google Forms for In-lab Evaluation Experiments

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

D.1 System admin Assessment

There are two forms to assess the system admin efficiency.

D.1.1 Makahiki Local Installation Log

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

Thank you!

* Required

2.1.1.1.1.2. Install Python *

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

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

- 10 minutes
- 30 minutes
- 1+ hour

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

2.1.1.1.1.3. Install C Compiler *

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

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

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

2.1.1.1.1.4. Install Git *

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

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

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

2.1.1.1.1.5. Install Pip *

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

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

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

2.1.1.1.1.6. Install Virtual Environment Wrapper *

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

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

Record the problem you encountered when installing virtual environment wrapper:

2.1.1.1.1.7. Install Python Imaging Library *

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

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

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

2.1.1.1.1.8. Install PostgreSQL *

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

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

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

2.1.1.1.1.9. Install Memcache *

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

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

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

2.1.1.1.1.10. Download the Makahiki source *

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

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

Record the problem you encountered when download the Makahiki source:

2.1.1.1.1.11. Workon Makahiki *

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

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

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

2.1.1.1.1.12. Install required packages *

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

- 5 minutes
- 10 minutes

- 30 minutes
- 1+ hour

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

2.1.1.1.1.13. Setup environment variables *

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

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

Record the problem you encountered when setting up environment variables:

2.1.1.1.1.14. Initialize Makahiki *

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

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

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

2.1.1.1.1.15. Start the server *

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

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

Record any problem you encountered when starting the server:

2.1.1.1.1.16. Verify that Makahiki is running *

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

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

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

Your UH email: *

D.1.2 Makahiki Local Installation Log

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

Thank you !

* Required

2.1.1.2.1. Install Heroku *

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

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

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

2.1.1.2.2. Add your SSH keys to Heroku *

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

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

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

2.1.1.2.3. Verifying your Heroku account *

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

- 0 minute (Already installed from previous assignments)

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

Record any problem you encountered when verifying your Heroku account:

2.1.1.2.4. Setup Amazon S3 *

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

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

Record any problem you encountered when setting up S3:

2.1.1.2.5. Setup environment variables *

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

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

Record any problem you encountered when setting up environment variables:

2.1.1.2.6. Download the Makahiki source *

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

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

Record any problem you encountered when download the Makahiki source:

2.1.1.2.7. Initialize Makahiki *

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

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

Record any problem you encountered when initializing Makahiki:

2.1.1.2.8. Start the server *

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

- 5 minutes
- 10 minutes

- 30 minutes
- 1+ hour

Record any problem you encountered when starting the server:

2.1.1.2.9. Verify that Makahiki is running *

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

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

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

Your UH email: *

D.2 Game designer Assessment

There is one form to assess the game designer efficiency.

D.2.1 Makahiki Configuration and Management Log

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

Thank you !

* Required

0. Update your Heroku Makahiki instance *

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

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

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

1. Getting to the challenge design page *

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

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

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

2. Design the global settings *

Read the "Design the global settings" section in Makahiki Manual (http://makahiki.readthedocs.org/en/latest/challeng
design-name-settings.html). In your Heroku instance, change the "Name" of the challenge and the "Logo" fields to ones of your choosing. Test that your change is in effect by checking the Logo image and label at the top of any page. Record the time you spent for this step only:

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

Record any problem you encountered in this step:

3. Design the teams *

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

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

Record any problem you encountered in this step:

4. Set up users *

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

- 5 minutes
- 10 minutes
- 30 minutes

- 1+ hour

Record any problem you encountered in this step:

5. Specify the games to appear in your challenge *

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

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

Record any problem you encountered in this step:

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

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

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

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

- 5 minutes
- 10 minutes
- 30 minutes

- 1+ hour

Record any problem you encountered in this step:

7. Learn about how to design Smart Grid Games *

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

7.0. Design on paper *

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

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

Record any problem you encountered in this step:

7.1. Create a Level *

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

- 5 minutes

- 10 minutes
- 30 minutes
- 1+ hour

Record any problem you encountered in this step:

7.2 Create a new Activity action *

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

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

Record any problem you encountered in this step:

7.3 Create a new Event action *

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

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

Record any problem you encountered in this step:

7.4 Create a new Commitment action *

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

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

Record any problem you encountered in this step:

7.5 Finalize the grid *

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

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

Record any problem you encountered in this step:

8. Design the Top Score Game *

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

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

Record any problem you encountered in this step:

9. Design the Raffle Game *

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

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

Record any problem you encountered in this step:

10. Design the Badge Game Mechanics *

Read the ”Design the Badge Game Mechanics” section in the Makahiki Manual (http://makahiki.readthedocs.org/en/l
design-game-admin-badge.html). Create a new badge with an award trigger type of ”smartgrid”. Specify some kind of awarding condition depending on the smartgrid operations. Verify that your badge shows up in the badge catalog page and you can be awarded the new badge by doing the specified smartgrid action. Record the time you spent for this section only:

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

Record any problem you encountered in this step:

11. Manage Action submissions *

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

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

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

Your UH email: *

Appendix E

SGSEAM Assessment Guide for Lucid BuildingOS and BuildingDashboard

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

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

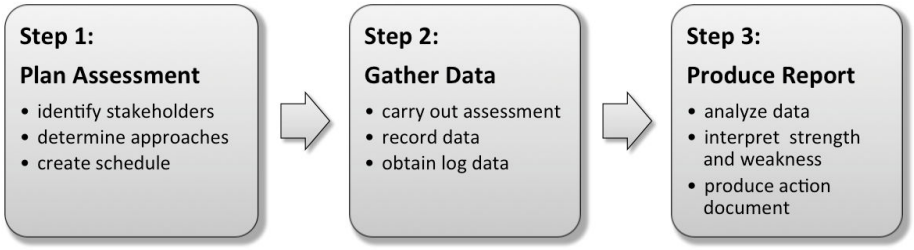


Table E.1. Applying SGSEAM to a framework

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 strength and weakness 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.

E.2 Step 1: Plan Assessment

E.2.1 Identify Stakeholders

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

SGSEAM Stakeholder	BuildingOS Users	Tasks	Comments on stakeholder definitions
Player	Building resident	Use BuildingDashboard to view building data and participate in the competition.	
System admin	Internal system admin or developer	Install software, backup, patch, monitor and scale the system.	
Game designer	Behavior Change Manager, Technical Manager, Competition Director, Research Manager	• Decide on a competition format/structure • Set up buildings, meters, and competition in BuildingOS	
Game manager	Technical Manager, Marketing Manager, Building Captain Manager, Events Manager	• Collect, verify baseline and competition data, enter into BuildingOS • Kick-off and other events • Coordinate competition prizes • Manage social media • Monitor competition status	
Game developer	Internal or external Developer	• Develop interface to support other meters • Customize dashboard interface	

Table E.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 E.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.

E.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. Section E.5 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 E.3 shows the approaches we recommend for each stakeholder.

Stakeholder	Assessment Approaches	Expected Outcomes	Comments on approach
Player	Pre-post effectiveness study	Determine effectiveness in resource usage reduction.	
	Usability survey	Identify problem areas in game interface	
	Engagement metrics	Determine the extent of engagement	
System admin	Post-hoc admin interview	Identify strengths and weaknesses in the installation and maintenance process.	
Game designer	Post-hoc designer interview	Determine strengths and weaknesses in the game design interface.	
Game manager	Post-hoc manager interview	Determine strengths and weaknesses in the game managing interface.	
Game developer	Post-hoc developer interview	Determine strengths and weaknesses in developing enhancement.	

Table E.3. BuildingOS Assessment Approaches

Refer to Section E.5 for the detailed 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.

E.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.

Stakeholder	Person name(s)	Organization(s)	Contact(s)
Player(s)			
System admin(s)			
Game designer(s)			
Game manager(s)			
Game developer(s)			

Table E.4. Choose Participants

Table E.4 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.

E.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 E.5.

Week	CCN Milestone	CCN Task	SGSEAM Task	Comments on schedule
Mar 3 - 7		Set up buildings, meters, and competition in BuildingOS	Finalize stakeholders and assessment approaches	
Mar 10 - 14		Data collection dry run week, troubleshooting and resolve problems	Finalize interview and survey questionnaires	
Mar 17 - 21	Baseline (2 weeks)	Collect & verify baseline data	Choose participants	
Mar 24 - 28				
Mar 31 - Apr 4	Competition (3 weeks)	Kick-off, Collect competition data, Enter data into BuildingOS, manage events, Social media		
Apr 7 - 11				
Apr 14 - 18				
Apr 21 - 25		Collect, verify and enter final competition data into BuildingOS	Obtain log data, System admin post-hoc interview	
Apr 28 - May 2			Player effectiveness & usability study	
May 5 - 9			Game designer post-hoc interview	
May 12 - 16			Game manager post-hoc interview	
May 19 - 23			Game developer post-hoc interview	
May 26 - 30			Analyze data, interpret strength and weakness, produce action document	

Table E.5. Assessment Schedule

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.

E.2.5 Assess Player Stakeholder Experience

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 E.6.

1. Player Pre-Post Effectiveness Goals		
Category	Goals	Comments
Education	50% of players can name three things to save electricity	
Behavior Change	50% of players did one thing that reduces their consumption	
	20% of players made at least 1 conservation commitment	
Resource Reduction	3% of average reduction	
2. Player Usability Survey Questionaire		
Question	Response type	Comments
1. What did you like most about the game?	short answer	
2. What did you found confusing?	short answer	
3. What issues did you have while using the game?	short answer	
4. What was the thing you liked the least about the game?	short answer	
5. What can we do to improve the game?	short answer	
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	
3. Player Engagement Metrics Goals		
Metric	Goals	Comments
participation (percentage of players who participated in the game)	30%	
daily player (average percentage of players per day)	5%	
daily play time (average play time of a player per day)	5 minutes	
submission (average submissions of a player)	2%	
social interaction (average social interaction of a player)	2%	
game error (percentage of players who encountered errors)	1%	

Table E.6. Player Assessment

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.

E.2.6 Assess System Admin Stakeholder Experience

We recommend the post-hoc interview approach for system admin assessment. The attached spreadsheet outlines the planned interview questionnaires, as shown in Table E.7.

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.

System admin Post-hoc Interview Questionnaires	Comments on question
1. How much time did you spend to install the system and the dependencies?	
2. How much time did you spend to configure the meters?	
3. How much time did you spend to maintain the system such as backup, patching, monitoring?	
4. Did you need to scale the system? if Yes, how much time did you spend?	
5. What problems did you encounter?	
6. Did you find it difficult to admin the system? What was difficult?	
7. Can we call you for a short phone interview if we have more questions regarding your experience with the system?	

Table E.7. System Admin Assessment

E.2.7 Assess Game Designer Stakeholder Experience

We recommend the post-hoc game designer interview approach for assessing game designer stakeholder experiences. The attached spreadsheet outlines the planned interview questionnaires for game designer, as shown in Table E.8.

Game Designer Post-hoc Interview Questionnaires	Comments on question
1. How much time did you spend to set up the buildings including meters?	
2. How much time did you spend to setup the competition (competition periods, baseline period, participants)?	
3. How much time did you spend to setup the homepage by deciding which widgets to include?	
4. How much time did you spend to monitor analytical data to understand the state of the game	
5. What problems did you encounter?	
6. Did you find it difficult to use the interface? What was difficult?	
7. Do you agree for us to call you for a short phone interview if we have more questions regarding your experience with the system?	

Table E.8. Game Designer Assessment

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.

E.2.8 Assess Game Manager Stakeholder Experience

We recommend the post-hoc interview approach for game manager assessment. The attached spreadsheet outlines the planned interview questionnaires, as shown in Table E.9.

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.

Game Manager Post-hoc Interview Questionnaires	Comments on question
1. How much time did you spend to enter the meter data manually for the baseline period?	
2. How much time did you spend to enter the meter data manually for the competition period?	
3. What problems did you encounter?	
4. How much time did you spend to monitor analytical data to understand the state of the game	
5. Did you find it difficult to manage? What was difficult?	

Table E.9. Game Manager Assessment

E.2.9 Assess Game Developer Stakeholder Experience

We recommend the post-hoc game developer interview approach for assessing game developer stakeholder experiences. The attached spreadsheet outlines the planned questionnaires for game developer interview, as shown in Table E.10.

Game Developer Post-hoc Interview Questionnaires	Comments on question
1. How much time did you spend to implement the creation of a new widget?	
2. How much time did you spend to implement adding a new type of meter?	
3. What problem(s) did you encounter?	
4. Did you find it difficult to understand, extend and debug the system? What was difficult?	

Table E.10. Game Developer Assessment

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.

E.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.

E.3.1 Carry Out Assessments

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

E.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.

E.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.

E.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.

E.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.

E.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.

E.5 SGSEAM Assessment Approaches for BuildingOS

There are usually multiple assessment approaches for each stakeholder. Table E.11 provides an overview of the assessment method and the approaches. The appropriate assessment approaches should be determined according to the resource available. The approaches for a stakeholder is additive. The more approaches applied, the higher confidence of the assessment can be achieved.

Stakeholder	**Assessment goal**	**Assessment approaches**
Player	Determine the extent the framework affect and engage players.	Pre-post effectiveness study(E.6.1); Self-reported usability survey(E.6.2); Engagement metrics(E.6.3)
System admin	Determine strengths and weaknesses in system install and maintenance.	Post-hoc admin interview(E.7.1); In-lab system admin study(E.7.2)
Game designer	Determine strengths and weaknesses in facilitating the game design process.	Post-hoc designer interview(E.8.1); In-lab game design study(E.8.2)
Game manager	Determine strengths and weaknesses in managing the game.	Post-hoc manager interview(E.9.1); In-lab game management study(E.9.2)
Game developer	Determine strengths and weaknesses in developing system enhancement.	Post-hoc developer interview(E.10.1); In-lab game development study(E.10.2)

Table E.11. SGSEAM approaches

The following sections describe in detailed 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.

E.6 Player Assessment

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 proposes three approaches for assessing the player's experience with Lucid's framework.

E.6.1 Player Assessment Approach: 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 reveals the extend of effectiveness of the game produced by the framework, regarding to the resource consumption reduction.

E.6.2 Player Assessment Approach: Self-reported 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 Table E.12.

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.

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

Table E.12. Player self-reported usability survey questionnaires

This assessment reveals the strengths and weaknesses of the framework regarding the usability of the game interface.

E.6.3 Player Assessment Approach: 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 Table E.13. Calculate as many as possible the player engagement metrics. The more metrics obtained, the better understanding of the extent of player engagement.

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

Table E.13. Player engagement metrics

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.

E.7 System Admin Assessment

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 propose the post-hoc system admin interview approach to assess the system admin's experience for Lucid's framework.

E.7.1 System Admin Assessment Approach: Post-loc System Admin Interview

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:

1. How much time did you spend to install the system and the dependencies?
2. How much time did you spend to configure the meters?
3. How much time did you spend to maintain the system such as backup, patching, monitoring?
4. Did you need to scale the system? if Yes, how much time did you spend?
5. What problems did you encounter?
6. Did you find it difficult to admin the system? What was difficult?
7. Do you agree for us to call you for a short phone interview if we have more questions regarding your experience with the system?

Table E.14. System admin interview questionnaires

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.

E.7.2 System admin assessment approach: In-lab system admin study (Not Recommended for Lucid)

This approach assesses the system admin's experience using the in-lab experimental study. First identify a group of participants who have some levels of system administration experience. Second, provide instructions on each installation steps, 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 correlated with the reported time data to identify the areas of strength (less time spent) and weakness (more time spent and problems or difficulties).

Due to the cost of in-lab assessment, this approach is not recommended to Lucid BuildingOS assessment.

E.8 Game Designer Assessment

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 propose the post-hoc game designer interview approach to assess the game designer's experience.

E.8.1 Game Designer Assessment Approach: Post-hoc Game Designer Interview

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:

1. How much time did you spend to set up the buildings including meters?
2. How much time did you spend to setup the competition (competition periods, baseline period, participants)?
3. How much time did you spend to setup the homepage by deciding which widgets to include?
4. How much time did you spend to monitor analytical data to understand the state of the game
5. What problems did you encounter?
6. Did you find it difficult to use the interface? What was difficult?
7. Do you agree for us to call you for a short phone interview if we have more questions regarding your experience with the system?

Table E.15. Game designer interview questionnaires

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 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.

E.8.2 Game designer assessment approach: In-lab game design study (Not Recommended for Lucid)

This approach assesses the game designer experience using the 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 designing steps, 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 experiment 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).

Due to the cost of in-lab assessment, this approach is not recommended to Lucid BuildingOS assessment.

E.9 Game Manager Assessment

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 propose the post-hoc game manager interview approach for assessing game manager's experience.

E.9.1 Game Manager Assessment Approach: Post-hoc Game Manager Interview

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:

1. How much time did you spend to enter the meter data manually for the baseline period?
2. How much time did you spend to enter the meter data manually for the competition period?
3. What problems did you encounter?
4. How much time did you spend to monitor analytical data to understand the state of the game
5. Did you find it difficult to manage? What was difficult?

Table E.16. Game manager interview questionnaires

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.

E.9.2 Game manager assessment approach: In-lab game management study (Not Recommended for Lucid)

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 correlated with the reported time data to identify the areas of strength (less time spent) and weakness (more time spent and problems or difficulties).

Due to the cost of in-lab assessment, this approach is not recommended to Lucid BuildingOS assessment.

E.10 Game Developer Assessment

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 propose the post-hoc game developer interview approach to assess the game developer's experience.

E.10.1 Game Developer Assessment Approach: Post-hoc Game Developer Interview

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 interview is designed with the questionnaire outlined in Table E.17.

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.

1. How much time did you spend to implement the creation of a new widget?
2. How much time did you spend to implement adding a new type of meter?
3. What problem(s) did you encounter?
4. Did you find it difficult to understand, extend and debug the system? What was difficult?

Table E.17. Game developer interview questionnaires

E.10.2 Game developer assessment approach: In-lab game development study (Not Recommended for Lucid)

This approach assess the game developer's experience using the 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 some levels of the required development skills. Third, provide requirement specification or instructions on how to develop a new enhancement 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 experiment 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).

Due to the cost of in-lab assessment, this approach is not recommended to Lucid BuildingOS assessment.

Bibliography

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

[2] Florian Berger and Wolfgang Mller. Towards an open source game engine for teaching and research. In Zhigeng Pan, AdrianDavid Cheok, Wolfgang Mller, Maiga Chang, and Mingmin Zhang, editors, *Transactions on Edutainment VIII*, volume 7220 of *Lecture Notes in Computer Science*, pages 69–76. Springer Berlin Heidelberg, 2012.

[3] Torie Bosch. Score one for gamification. *Retrieved February, 2012*, 2011.

[4] Robert S. Brewer. *Fostering Sustained Energy Behavior Change And Increasing Energy Literacy In A Student Housing Energy Challenge*. PhD thesis, University of Hawaii, Department of Information and Computer Sciences, March 2013.

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

[6] Jeanne H Brockmyer, Christine M Fox, Kathleen A Curtiss, Evan McBroom, Kimberly M Burkhart, and Jacquelyn N Pidruzny. The development of the game engagement questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology*, 45(4):624–634, 2009.

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

[8] Mohammad Chuttur. Overview of the technology acceptance model: Origins, developments and future directions. 2009.

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

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

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

[12] Fred D Davis Jr. *A technology acceptance model for empirically testing new end-user information systems: Theory and results*. PhD thesis, Massachusetts Institute of Technology, 1986.

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

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

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

[16] R.H. Ellaway. Openlabyrinth: An abstract pathway-based serious game engine for professional education. In *Digital Information Management (ICDIM), 2010 Fifth International Conference on*, pages 490–495, July 2010.

[17] Fabula Engine. Fabula game engine. http://fabula-engine.org/.

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

[19] foursquare. foursquare. *http://foursquare.com/*, 2011.

[20] Gartner. Press release. *https://www.gartner.com/it/page.jsp?id=1629214*, 2011.

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

[22] Ben D Harper and Kent L Norman. Improving user satisfaction: The questionnaire for user interaction satisfaction version 5.5. In *Proceedings of the 1st Annual Mid-Atlantic Human Factors Conference*, pages 224–228, 1993.

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

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

[25] Marthe Hurteau, Sylvain Houle, and Stéphanie Mongiat. How legitimate and justified are judgments in program evaluation? *Evaluation*, 15(3):307–319, 2009.

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

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

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

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

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

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

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

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

[34] Jane McGonigal. Gaming can make a better world. *Retrieved February, 2012*, 2010.

[35] nikeplus. nikeplus. *http://nikeplus.com/*, 2011.

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

[37] Papaya Mobile. Papaya mobile social game engine. http://papayamobile.com/developer/engine.

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

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

[40] RecycleBank. Recyclebank. *http://www.recyclebank.com/*, 2011.

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

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

[43] ribbonhero. ribbonhero. *http://ribbonhero.com/*, 2011.

[44] J. Schell. Design outside the box. *DICE summit*, 2010.

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

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

[47] SurveyGizmo. Surveygizmo website. http://www.surveygizmo.com/, 2013.

[48] The Unreal Engine. Unreal engine. https://www.unrealengine.com/, 2004.

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

[50] Thomas Tullis and William Albert. *Measuring the user experience: collecting, analyzing, and presenting usability metrics*. Morgan Kaufmann, 2010.

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

[52] Wikipedia. Serious game. *http://en.wikipedia.org/wiki/Serious*$_g ame$, 2011.

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

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

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

[56] N. Yee. Understanding mmorpg addiction. *Retrieved February, 2012*, 15:2008, 2002.

[57] Michael Zyda. From visual simulation to virtual reality to games. *IEEE Computer*, 38(9):25 – 32, Sep 2005.