Lappeenranta University of Technology
School of Business and Management
Erasmus Mundus Master's Programme in Pervasive Computing & Communications for sustainable Development PERCCOM

Chandara Chea

Gamified Participatory Sensing: Impact of Gamification on Public's Motivation in a Lake Monitoring Application

2017

Supervisors: *MSc. Maria Palacin Silva (Lappeenranta University of Technology)*
Prof. Jari Porras (Lappeenranta University of Technology)

Examiners: *Professor Eric Rondeau (University of Lorraine)*
Professor Jari Porras (Lappeenranta University of Technology)
Associate Proessor. Karl Andersson (Luleå University of Technology)

This thesis is prepared as part of an European Erasmus Mundus programme PERCCOM - Pervasive Computing & COMmunications for sustainable development.

This thesis has been accepted by partner institutions of the consortium (cf. UDL-DAJ, n°1524, 2012 PERCCOM agreement).

Successful defense of this thesis is obligatory for graduation with the following national diplomas:

- Master in Complex Systems Engineering (University of Lorraine)
- Master of Science in Technology (Lappeenranta University of Technology)
- Degree of Master of Science (120 credits) –Major: Computer Science and Engineering,

Specialisation: Pervasive Computing and Communications for Sustainable Development (Luleå University of Technology)

ABSTRACT

Lappeenranta University of Technology
School of Business and Management
PERCCOM Master Program

Chandara Chea

Gamified Participatory Sensing: Impact of Gamification on Public's Motivation in a Lake Monitoring Application

Master's Thesis

2017

88 pages, 33 figures, 5 tables, 6 appendixes

Examiners: *Professor Eric Rondeau ((Université de Lorraine)*
Professor Jari Porras (Lappeenranta University of Technology)
Associate Professor Karl Andersson (Luleå University of Technology)

Keywords: Participatory sensing, gamification, public engagement, ICT for greening, lake monitoring

Participatory sensing is the concept or practice whereby individuals or publics using ICTs such as mobile phones, contribute to data collection, analysis and sharing of knowledge. The lack of motivation from publics is usually one of the main challenges since the system is doomed to fail when there is no abundance of participant contributing. A potential technique to engage participants is the use of gamification or elements of game design. This research aims to study the effects of gamification on publics' motivation in participatory sensing system. Game elements such as challenges, achievement, storytelling and feedback were investigated for motivating citizens to continuously participate in observation of lakes' ice condition. In order to evaluate the effects of gamification on user engagement and usability of the application, an experiment was conducted with 41 participants during spring 2017 for 20 days. By comparing with a normal application (without gamified elements implemented), the results suggested that gamification is a promising technique for engaging citizens.

ACKNOWLEDGEMENTS

This thesis is part of Erasmus Mundus Master programme in Pervasive Computing and Communication for Sustainable Development (PERCCOM) of the European Union (Klimova et al., 2016; Porras et al., 2016).

I would like to take this opportunity to thank to the PERCCOM Selection committee, the host universities, such as University of Lorraine, Lappeenranta University of Technology, ITMO University, Luleå University of Technology and Leeds Buckett University, and especially Professor Eric Rondeau for the efforts that have been invested in PERCCOM.

I would like to express my deep gratitude to my supervisors MSc. Maria Palacin Silva and Professor Jari Porras for all kinds of support, meaningful feedbacks and encouragement throughout this master thesis.

Special thanks to Dr. Leonardo Alonso Segura from UNESCO-IHE for providing useful feedback to the design of mobile application, and DSc. Antti Knutas from Lappeenranta University of Technology for giving meaningful feedback to the design of the experiment.

Thanks to my proof readers Emil, Samath and Rottana for all the effort despite their busy schedule.

This two-year study was a great journey also thanks to my PERCCOM friends for all the precious and unforgettable memories together.

Finally, I would like to thank my beloved parents and my family for all the love and support. Without you I wouldn't be here today. I love you all.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

API	Application Programming Interface
CSS	Cascading Style Sheet
GPS	Global Positioning System
HTML	Hyper Text Markup Language
ICT	Information and Communication Technology
IT	Information Technology
ISO	International Organization for Standardization
NASA	National Aeronautics and Space Administration
SDK	Software Development Kit
SQL	Structured Query Language

1 INTRODUCTION

Although Earth satellites are very powerful and can provide undeniable fact of how the Earth changes over years, in situ observations are still needed for some monitored parameters in order to compliment data from the satellites. The increase of smartphones and advancement of pervasive technologies make these onsite observations easier and lead to a data collection model called participatory sensing. Participatory sensing is the practice where publics contribute in data collection, analysis and sharing of knowledge by using Information and Communication Technology (ICT). However, this practice can be possible only when people are willing to contribute their time and devices in the data collection process. This thesis aims to look at gamification as an incentive mechanism for motivating publics to participate in participatory sensing systems.

1.1 Background

The rising of the Earth's temperature also known as, "Global warming" may fuel hotter heat waves, heavier rainfall, prolonged drought, terrible hurricanes and other catastrophes. Global warming has become a topic of discussion in political controversy in the last decade and there was a debate among many people and sometimes in the news, on whether global warming is real or just a hoax (Lewandowsky et al., 2013). However, by looking at the recorded data of Earth and recent climate occurrences, such as sea level, temperature, droughts, etc., scientists agree that the Earth is getting warmer. According to National Aeronautics and Space Administration (NASA)'s website, the temperatures of the Earth in 2016 were the warmest since modern recordkeeping began in 1880, in which the average temperature has risen to 0.99 degree Celsius. Moreover, the magnitude of Arctic sea ice has diminished rapidly over the last several decades, and snow cover in the Northern Hemisphere has reduced over years ("NASA: Climate Change and Global Warming," n.d.)

These important data that can help scientists study the trend of climate change is possible thanks to the satellite and earth observation technologies for environmental monitoring. Satellites can capture big terrestrial changes in time, but cannot provide granulated information about changes of particular places. As a result, onsite observations are needed to encompass all Earth observation systems. In this context, (Pyhalahti et al., 2015). Involving citizens for such purposes poses a great opportunity as there are already 2.1 billion people carrying smartphones worldwide in 2016 (DeviceAtlas, 2016). These devices are able to capture, classify and transmit location, image, voice and other data autonomously and act as data collection instruments.

Humans have a natural instinct to understand and explain phenomena and the environment, which has made the observation of surrounding nature and society possible since ancient times. The practice of having independent professionals and regular citizens cooperating evolved through the human history, has becoming known as “citizen science” or “participatory sensing” by computer scientists. Citizens and scientists collaborate actively in the research, such as data gathering, classification and dissemination in participatory sensing (Bonney et al., 2009; Chilvers et al., 2014; Paul, Quinn, Huijser, Graham, & Broberg, 2014; Resnik, Elliott, & Miller, 2015).

However, participatory sensing project can be operated successfully as long as there is participation from publics. Attracting and retaining abundant participants are usually a major concern for participatory sensing as well as for socio-computational system design (Crowston & Prestopnik, 2013). Motivation is usually seen as a crucial aspect of the system. Designing a method that can motivate people to participate and maintain their motivation in continuous participation is a problem needed to tackle.

1.2 Goal and Delimitation

Gamification has gained momentum as a solution for user engagement (Zichermann & Cunningham, 2011) and change of behavior (Cafazzo et al., 2012; Gustafsson et al., 2009). Gamification is defined with different terms between the academia and industry, which serve the similar purposes. From academic perspective, gamification is “*the use of game design elements in non-game contexts*” (Deterding et al., 2011). On the other hand, people from industrial background, such as vendors and consultants describe gamification as “*the process of game-thinking and game mechanics to engage users and solve problems*” (Zichermann & Cunningham, 2011). The goal of this thesis is to study the impacts of gamification on public's motivation of a participatory sensing application. Participatory sensing has been applied worldwide in many different fields. According to the report from Finnish Environmental Institute, species monitoring, city management and water, stream, snow and sea are the most common observations in participatory sensing (Palacin-Silva et al., 2016). Hence, the scope of the research in this thesis focuses on one of the mainstream observations (water, stream, snow and sea observation), specifically the observation of lake's ice condition.

1.3 Research Question and Methods

Participant's motivation was defined in term of two aspects: the engagement of participants (behavioral change) and the usability of the system (usefulness and satisfaction). The research questions that are going to be investigated are:

1) How does gamification affect the engagement of participants?
2) How does gamification affect the usability of the system?

To answer these research questions, design science was used as a research methodology. In Design Science, the design and development of artefact is a crucial part to answer the research questions. The methodology is comprised of five important steps: identifying problem, defining requirements, designing and developing artifact, demonstration, and evaluation. The **mobile participatory sensing application** was developed as a mean to enable citizen to monitor the ice condition of the lakes. Gamification mechanics such as challenge, achievement, storytelling and feedback were implemented to involve citizens in monitoring the ice condition of lakes. To evaluate the effects of gamification on public's motivation, the experiment was carried out and took place for 20 days from 24 March to 12 April 2017. In designing experiment, two hypotheses: 1) game elements increase user engagement and 2) game elements increase usability, were constructed for carrying in the experiment.

1.4 Structure of Thesis

Chapter 2 presents the related concept of participatory sensing, which is citizen science. It then continues to define participatory sensing and its domains and applications. Finally, it describes gamification, explore the motivation of gamification's users and discuss the gamification's mechanics.
Chapter 3 presents the research methodology used in the thesis study. Each stage of methodology will be discussed in detail.
Chapter 4 provides the result obtained from the experimental study that evaluate the impacts of gamification on user engagement and usability.

Chapter 5 discusses the result from this thesis study, general remarks outside the problem or scope and limitations of the study.
Chapter 6 summarizes the outcome of the thesis work and future work. Following this chapter is a list of references and appendices.

2 RELATED WORK

In this section, three important sections are covered: brief review of citizen science, overview of participatory sensing and introduction to gamification.

2.1 Citizen Science

The practice of citizen science project dated back since 19th century, even though the term "citizen science" was introduced in Oxford English Dictionary in 2014 (Oxford English Dictionary, 2014). Wells Cook, an American ornithologist called the "*father of cooperative study of bird migration in America*", gathered people and asked them to gather information about the arrival and departure of the birds in the spring and the fall (Palmer, 1917). The program ran from the 1880s and continued through 1970s. Later this was taken up by non-governmental organization as well as the government. Over the years, there were 6 million records with thousands of volunteers gathering this kind of information (Droege, 2007). According to the paper published by European Commission, "*Citizen Science is the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources.*" (Socientize Project, 2013). Citizen science engages non-professionals in authentic scientific research that ranges from personalized to long-standing and large-scale project (Dickinson et al., 2012).

Citizen science projects involve volunteers of all ages, professions, backgrounds, and skills often across broad geographic areas to engage in a variety of tasks. They are divided into three categories (Participation, Potential, & Education, 2009). *Contributory project* is the project that entirely designed by scientist and the members of public collect or analyses data. *Collaborative project* refers to the project that volunteers cannot only contribute in data collection process but also assist in the project design, while *Co-created project* involves both scientists and volunteers in all parts of the project. Most of citizen science projects fall into the contributory type, where volunteers are asked to share or contribute their data such as classification or documentation in the form of data collection under the supervision of scientists or researchers. For instance, eBird (http://ebird.org/content) is an online documenting observing tool that asks people to enter the information of the time and location that they went bird watching and fill out the checklist of all birds they have seen and heard. Another example is one of the most successful online citizen science project called Galazy Zoo (https://www.galaxyzoo.org/).

Launched in 2007, Galazy Zoo asks volunteers to contribute in astronomy research by classifying the images of galaxy such as to identify how round or elliptical the galaxy is. In April 2009, more than 200,000 people from approximate 170 countries had been involved in making more than 100 million classifications of galaxies, which the data have been used in more than 50 research projects (Raddick et al., 2009).

Citizen sciences is naturally suitable for scientific endeavors due to its engagement with affected populations from the beginning although the project is appeared to be contributory, collaborative or co-created (Dickinson et al., 2012). It is able to raise public awareness and support for science, environment, and Earth stewardship because of its participatory nature (Dickinson & Bonney, 2012). Citizen science that engages non-professional in ecological research contributes to the field of ecology. For instance, from the involvement of massive research teams (i.e. non-professionals), citizen science can help to obtain data that cannot be taken from satellite images or other remote-sensing technologies (Dickinson et al., 2012).

2.2 Participatory Sensing

Citizen Science is a broad concept, and is often considered as a wider group that contain *participatory sensing* and *crowdsourcing* (Moraes et al., 2014). Created by Jeff Howe and Mark Robinson in 2006 (Howe, 2006), the term "crowdsourcing" describes a business model of using a distributed network to outsource work to the crowd (Brabham, 2008). Later, there are more than 40 definitions of crowdsourcing published in scientific literature (Estellés-Arolas & González-Ladrón-de-Guevara, 2012), which shows the lack of consensus and semantic confusion. (Estellés-Arolas & González-Ladrón-de-Guevara, 2012) proposed an integrated definition as below:

"Crowdsourcing is a type of participative online activity in which an individual, an institution, a nonprofit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task. The undertaking of the task, of variable complexity and modularity, and in which the crowd should participate bringing their work, money, knowledge and/or experience, always entails mutual benefit. The user will receive the satisfaction of a given type of need, be it economic, social recognition, self-esteem, or the development of individual skills, while the crowdsource owner

will obtain and utilize to their advantage what the user has brought to the venture, whose form will depend on the type of activity undertaken."

With the increasing number of smartphones incorporated with cameras, microphones and GPS, the ubiquity of these technologies has also emerged the new paradigm for collecting large-scale sensing data known as **participatory sensing** (Christin et al., 2011). Professional scientists and citizens collaborate actively in the research, such as data gathering, classification and dissemination in participatory sensing (Bonney et al., 2009; Chilvers et al., 2014; Paul et al., 2014; Resnik et al., 2015). Participatory sensing is the process whereby publics contribute to systematic data collection, analysis and dissemination through information and communication technologies (ICTs) (Estrin, 2010; Goldman et al., 2009). Christin et al. (2011) gave definition to participatory sensing as a term to describe the use of mobile phones as sensors, where participants voluntarily contribute sensor data for their own benefit and/or for the sake of community. Participatory sensing is categorized into two categories: people-centric sensing and environment-centric sensing. People-centric applications collect data regarding the activities and behaviors of users (e.g., sport experiences and eating disorders), while environment-centric applications use mobile phones embedded sensor to capture data about surroundings of the users (e.g., air quality and road conditions) (Christin et al., 2011).

The term crowdsourcing and participatory sensing are somehow overlapped and have been used interchangeably. However, the main difference of these two concept is lied upon the use of embedded existing sensing (e.g., mobile phones) and communication (cellular or WIFI) infrastructure to collect data (Moraes et al., 2014).

2.2.1 Domains and Applications in Participatory Sensing System

From the analysis's results of 108 participatory sensing, Finnish Environmental Institute (SYKE) grouped the application's domains of participatory sensing (Palacin-Silva et al., 2016) as following :

1. **Species monitoring**: involves observations of species, such as insects, bats, birds, butterflies, sea species, and animals
2. **City management**: involves observatories that support decision-making process of urban issues, such as transportation, bicycle routes, land usage, energy consumption,

surroundings classification, environmental conditions, traffic and parking monitoring, citizen needs and perceptions.

3. **Water, streams, snow, sea**: involves observations about water quality, precipitations, streams, lakes, snow, ice and sea environments
4. **Tools for citizen observatories**: involves tools needed for creation or integration of participatory sensing
5. **Biodiversity monitoring**: involve the monitoring of biodiversity, flora, forests, mountains, biosphere and trees.
6. **Air and spectrum monitoring**: involve observations of air quality, noise, sounds and radiation
7. **Global monitoring**: involve observations that monitor global trends (astronomy and climate change)
8. **Disasters monitoring**: involve observatories of earthquake monitoring and early detection.

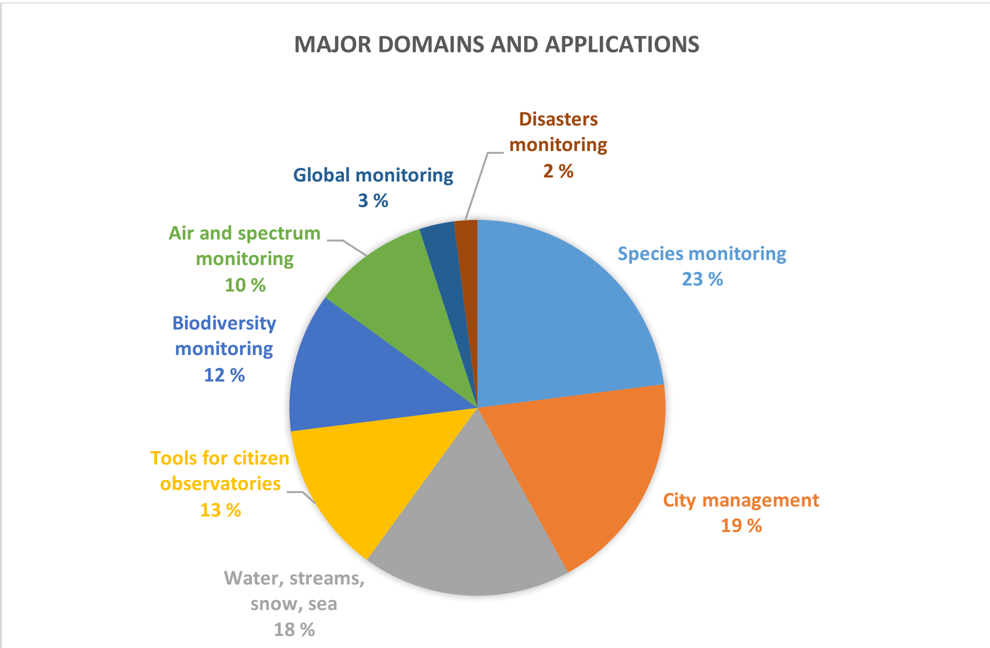


Figure 1: Domains and applications in participatory sensing adapted from (Palacin-Silva et al., 2016)

Citizen science has been a long tradition among citizens and government agencies in Finland, and organizations, such as LUOMUS (National History Museum of Helsinki) have received data from citizens with dates up to 1900s (Palacin-Silva et al., 2016). Water, streams, snow and sea observation is one of the most common observations across the world and especially in

Finland due to the geographical fact that Finland has more than hundred thousand of lakes all over the country. According to Finnish Environment Institute website, satellite measurement can provide information such as the magnitude of snow cover, the temperature of sea surface, and the existence of algae blooming (Finnish Environment Institute, 2013). However, since satellites cannot be deployed everywhere, a number of volunteers across the countries have been recruited to observe the ice seasonality in addition to the hydrological features satellite measurements.

Lake and river ice seasonality, known as dates of ice freeze-up and breakup, responds sensitively to climate change and variability (Sharma et al., 2016). Freeze-up is referred to *the time at which a continuous and immobile ice cover forms*, while breakup is referred to *the time when the ice cover begins to move downstream in a river or when open water becomes extensive at the measurement location for lakes* (Sharma et al., 2016). Freeze-up and breakup dates of lake and river ice are significant to human activities and they have been documented in different locations around the world since long time ago. These records offer crucial climate information, which can be used for climate change research, the preparation of flood forecasting and other security situation awareness (Sharma et al., 2016).

Järviwiki (https://www.jarviwiki.fi/) is a web platform that is built and maintained collaboratively between citizens and authorities. It was founded and maintained by the Finnish Environment Institute (SYKE) since March 2011. Järviwiki aims to share information of lakes in Finland, raise awareness and promote the protection of waters, by allowing volunteers across Finland to report the observation of lake, sea, aqua plants and animals.

2.2.2 Challenges in Participatory Sensing

Participatory sensing can operate as long as there is participation from publics or volunteers. Attracting and retaining abundant participants require major efforts (Dickinson et al., 2012) and are usually a major concern for participatory sensing projects (Crowston & Prestopnik, 2013). **Participants' motivation** is an important aspect of participatory sensing and also a growing interest of research topic in multiple scientific communities and governance circles. To recruit a large number of participants, (Dickinson et al., 2012; Snyder & Omoto, 2001) highlighted that the projects should be designed in a way that are easy, fun and social. However, for projects that need moderately substantial numbers of participants and ongoing commitment, a potential approach is to work intimately with the participants, target the interest of the participants from the beginning to create shared values, and make partnership with various community organizations.

The sense of having community involvement is very essential in encouraging participants to participate actively in the project. Batson et al. (2002) categorized the motivation for community involvement into four types. The differences between these types are based on the ultimate goal for each motive. *Egoism* has the goal of improving one's own welfare. *Altruism* occurs when a person want to increase the welfare of another individual or individuals. *Collectivism* is to increase the welfare of a group that one belongs to, and finally, *principlism* is to show maintain on or more moral principles.

Raddick et al. (2009) used the Galaxy Zoo (https://www.galaxyzoo.org/) project as a case study to identify motivation categories that drive participants in the project of classifying images. The participants and volunteers in Galaxy Zoo project were questioned about their motivations for participation. There were twelve main reasons that were identified through a content analysis approach. Those reasons were *contributing* (excited to contribute to original scientific research), *learning* (find the site and forum useful for learning astronomy, *discovery* (can look at galaxies that few people have seen before) , *community* (meet other people with similar interests) , *teaching* (find galaxy zoo a useful resource to teach people) , *beauty* (enjoy looking at the beautiful galaxy images), fun (had a lot of fun categorizing the galaxies) , *helping* (believe that they can help scientist to find new galaxy), *zoo* (specifically interest in the galaxy zoo project), *vastness* (amazed by the vastness of space), *astronomy* (interest in astronomy) and *science* (interest in science subject). Several of these reasons generally motivated participants at the same time. Contributing and helping are similar to altruistic motivations mentioned by (Batson et al., 2002). The desires to have fun, participate in a community, learn and discover new things can be counted into egoism category.

Data quality is also a critical issue in participatory sensing system. R. Y. Wang & Strong (1996) proposed a conceptual framework of data quality, which is composed of four attributes: "*1) intrinsic data quality: accuracy, objectivity, believability and reputation of data; 2) contextual data quality: value-added, relevancy, timeliness, completeness, and appropriate amount of data; 3) representational data quality: interpretability, ease of understanding, representational consistency, and concise representation of data; 4) accessibility data quality:*

accessibility and access security of data". The concern on the quality of data may arise from human or mobile devices, which are embedded with sensor. The participation that allows anyone to contribute data can bring the system to erroneous and malicious contributions (Kanhere, 2011). For example, participants may send incorrect, low quality or even fake data. On the other hand, faulty measurements are possibly recorded even when users position their devices inattentively. For example, sensor may sense the urban noise data when user places mobile phone in a pocket or bag. Schnoor (2007) highlighted the importance of training materials, user supports and even direct communication channel for participants to achieve high quality data and minimize the complexity of the tasks. Moreover, to assure the quality of data, a possible approach is to compare the measurement collected within a predefined time window for calculating the most frequent value, the mean and the standard deviation (Mazzoleni et al., 2015).

Participants' privacy is another challenging issue in participatory sensing. The sensor data from mobile devices are crucial for all participatory sensing application since their deficiency may endanger and mark the doom of the system. However, simultaneously, these contributed data from participants always contain participants and/or their environment information, which can pose threats to participants ranging from social to security threats if the data are not considered seriously and properly. Privacy in participatory sensing refers to the certainty that participants have full control over their released information. This includes the protection of information from both sensor reading or interaction of users in the system (Christinet et al., 2011). Christin et al. (2011) introduced several countermeasures for the privacy issue in participatory sensing system. One of the measures is to manage the process of data collection at participants' level and let participants to select their own privacy preferences. Moreover, system should be capable of distributing the task anonymously or providing the feature of anonymous reporting for participants.

2.2.3 Gamification in Participatory Sensing

Participatory sensing has been around for many years, and gamification has also been applied in many different field. Gamification was also proved as an promising technique in engaging participants and encouraging the changes of behaviors; however, there are not many studies that actually applied gamification in participatory sensing for participant engagement. (Arakawa & Matsuda, 2016) used gamification as an incentive mechanism in a participatory sensing system called NAIST photo. Status level scheme, ranking scheme and badge scheme were used for attracting participants doing the sensing task. The sensing tasks were categorized as the task with gamification schemes and without gamification schemes. In 30-day experiment of 18 users, the result showed that the task with gamification schemes received more responses, which gamification increased the participation probability from 53% (without gamification) to 73%. Another participatory sensing application that considered gamification for user engagement is Noisemap. As noise pollution is an increasing problem in dense urban areas, Noisemap is a multi-platform measuring tool that is used to measure sound pressure. It used game elements such as statistics and badges as internal incentives. Users can see their complete measurement history such as time spending, number of measurement or distance covered. Users received badges as unique honors by completing special measurement activities. There were around 100 badges in five categories: geo-location, statistic, date-time, social and special badges. Moreover, social competition was used as an external incentive in Noisemap. After completing measurement activities, users were awarded points, and those points are used to calculate the ranking of users in daily, weekly, monthly and global ranking. The authors claimed that gamification is a promising technique to motivate users, and they employed gamification in the Noisemap application (Meurisch et al., 2013); however, the authors did not study the effects of before and after employing those game elements in the application. The result showed that the number of registered users and the number of measurement had increased over time (2012-2013), which was the result from the combination of using incentive mechanism(gamification) and implementing on multiple platforms (iOS and android).

2.3 Gamification

This section presents incentive mechanisms needed in participatory sensing system, and illustrates gamification as one of the mechanisms. The section continues by defining gamification and situating it in relative to its related concept, presenting motivation of player in the gamification scheme and finally exploring the existing game elements.

2.3.1 Incentive Mechanisms

An incentive is a stimulus that encourages or motivates a person to do something. The need of incentive mechanism is crucial to make data sharing feasible since sensor information is often highly sensitive and mobile devices usually have limited resources (Guo et al., 2015).

Participatory sensing system requires substantial number of participants or volunteers, and those participants usually drop out on the way unless they get higher return of investment (Guo et al., 2015). This problem often leads the system dooms to fail. Ogie (2016) classified **incentive mechanism for participatory sensing** or crowdsourcing system in two categories: monetary incentives and non-monetary incentives. Monetary incentives or financial incentives are the real money or any other commodity that users consider valuable, and this incentive is probably the most straightforward way to motivate participants (Y. Wang, Jia, Jin, & Ma, 2016). For example, Amazon Mechanical Turk (https://www.mturk.com/mturk/) is a crowdsourcing system that provides incentive in form of micro payment to participants who complete the crowdsourcing tasks. Non-monetary incentives are referred to rewards, not involving money or financial commodities and they can be divided into three categories: social, service and entertainment incentives (Ogie, 2016).

Social incentives are based on the belief that people can be motivated to participate in sensing tasks for social or ethical reasons such as socializing, reputation or recognition (Guo et al., 2015). Other factors that drive social incentive include mental satisfaction from engaging in crowd sensing tasks, self-esteem and love of the community in which a crowd-sensed task is being performed (Y. Wang et al., 2016). Antin & Cheshire (2008) suggested displaying the individual' efforts and their unique values of each contribution to make them feel each of their work is counted.

Service incentive refers to the rewards in which participants are requested to provide sensing data in return for service usage (Y. Wang et al., 2016). Antin & Cheshire (2008) presented a crowd sensing application, called "BX Tracker", for measuring human mobility and signal coverage in cellular networks. In order to attract users to use their application, the authors claimed that the application could be used as an ordinary GPS tracking tool for many tasks, like recording a walking tour. Hence, once the participants installed the application, they can also enjoy using the free and no-ads tracking tool.

Entertainment incentives is a non-monetary reward system that motivate users based on interestingness and enjoyment (Ogie, 2016). For instance, participants get involved in the system because they find the tasks are interesting, entertaining or enjoyable. Taking entertaining and engaging elements from online games and using them to incentivize participation in non-game contexts, known as "**gamification**" are increasingly studied in a variety of fields (Y. Wang et al., 2016). However, the problem of designing complicated and boring participatory sensing tasks into enjoyable game is also a noticeable challenge (Y. Wang et al., 2016).

2.3.2 Situating and Defining Gamification

Rollings & Adams (2003) defined **digital game** as a distributed game in which players are connected through the Internet or computer network. It is also known as pervasive game on modern gaming platforms, including PCs, consoles and mobile devices. Digital games are usually fun and enjoying that can make people highly engaged in practicing some behaviors and thought processes in a simulated environment. It can probably give people social motivation to connect to other people, and may or may not improve people's present level of awareness or knowledge. The obvious example of trendy digital game is Pokemon Go (http://www.pokemongo.com/), which became phenomenally popular and demonstrated an astounding potential for growth. Pokemon Go is a geo-location augmented reality game that has generated revenue of 258 million US dollars in total as of August 12 according to Pokemon go statistic report 2016 (BusinessofApps, 2016). However, the game has been received both positive and negative feedback from the world and the matter of ban or boycott the game is still a controversial topic.

The movement of using serious games started in the late 1950s firstly in the form of using non-electronic, pen- and-paper and board games (Egenfeldt-Nielsen et al., 2013) even though the term serious games was only coined in 1968 by the American academic Clark Abt (Egenfeldt-Nielsen et al., 2013). **Serious game** or purposeful game, on the other hand, is the game design that usually come with the strong and meaningful purpose to encourage learning experiences (Deterding et al., 2011). Theoretically, video game can also be considered as a serious game, which depends on its actual use and the perception of players on game experience. Ritterfeld et al. (2009) defined Serious Game as "any form of interactive computer-based game software for one or multiple players to be used on any platform and that has been developed with the intention to be more than entertainment". Foldit (http://fold.it/portal/) is a crowdsourcing computer game that allow people to contribute to scientific research. Foldit asks participants to play a puzzle game to predict and design protein structure. The more people play the game, the more they can help in research to cure diseases that proteins involved, such as HIV/AIDS, cancer and Alzheimer's. Old Weather (https://www.oldweather.org/) is an online web game that asks people to explore, mark and transcribe historic ship's logs from mid-19th century onward. Participants have choices to choose which ship to serve on and raise their position or rank, as they are more involved in the project. The purpose of the game is to help weather scientists digitalize the handwriting weather observation records, which can be used to advance research in multiple fields.

Gamification first originated in the digital media industry (Deterding et al., 2011) and was invented in 2002 by a British computer programmer, Nick Pelling (Marczewski, n.d.) but then started to gain its popularity in second half of 2010. Gamification was defined in different terms between the academia and industry, which serve the similar purposes. From academic perspective, gamification is "*the use of game design elements in non-game contexts*" (Deterding et al., 2011). On the other hand, people from industrial background such as vendors and consultants describe gamification as "*the process of game-thinking and game mechanics to engage users and solve problems*" (Zichermann & Cunningham, 2011), which illustrate the concept around users and clients.

The term "*gamification*" and "*serious game*" can be sometimes overlapping since gamification use elements of games also for purpose other than just entertainment. However, gamification incorporates game elements (Brathwaite & Schreiber, 2009) for the intention of joy of use, engagement or improvement of the user experience (Deterding et al., 2011) rather than solely for strong, purposeful and non-entertainment goal like "serious game". Deterding et al.(2011) situate serious games and gamification through two dimensions of playing/gaming and whole/parts (Figure 2).

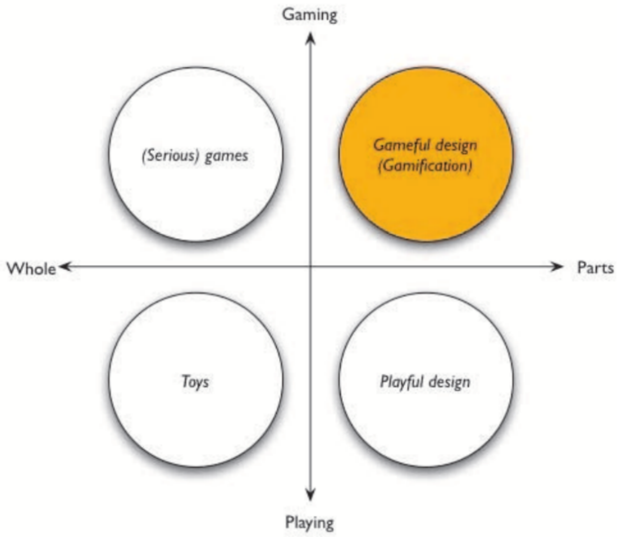


Figure 2: Situating gamification (Deterding et al., 2011)

2.3.3 Player Motivation

Exploring users or players' needs is very important to design an experience that will drive user's behavior in a vision of developer (Zichermann & Cunningham, 2011). Lazzaro (2004) explored four underlying reasons behind people's motivation in playing games: 1) to win some forms of competition 2) to explore the system 3) to have fun 4) to engage with other players. Bartle (1999) developed a taxonomy, known as Bartle taxonomy of player types, in which he categorized players into four types as in Figure 3.

1. Explorers: like to go out into the world in order to bring things back to their community with the objective of experience new things.
2. Achievers: consider that wining and achievement are important for them.
3. Socializers: play game for the sake of social interaction.
4. Killers: are similar to achievers but for them winning alone is not enough because they must see other players lose and express admiration toward them.

Designing a game for achievers could be very challenging. It is not an easy task to develop a system or application that make players to achieve and win at the same time, and achievers are likely to easily lose the interest in playing once they lost the game (Zichermann & Cunningham, 2011).

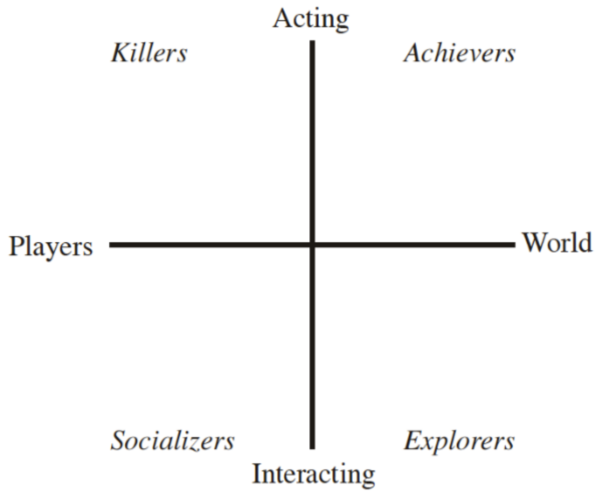


Figure 3: Player types (Zichermann & Cunningham, 2011)

2.3.4 Game Elements

"The use of game design elements in non-game contexts"
(Deterding et al., 2011)

The mechanics of a gamified system usually consist of elements that can receive worthwhile response from the players (Zichermann & Cunningham, 2011). Table 1 below illustrates the gamified elements along with the motivation behind each element.

Motivation	**Game Mechanics**	**Description**
Feedback	Experience bar	Show the progress of the task that users have completed or will need to complete
Reward	Score/points	Track progress of users based on point system. This is an absolute requirement for all gamified system.
	Levels	Map user's progress throughout a system.
Competition	Leaderboard	Show user where they are ranked in the system and where they stand in relative to their friends
Collaboration	Social network	Allow user to socially connect to each other
Challenge	Challenges	Sometimes known as mission or quest. It provides users a goal to achieve and a sense of accomplishment.
Narrative	Storytelling	Strengthen understanding of the system by telling the story

Table 1: Game mechanics adapted from (Zichermann & Cunningham, 2011)

3 METHODOLOGY

In this study, Design Science was used as a research methodology. Design science is a methodology for scientific study, which the artefacts are developed and used to solve practical problems or gaps between current and desirable state (Johannesson & Perjons, 2014).
There are five important steps (Figure 4) in design science research as following:

- ***Explicate the problem****: investigates and analyses a practical problem*
- ***Define requirements****: outlines a solution to the explicated problem in the form of an artefact and elicits requirements, which can be seen as a transformation of the problem into demands on the proposed artefact*
- ***Design and develop artefact****: creates an artefact that addresses the explicated problem and fulfils the defined requirements*
- ***Demonstrate artefact****: uses the developed artefact in an illustrative or real-life case, sometimes called a "proof of concept", thereby proving the feasibility of the artefact.*
- ***Evaluate artefact****: determines how well the artefact fulfils the requirements and to what extent it can solve, or alleviate, the practical problem that motivated the research.*

The design and development of artefact is the most important part because the artefact is used to answer the research questions.

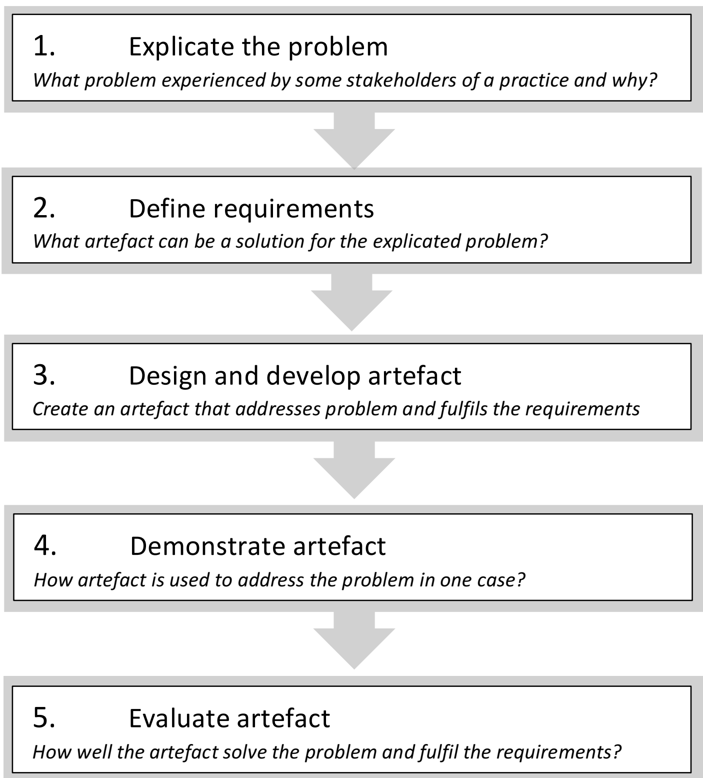


Figure 4: Design Science Methodology adapted from (Johannesson & Perjons, 2014)

3.1 Explicating the problem

"What is the problem experienced by some stakeholders of a practice and why is it important?" (Johannesson & Perjons, 2014)

For many years, scientists have discussed about deploying large-scale sensor networks to alleviate problems like global warming, or understand global phenomena (Heggen, 2013). However, it is often impeded by the cost and complexity of such systems. Participatory sensing is considered as a low-cost data collection method with the purpose of allowing citizens to monitor various phenomena related to themselves, such as health, social connections, or to their community (i.e. environment) (Restuccia et al., 2015) . Nowadays, there are more than 1 billion of smartphone using around the world and each phone embedded with various sensors that can be used as a data collection tool. On the other hand, the biggest challenge and obstacle to overcome is how to make people commit their time, efforts and resources for this meaningful purpose. Public engagement is a key to success as well as a challenge to participatory sensing system; hence, having a mechanism for motivating or encouraging participants to contribute in sensing tasks and for preventing them to dropout is extremely important.

3.2 Defining Requirements

"What artefact can be a solution for the explicated problem and which requirements on this artefact are important for the stakeholders?" (Johannesson & Perjons, 2014)

To solve the problem of public's engagement in participatory sensing systems described above, gamification, game design elements in non-game contexts (Deterding et al., 2011), was applied in the system and investigated through the experimentation.

Water, streams, snow and sea observations are one of the most common types of observations across the world and especially in Finland due to the geographical fact that Finland has more than hundred thousand lakes all over the country. According to Finnish Environmental Institute website, satellite measurement can provide information, such as the extent of snow cover, the temperature of sea surface, and the existence of algae blooming (Finnish Environment Institute, 2013). However, a number of volunteers across the countries have been recruited to observe the ice seasonality in addition to the hydrological features satellite measurements.

Figure 5 illustrates the global overview of participatory sensing system. In the system, there are two important stakeholders: participants and requesters. Participants can be general citizens who register on the platform to contribute their sensing data through observation, while requesters can be any organization or individual who register on the platform to propose an observation task that need the participation from the crowd or participants. Firstly, requesters will upload/submit the observation task to the platform/database of the system, and all the available observation task will be listed on participants' interface (mobile application). Based on the tasks, participants submit the observations, and all the observations will be made available to requesters to make use of the data accordingly. The core value of the system is to provide participants the **satisfaction of contribution**, which means that participants are able to see how their contributed data will be used and how it will make an impact to their community or society. Hence, to use this system, requesters need to commit to share their open data and planning/follow-up report to the platform, which will be accessible to participants, after the observation period is over.

The participatory sensing system requirements are divided into functional requirements and nonfunctional requirements. The complete system requirements document is found in appendix1.

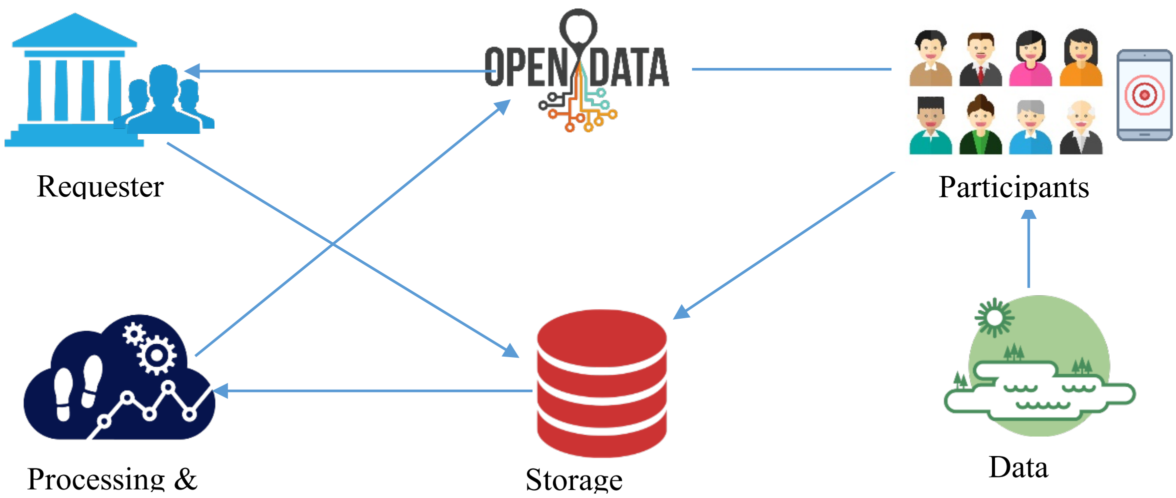


Figure 5: Participatory sensing system adapted from (Khan, Kiani, & Soomro, 2014)

3.3 Design and Development of Artefact

"Create an artefact that addresses the explicated problem and fulfils the defined requirements." (Johannesson & Perjons, 2014)

A mobile application with gamification was considered as an artefact, and was used to solve the described problem of public's engagement in participatory sensing systems. In this study, two mobile applications were developed. One application was the normal application that provided basic features for environmental observation. Another application provided the same features for environmental observation but with game elements included. The reason of having two applications implemented will be discussed later in Evaluation of Artefact section 3.5.

The **non-gamified application** was developed for both Android and iOS platform. At the first time using application, participants were prompted to provide username, email and password. The participants' registrations to the system were handled by Firebase authentication service. Once participants were successfully registered, they were directed to the main page (Figure 7) that provided a list of all observations available. After participants clicked on start observation, the observation submission page (Figure 8) would appear. In submission page, participants were asked to select observation value, add description, upload photo or choose from library, and add location. Participants could also the see the overall data that has been submitted in their region.

Jarvida

Figure 6: Javida (non-gamified) logo

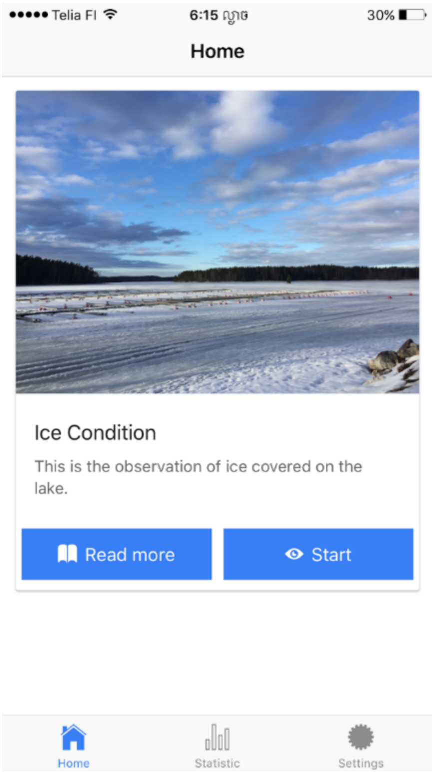


Figure 7: Home page

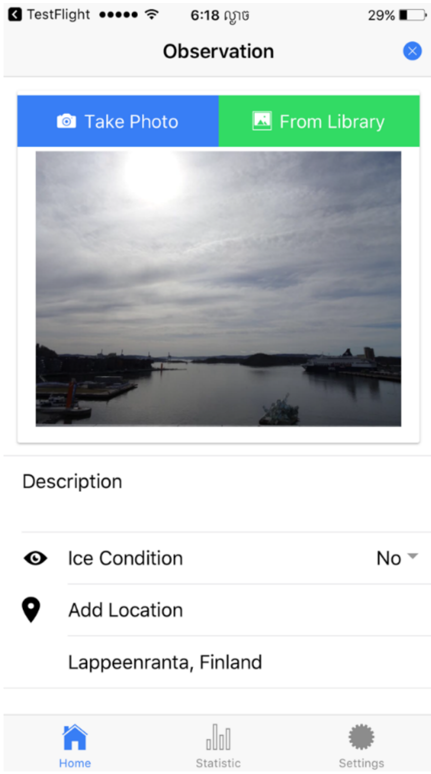


Figure 8: Submission page

The **gamified application** was developed for both Android and iOS platform. Participants needed to provide their username, email and password for registering in the system. The signup process was also handled by Firebase authentication service. After successfully registered, participants were directed to the storyboards. The storyboards described the story related to global warming and asked participants to accept the challenge (submitting observations). After participants clicked on accepting the challenge, they would see the map having all observations listed. Participants could click on the marker in the map, and the submission page (Figure 10) would appear. In submission page, participants were asked to select one of the observation values. For example, in ice on lake observation, there were three observation values: no ice (water has not yet frozen or completely melted), partially ice-covered (water is partially frozen or melted) and compactly ice-covered (water is compactly frozen and ice thickness can be measured). Participants could also upload photo, select photo from library and add more description on the observation. Participants would receive 20 points after each submission, and the top 10 participants who had the most points appear on the leaderboard. Meanwhile, participants could see their own progress and the overall data that was submitted in their region (Figure 11).

Figure 9: Jarvi (gamified application) logo

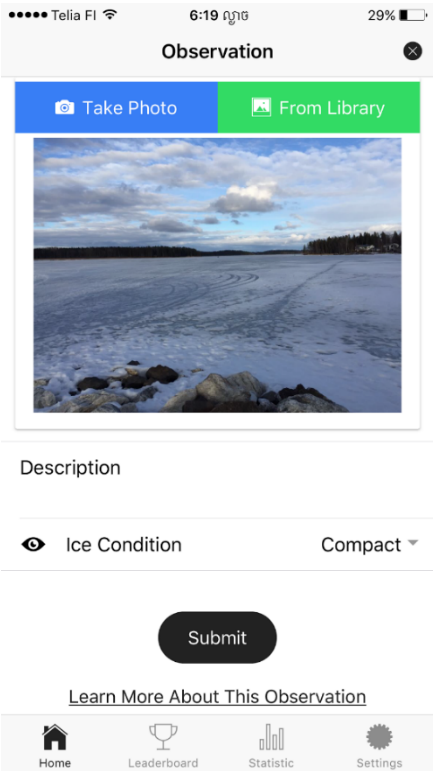


Figure 10: Submission page

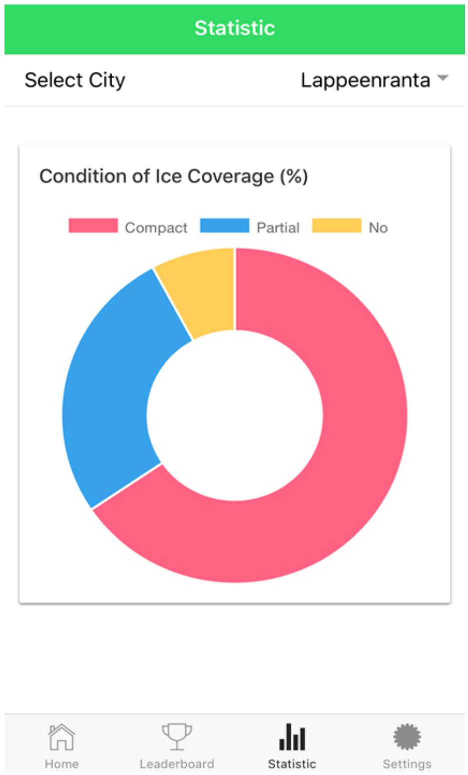


Figure 11: Statistic Page

3.3.1 Architecture

The applications were developed by using Ionic 2 framework and Firebase services. Ionic 2 (http://ionicframework.com/) is a powerful HTML5 SDK that is used to build native-feeling mobile apps using web technology like HTML, CSS and JavaScript, and built on top of Angular 2 and Apache Cordova. Firebase (https://firebase.google.com/) was used for backend as a service. In these applications, the authentication service, real time database and data storage of Firebase were used. Users were signed up and signed in to the application by using Firebase authentication SDK. Firebase authentication service integrates tightly with other Firebase services and leverages industry standards like OAuth 2.0. Besides, Firebase database, a real-time NoSQL database, was also used to store data. The real-time Database API allows operations to be executed quickly, and provide real-time experience that can serve millions of users without compromising on responsiveness. Firebase cloud storage was used to store all the images submitted by users, which this storage integrated seamlessly with Firebase authentication to secure file uploads and downloads. Figure 12 shows the architecture of the applications .

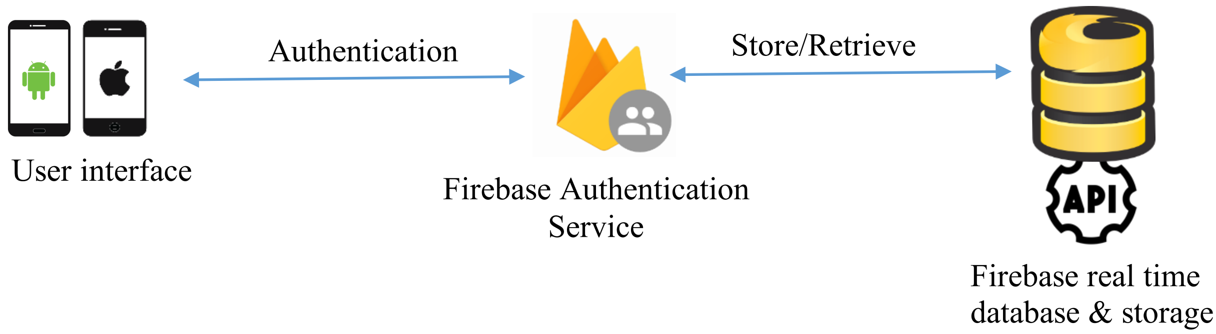


Figure 12: Application architecture

3.3.2 Database

Since participatory sensing system is capable of collecting data from anywhere and anytime, the need of data scalability is inevitable, which this can be tricky for SQL-based systems. Moreover, since this project did not have a rigid requirement documents from customers (in real-world project), the author decided to choose non-relational database for storing the data.

Figure 13 Firebase Database

3.3.3 Game Elements Implemented in Application

- **Visualization on map**

Map was adopted as a main part of the participatory sensing application. Basically, all the available observations near users were presented on the map. Users could choose to submit new observation from the listed points on the map or added new point when there was no observation point near them. Once users submitted an observation from that specific point, that observation point would change the color (from red to green) to tell users that they have already submitted observation from this point.

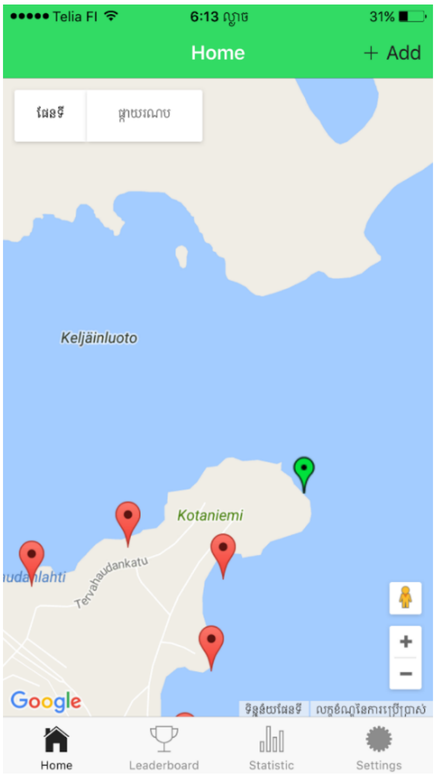


Figure 14: Map visualization

- **Challenge**

Challenge or sometimes known as mission or quest is one of the most common gamified mechanic (Zichermann & Cunningham, 2011). In this participatory sensing system, each observation task was seen as a challenge or mission that users needed to carry on for *specific period of time* depending on the observation period proposed by task owner.

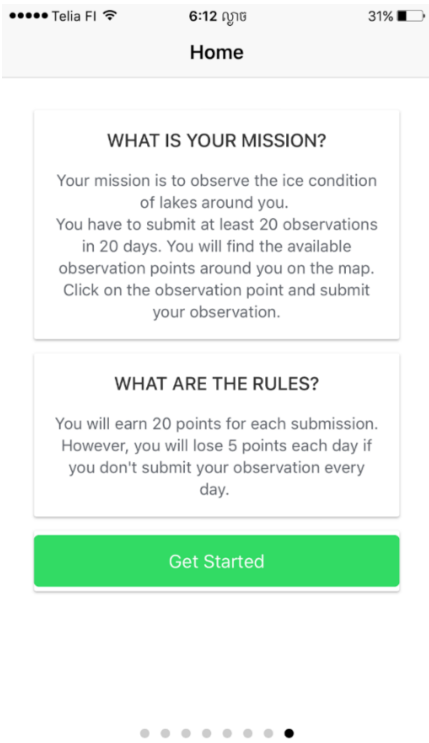


Figure 15: Challenge

- **Storytelling**

Storytelling is a feature of daily experience (Rollings & Adams, 2003). Storytelling and narrative approaches have been using in game design to make the game more appealing and make players feel attached to the game. They are also one of the best ways to present the context and rule of the game to players.

In the participatory sensing application, each story described an observation as a mission that users should accept. The story described the context of the task and gave users the useful information around the observation task. The information was given for the sake of raising awareness of users on the problem related to the observation task, and making users felt that their contributions could make an impact to their community or the world as a whole.

Figure 16: Storytelling

- **Points**

B.F Skinner, a famous American psychologist, introduced the theory of operant conditioning that behavior, which is rewarded, tends to be repeated, while behavior, which is punished, tends to be weakened. Points is the most basic but compulsory in gamified system (Zichermann & Cunningham, 2011). In this participatory sensing system, the gamified mechanics of using point as rewards were implemented. Users who were routinely submit the observation in the system were rewarded the experience points (XP).

Point	Activity	Purpose
20	Submit an observation	Reward user when complete a task
-5	No activity	Punish user for not returning back to the system in every two days

Table 2: Point system

- **Leaderboard**

Leaderboard is a straightforward way of making comparison and showing the achievement to users. In this application, users were ranked according to their earned points. Username and respective points of ten users who got the highest points from the system were displayed in the leaderboard.

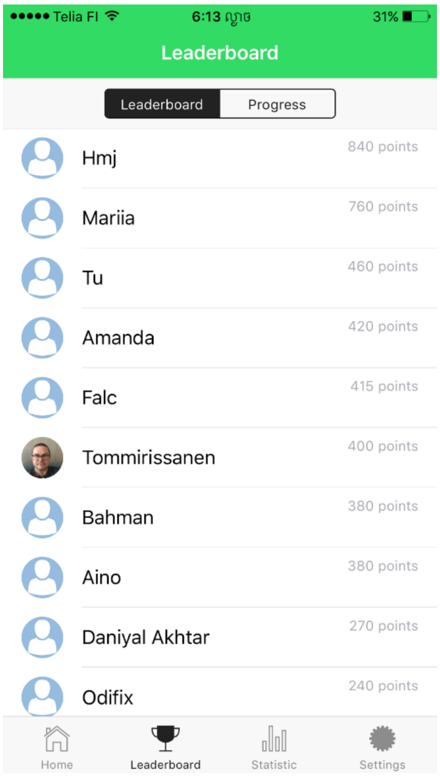


Figure 17: Leaderboard

- **Feedback**

Feedback is considered as a way of communication between system and users because without proper feedback, users can feel lost and unengaged. This game element is used to give information about game rule, progression and/or achievement. It also often associates with points or level.

Feedback was implemented in a form of showing users' points and their records of observation activities. This technique was to make users feel that their contributions were not taken for granted and it gave users the feeling of satisfaction from seeing their own contribution records.

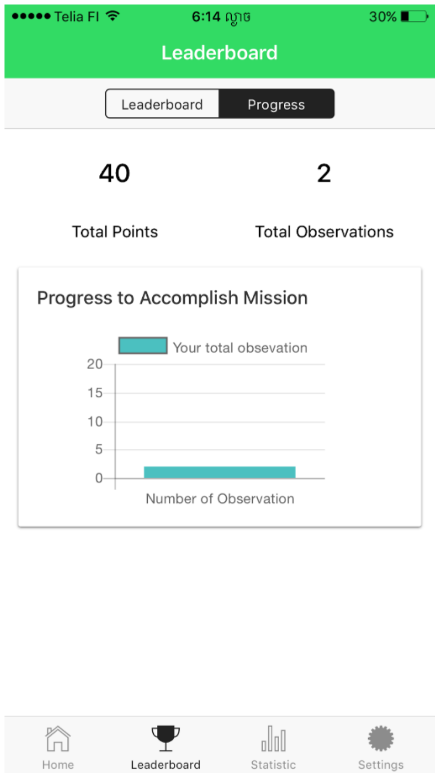


Figure 18: Feedback

3.4 Demonstration of Artefact

"How can the developed artefact be used to address the explicated problem in one case?" (Johannesson & Perjons, 2014)

Lake and river ice seasonality, known as dates of ice freeze-up and breakup, responds sensitively to climate change and variability (Sharma et al., 2016). Freeze-up and breakup dates of lake and river ice are significant to human activities and they have been documented in different locations around the world since long time ago. These records offer crucial climate information, which can be used for climate change research, the preparation of flood forecasting and other security situation awareness. Hence, due to its importance and feasibility, lake and river ice seasonality observation was used as case study for the proposed artefact.

After the participating application was developed, the application was demonstrated to a number of working researchers in Department of Business and Innovation in Lappeenranta University of Technology in order to gather some feedbacks. After collecting the feedbacks and make some necessary changes, the application was deployed to observe the ice condition of lakes in the experimental study for 20 days between 24 March and 12 April.

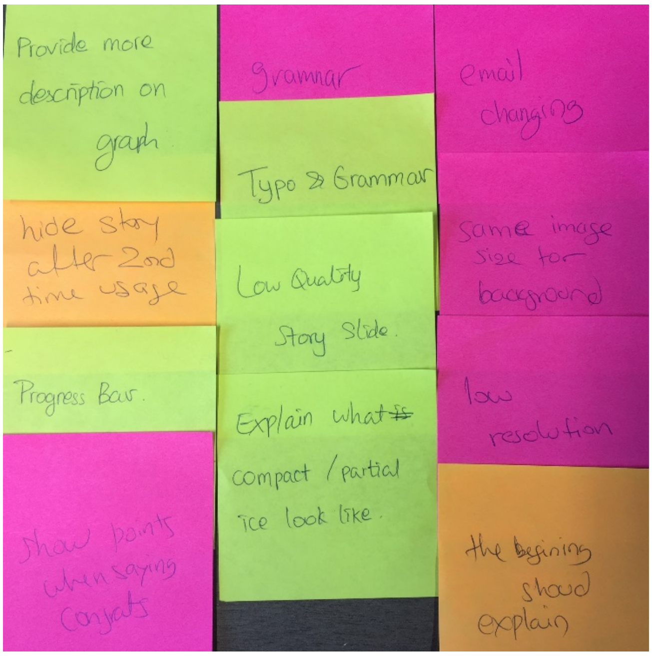


Figure 19: Post-it notes on users' feedback

3.5 Evaluation of Artefact

"How well does the artefact solve the explicated problem and fulfil the defined requirements?" (Johannesson & Perjons, 2014)

3.5.1 Context Selection

The context of the experiment is divided into four dimensions (Wohlin et al., 2012)

- Off-line vs. on-line
- Student vs. professional
- Toy vs. real problems
- Specific vs. general

The context of this experiment is the use of gamification in lake monitoring application during spring 2017. This experiment is running off-line because it is not a real industrial software development project or fully-fledged real system with concrete requirement documents, and it is conducted with students at Lappeenranta University of Technology (LUT). The experiment is specific because it focuses on the user engagement in lakes monitoring, and also it addresses a real problem i.e. the need of engaging citizens in environmental monitoring for climate change assessment.

3.5.2 Hypotheses Formulation

An important aspect of experiments is to know and state clearly what is going to be evaluated in the experiment (Wohlin et al., 2012). The experiment definition is formalized into hypotheses. Two hypotheses were formulated: null hypothesis and alternative hypothesis.

H1: Game elements increase the application usability
$H1_0$: Game elements do not increase the application usability

H2: Game elements increase user engagement
$H2_0$: Game elements do not increase user engagement

3.5.3 Variable Selection

There are two main variables in an experiment: independent variable and dependent variable. An **independent variable** is the variable that is changed or controlled in a scientific experiment to test the effects on the dependent variable, while a **dependent variable** is the variable being tested and measured in a scientific experiment ("Difference Between Independent and Dependent Variables," n.d.). Table 3 illustrates the independent variables and dependents variable used in the experiment.

Variable	Name	Description
Independent Variable	Gamification	Gamified elements such as map visualization, leaderboard, points, progress bar
Dependent Variable	Engagement	The level of user’s engagement with the application
	Usability	The extent that a product achieves specified goals with effectiveness, efficiency and satisfaction (ISO 9241:11) (“ISO 9241-11:1998(en), Ergonomic requirements for office work with visual display terminals (VDTs) — Part 11: Guidance on usability,” n.d.)

Table 3: Variables

3.5.4 Measures

To test the variables, data was gathered from *application usage logs* and *questionnaire*. Application usage log provided quantitative data that could be analyzed to determine the effect of gamification on motivation of participants and usability of applications. It measured indicators such as involvement, retention, dropout and effectiveness. Learnability time was recorded when the participants firstly use the application, while satisfaction was measured by data from questionnaire. The questionnaire was used to measure users’ satisfaction, motivation and gamification experience of each participant. The questionnaire used 5-point Likert-type questions, which responses included Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4) and Strongly Agree (5). Short answer responses were also recorded to obtain feedback from participants. Table 4 describes the indicator, unit and method for measurement of dependent variables (usability and engagement). Table 5 outlines the questions used in questionnaire to evaluate Users’ Satisfaction.

Variable	Indicator	How?
Engagement	Involvement	Number of observations
	Retention	Number of users using in the system until the end of study
	Dropout	Difference between number of user at the beginning and the end of study
Usability	Effectiveness (task complete rate)	Number of observation/number of opening submission page
	Learnability	Total time for using application at first time
	Satisfaction	Questionnaire

Table 4: Dependent variables

Users' satisfaction measures	
Perceived ease of use (Kim & Cho, 2009; Koufaris, 2002)	I think that I would like to use this system frequently.
	I found the system unnecessarily complex.
	I thought the system was easy to use.
	I think that I would need the support of a technical person to be able to use this system.
	I found the various functions in this system were well integrated.
	I thought there was too much inconsistency in this system.
	I would imagine that most people would learn to use this system very quickly.
	I found the system very clumsy or difficult to use.
	I felt very confident using the system.
	I needed to learn many things before I could get going with this system.
	I find it easy to get the system to do what I want it to do.
	Overall, I am satisfied with how easy it was to use the system.
User enjoyment (Koufaris, 2002)	The application makes measuring tasks more interesting
	Working with the program is fun.
	I found using the system to be enjoyable.
	The actual process of using the system is pleasant.
Motivation Measures	
Perceived motivation	I was motivated to submit observations.
	I was motivated to use the system regularly.
Perceived motivation by gamification	I achieved my challenge
	Seeing my name in the leaderboard motivated me to submit more observations
	Seeing my points reduced motivated me to submit new observations
	I learned about global warming with the storyboard
	I followed my own progress on the activity tab

Table 5: Questionnaire

3.5.5 Selection of Subjects

Forty-one students from Lappeenranta University of Technology (LUT) signed up to participate in the experimental study, which took place from 24 March to 12 April 2017. After signing consent agreement, those 41 students were completely randomized into 2 groups, so finally 21 students received treatment 1 (gamified application) and other 20 students received treatment 2 (non-gamified application).

Participants were informed that the researchers wanted to study the engagement of citizens in climate change mitigation by observing the changes in the snow and ice condition. However, they were not aware of the actual hypotheses stated nor the existence of two treatments (gamified application and non-gamified application) until the end of the experimental study. All participants were guaranteed anonymity and the below paragraph is taken from the survey being distributed to participants.

"*Jarvi is a gamified mobile application to monitor lakes across Finland. Jarvi invites you to observe the progress of spring in the lakes by reporting changes in the snow and ice during 20 days from 24 March to 12 April via a mobile application. The observations are being collected for research purposes to help study the opportunities for engaging citizens in climate change mitigation. All collected data will be handled and stored confidentially and, no data will be released for the use of any third party, with the exception of anonymized analysis as research results. From these published results, it will be impossible to deduct any information on names, products or answers from any individual participant.*"

3.5.6 Design Type

Wohlin et al. (2012) categorized experimental design into four main categories: one factor with two treatments, one factor with more than two treatments, two factors with two treatments and more than two factors each with two treatments. In this experimental study, **one factor with two treatments** was chosen as the experiment design. One factor with two treatments design compares two treatments against each other.

The aim of this experiment was to investigate if gamified application provided higher level of user's engagement and application usability than the non-gamified application. The factor in this experiment was the application and the treatments were the gamified and non-gamified.

- Treatment 1: Gamified application
- Treatment 2: Non-gamified application

3.5.7 Instrumentation

The instruments for an experiment are of three types, namely objects, guidelines and measurement instruments (Wohlin et al., 2012). Guidelines were needed to guide the participants in the experiments. The guidelines for the two applications were available in each application accordingly. Pre-survey and post-survey were used to study the background of participants and satisfaction after experimental study.

4 RESULTS

This section describes the results from the twenty-day experiment between 24 March and 12 April. There were 41 participants participated in this experiment, and all of the participants were students from Lappeenranta Technology University (LUT). To answer the research questions, the results were shown in comparison between two applications: non-gamified and gamified application.

A. Demographics

There were 41 participants signed to participate in the experimental study (Figure 19). Participants were completely randomized and divided into two groups. Finally, there were 20 participants using non-gamified application and other 21 participants using gamified application.

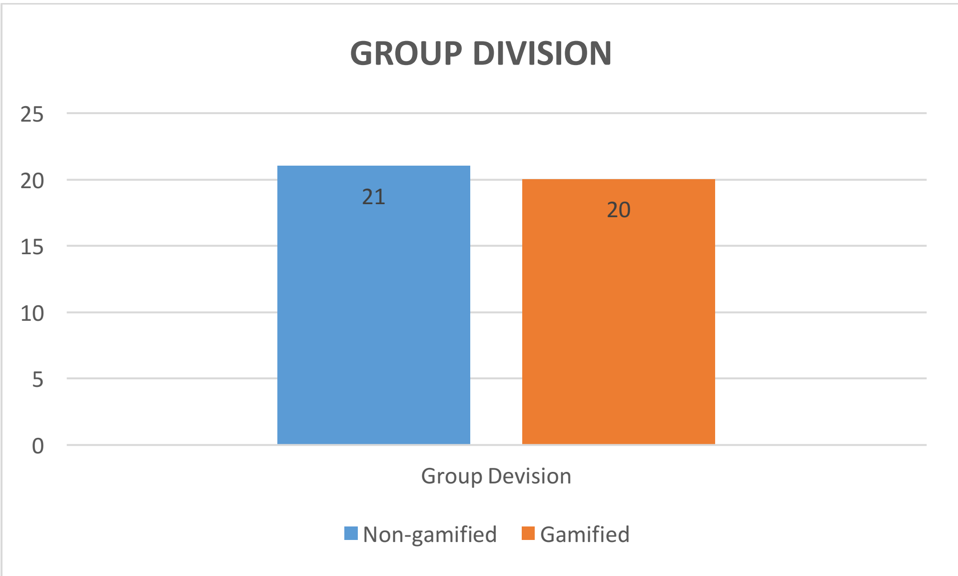


Figure 20: Group division

Thirty-eight out of 41 participants have ages between 22 and 34 years old, which represented 90% of total participants (Figure 20). There were only two participants who are 21 and under, while one participant is in range from 35 to 44 years old.

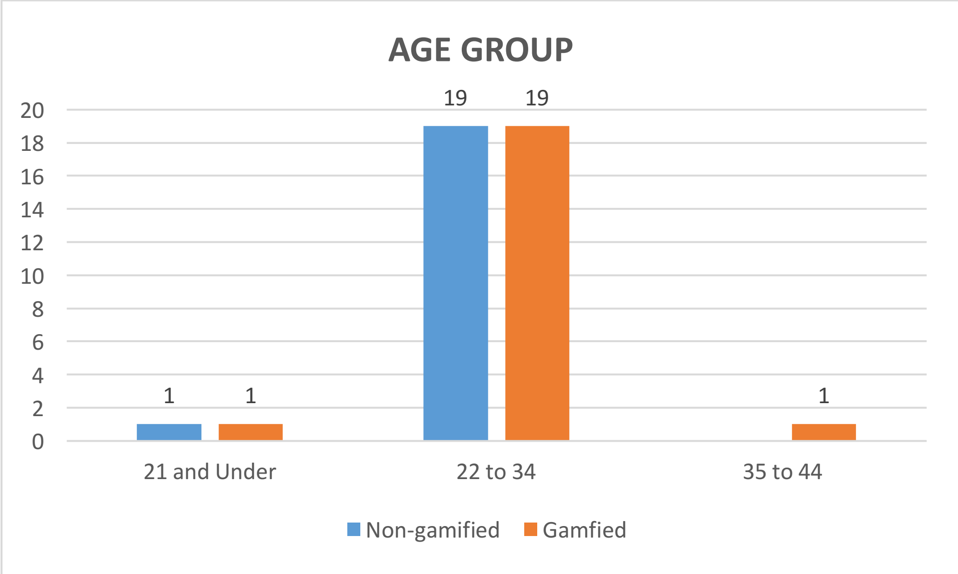


Figure 21: Age group

Before using the applications, participants were asked to do the pre-survey. Participants were asked about their background knowledge of understanding the importance of the observation. Almost all participants knew the importance of ice condition observation either completely or partially; however, only one participant mentioned that he or she had no idea about this observation (Figure 21).

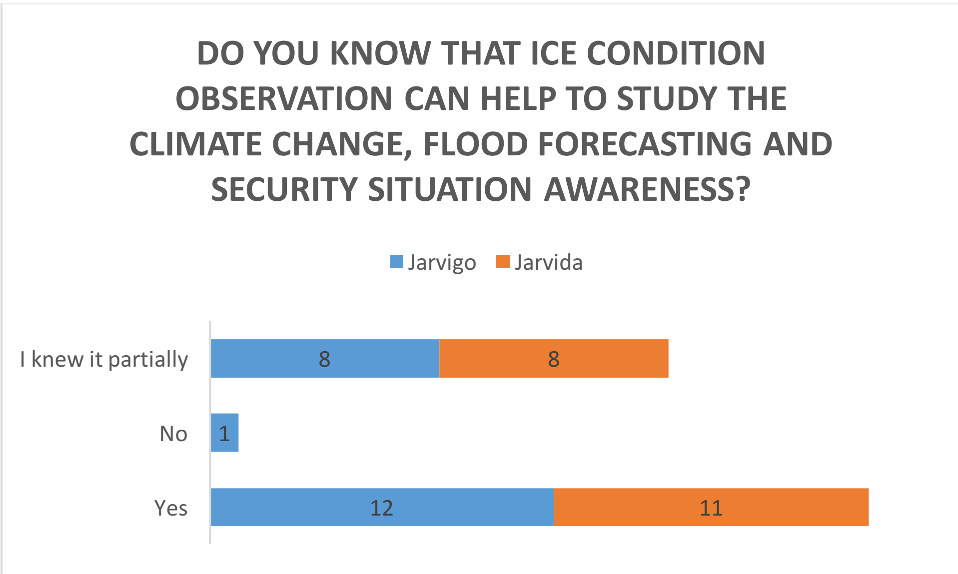


Figure 22: Background knowledge of participants

B. User Engagement

RQ1: How does gamification affect the engagement of participants?

Engagement was measured by three indicators such as involvement, retention and dropout. *Involvement* in this context referred to number of observations submitted by participants. There were 305 observations from both application, in which 45 observations from participants using non-gamified application and 260 observations submitted from gamified application. The number of observations from gamified application was 70% higher than that of non-gamified application (Figure 22).

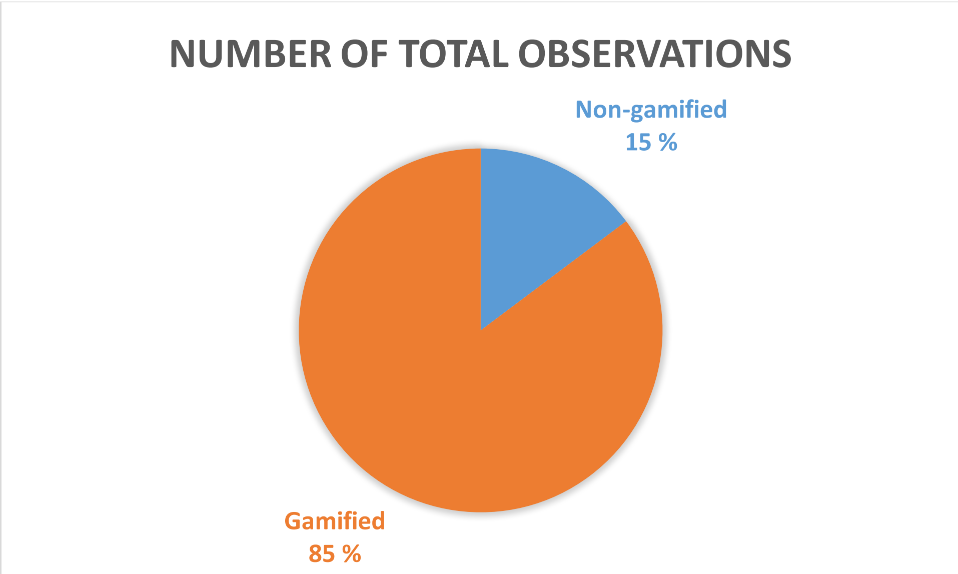


Figure 23: Number of observations

Retention referred to the number of participants who were still active or submit the observations from beginning until the end of the experiment. There were 20 participants using non-gamified application, which three of them were considered as active users corresponding to 15%. On the other hand, among 21 participants using gamified application, there were 10 active participants corresponding to 48%. The study showed that the level of retention of gamified application was 33% higher than that of non-gamified (Figure 23).

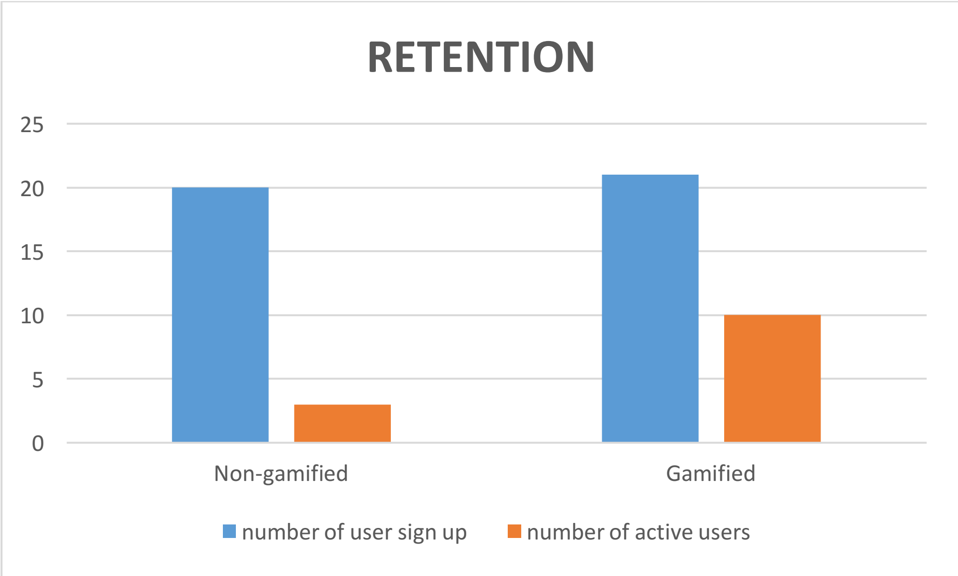


Figure 24: Retention

In non-gamified application, there were 20 participants at the beginning of the experiment, but there were only 18 participants who carried the experiment until the end. In gamified application, there were 21 participants in which one of them dropout in the middle of the study. The result illustrated that there weren't major differences in the *dropout* between the two applications (Figure 24).

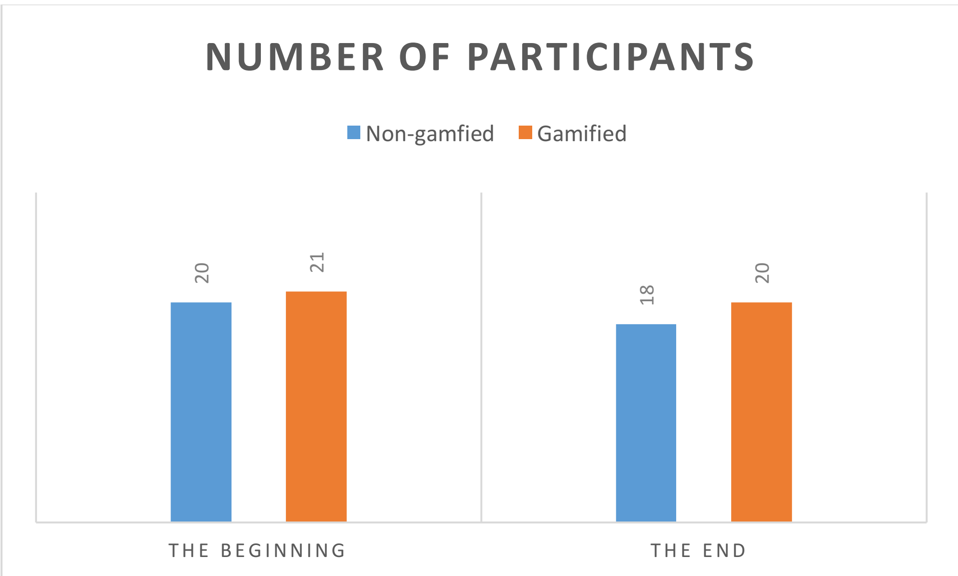


Figure 25: Dropout

C. Usability

RQ2: How does gamification affect the usability of the system?

Usability was measured by learnability, effectiveness and satisfaction. *Learnability* refers to the time users spent for using the application at the first time. Learnability was recorded at the beginning of the experiment. The two applications provided the same features except having gamified elements. The flow of both applications can be found in appendix 2 and 3. Non-gamified application users spent 166 seconds in average to use the application, while gamified application users spent 167 seconds in average. The study showed that the learnability between the two applications is approximately the same (Figure 25).

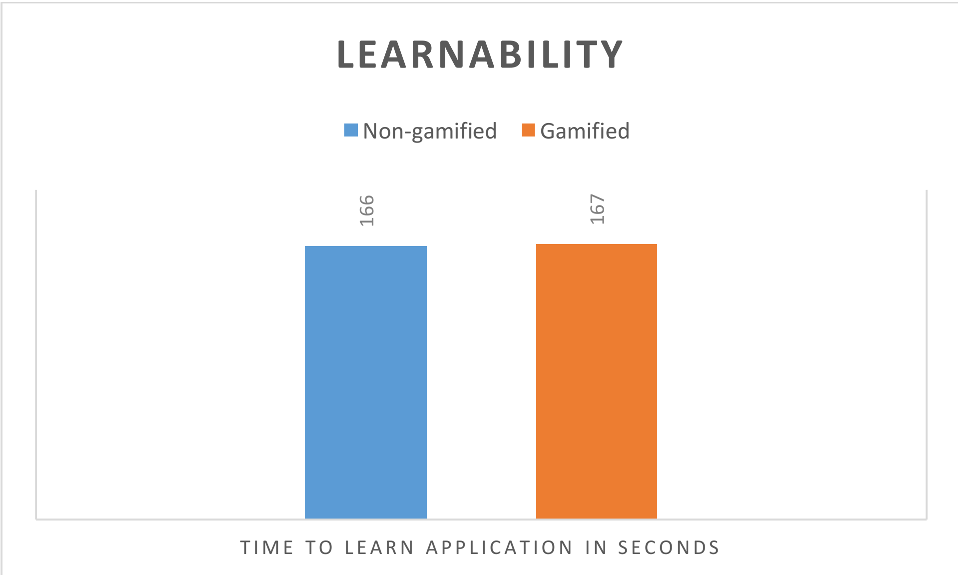


Figure 26: Learnability

Effectiveness refer to the success rate that user submit observations. It was calculated by taking number observations divided by number of submission page opening. There wasn't a large difference of effectiveness between the two applications although the gamified application (55%) has higher rate than the non-gamified (36%) (Figure 26).

$$Effectiveness = \frac{Total\ number\ of\ observations}{Total\ number\ of\ opening\ submission\ page} \times 100$$

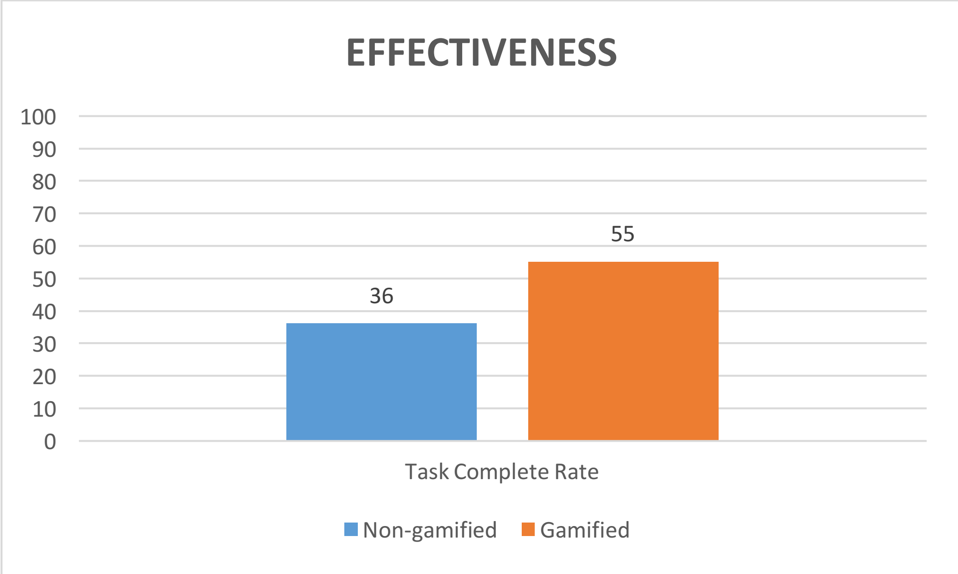


Figure 27: Effectiveness

At the end of the experiment, participants were asked to participate in the post-survey. Each group of participants rated their experiences after using the application accordingly. Figure 27 shows that the average ease of use of both groups were very positive. There was no a major difference between perceived ease of use of users for both applications, which mean that users were satisfied with the application they were using.

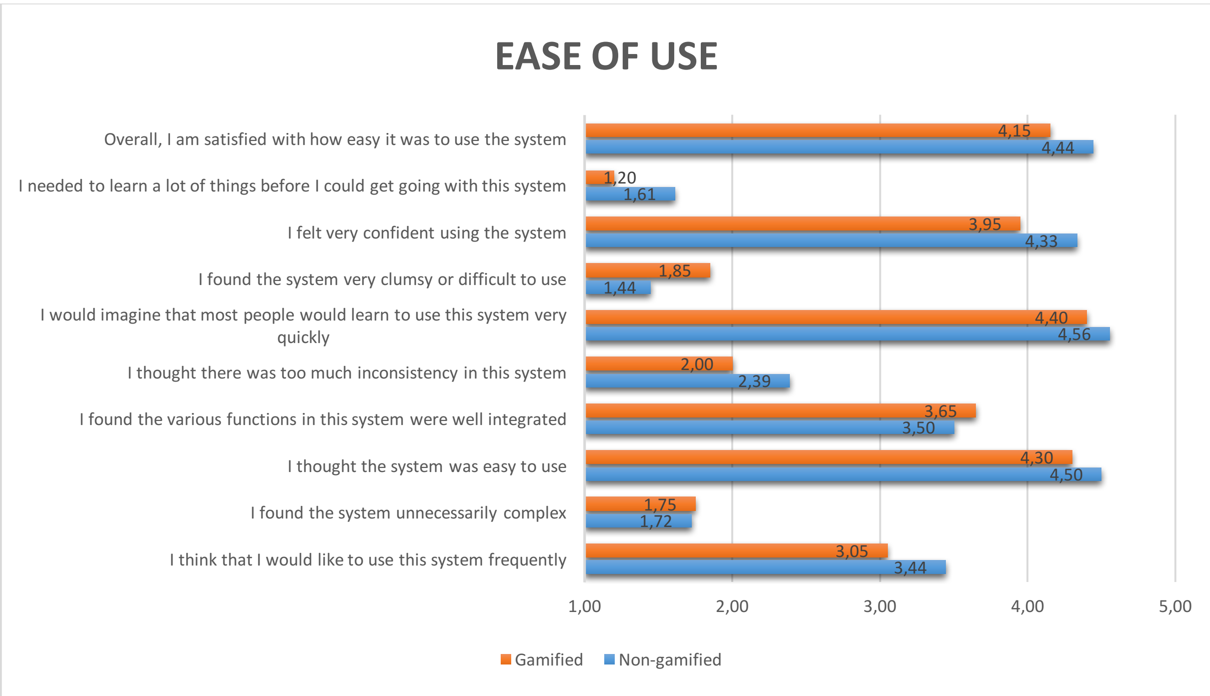


Figure 28: Ease of Use

Figure 28 shows the level of user's enjoyment between the two applications. According to the result from the questionnaire, the perceived enjoyments of using the non-gamified and gamified application are almost the same. In average of five scales, the enjoyment of participants in using non-gamified application was 0.03 higher than the gamified application in all questions.

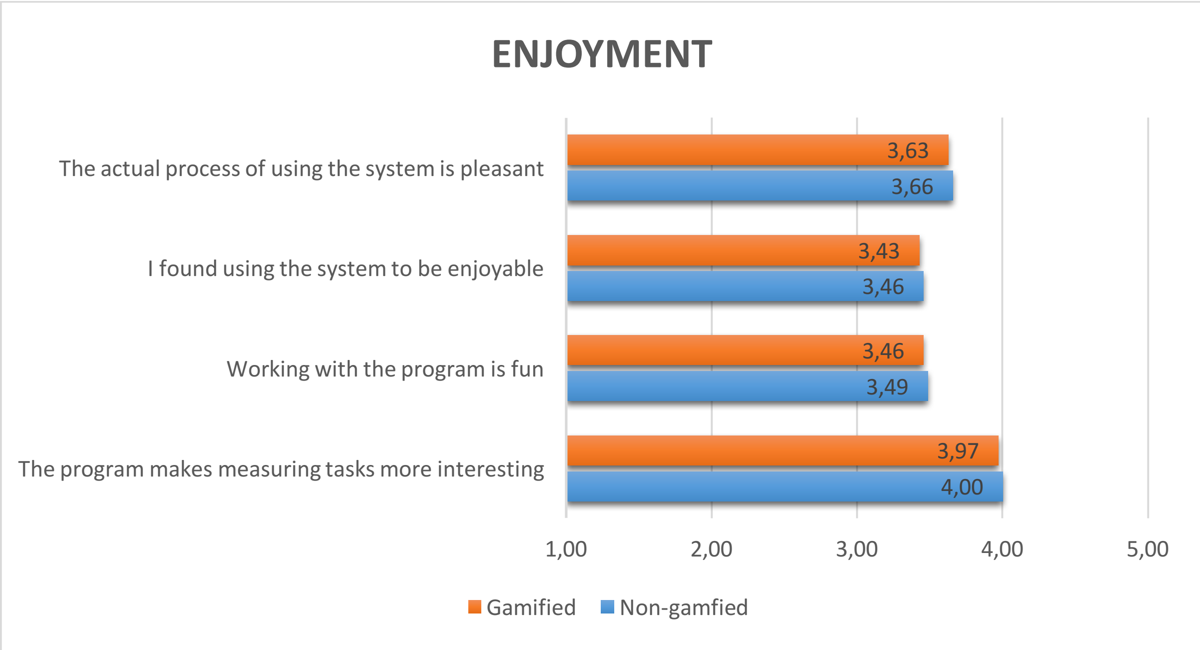


Figure 29: User enjoyment

D. User Motivation

After using applications, user were asked to answer questions about their motivation of using the applications at the end of the experiment.

Application in General

Figure 29 shows the motivation of participants in using the applications from their own perspective. According to results from questionnaire, both user groups were motivated to submit many observations and use the system regularly. In average, the motivations of both groups were almost the same.

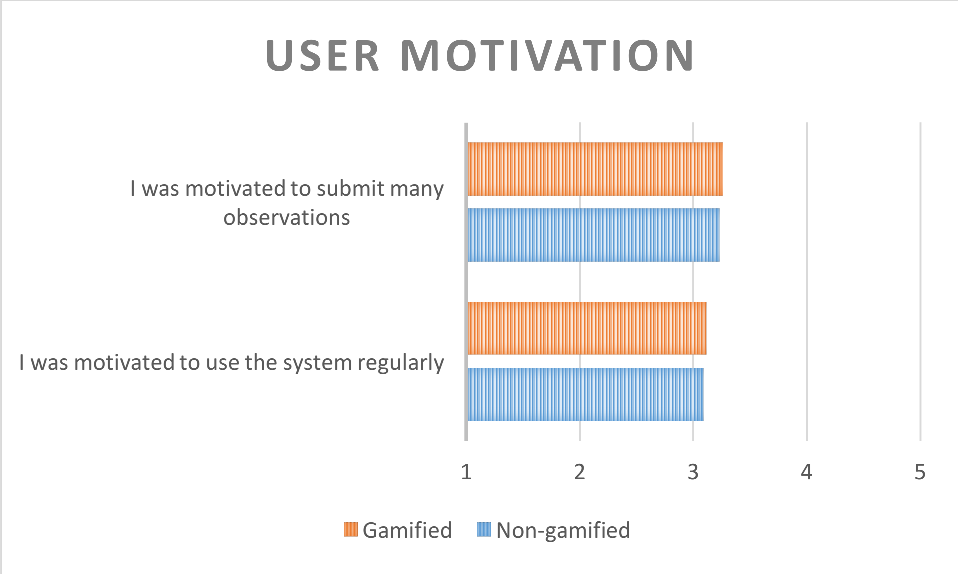


Figure 30: User motivation

Gamification

Participants were asked to rank their experiences with each gamified mechanics at the end of the experiment. Gamification scheme was ranked from the most important to the least important as below (Figure 30):

1. Seeing my name in the leaderboard motivated me to submit more observations
2. I followed my progress on the activity tab
3. I learned about global warming with the storyboard
4. Seeing my points reduced motivated me to submit new observations
5. I achieved my challenge of submitting 20 observations in 20 days

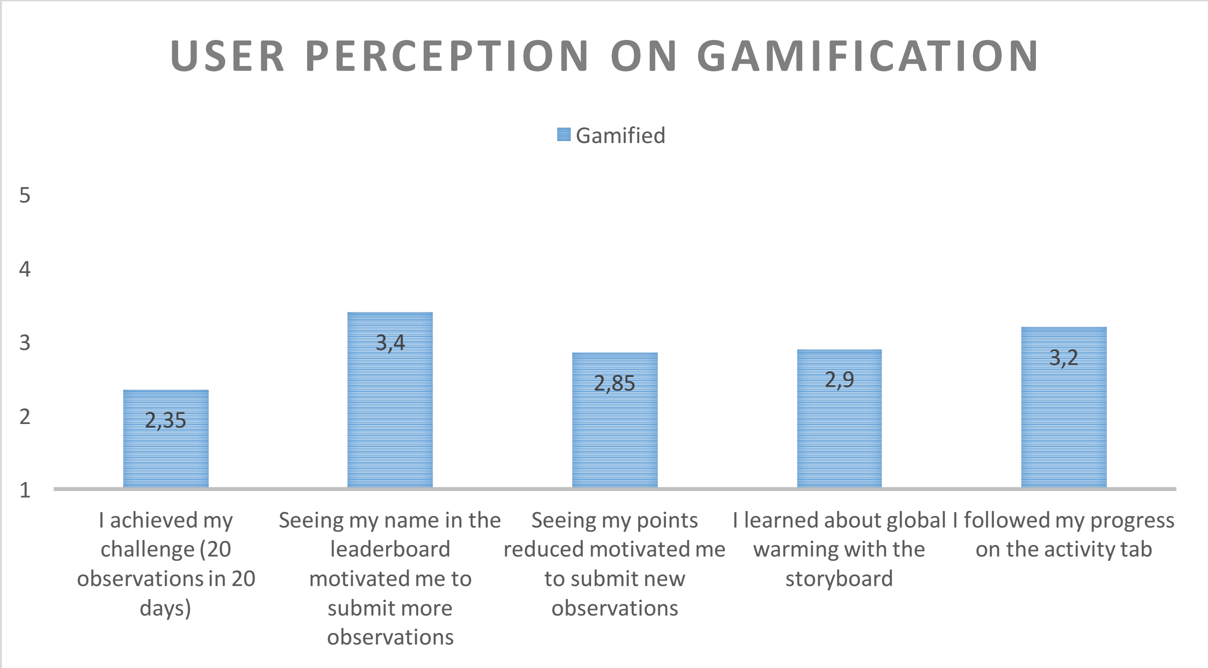


Figure 31: User perception on gamification

E. Awareness

At the end of the experiment, participants were asked to rate about the importance of ice condition observation. According the participants' perception, the benefits of ice condition observations were ranked from the most important to the least important (Figure 31) as below:

1. Provide safety information e.g. ice thickness
2. Understanding the long-term effects of climate change
3. Understanding natural phenomena
4. Understand the condition of the lakes
5. Predict future changes in nature
6. Complement data from satellites

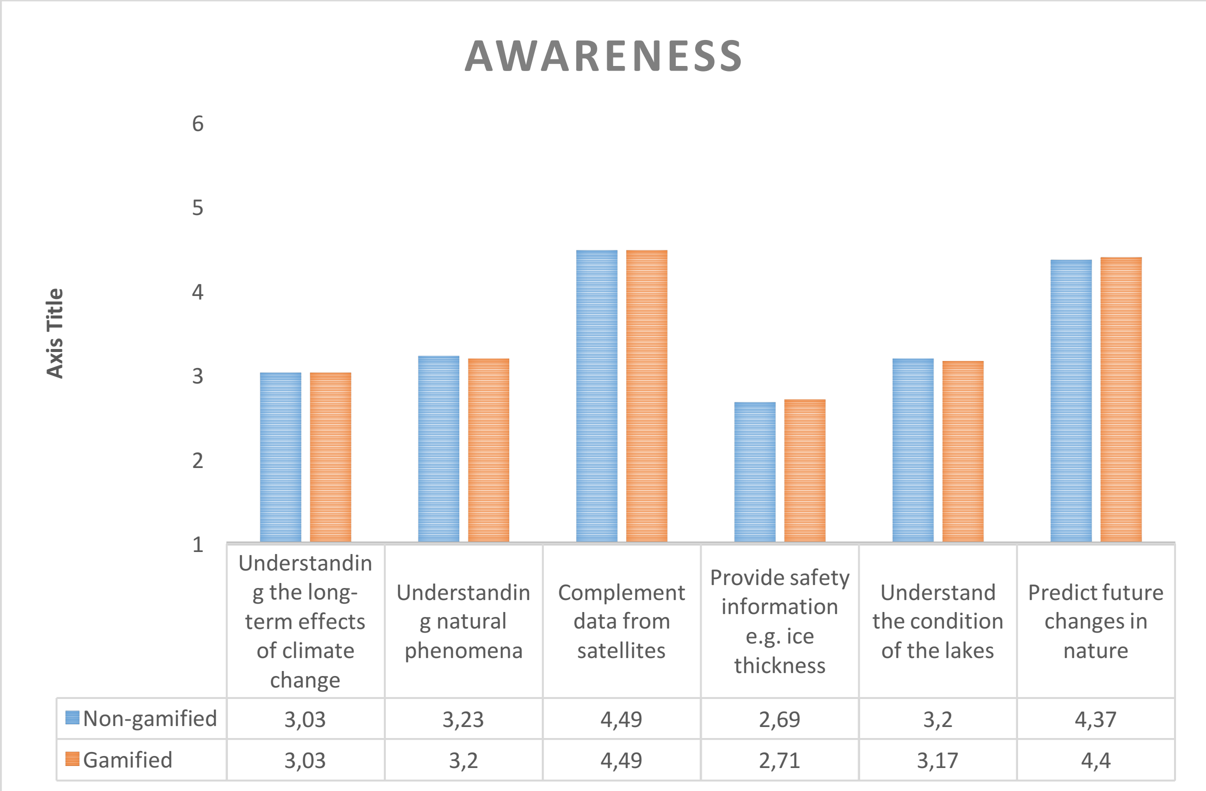


Figure 32: Awareness on importance of ice condition observation

In general, the findings can be concluded from the results are as below:

- Gamification or gamified application is more engaging than the non-gamified or normal application.
- Gamification doesn't have any impact on the usability of the system since both gamified and non-gamified application provide almost the same result in term of usability
- Interestingly, gamification affect users' behavior but not users' perception. Although participants of the gamified application were more engaging in the system in term of observation submission and level of activeness, their perceptions on using application with gamification are not higher than that of the normal application
- Providing the sense achievement/competition and feedback are very important in motivating users to participate in the application. Participants rated leaderboard and capability to see their progress as the most motivating mechanism.
- It seems that people see the importance of the observation in direct benefit to their daily life rather than as a long-term benefit that they cannot see since providing the safety information such as ice thickness was ranked as the most crucial benefit users' opinions.

5 DISCUSSION

This section will discuss how the findings from this thesis work are related to previous studies and theories, what the remaining challenges are, and finally what limitations are imposed in the study.

Research Question 1: How does gamification affect the engagement of participants?

Quantitative approach was used to study the impact of gamification on the engagement of participants in participatory sensing system. The engagement of participants was evaluated by the number of observations, the number of active users and the number of dropouts. According to the result presented in section IV, the system with gamification provided higher level of engagement than the normal system, which the gamified application scored higher in all indicators (involvement, retention and dropout) compared to the non-gamified application. Similarly, (Arakawa & Matsuda, 2016) also used gamification as an incentive mechanism in a participatory sensing system called NAIST photo. Status level scheme, ranking scheme and badge scheme were used for attracting participants doing the sensing task. The sensing tasks were categorized as the task with gamification schemes and without gamification schemes. In 30-day experiment of 18 users, the result showed that the task with gamification schemes received more responses, which gamification increased the participation probability from 53% (without gamification) to 73%.

Research Question 2: How does gamification affect the usability?

In this thesis, usability of the application was measured by three indicators, namely learnability, effectiveness and satisfaction. The application with gamification and without gamification did not provide a major or noticeable difference in term of usability based on these three indicators. Apart from the engagement, gamification has little significant impact on the usability of the application. However, the author would like to clarify that the effect of gamification on usability were in term of three indicators only (learnability, effectiveness and satisfaction). The study of gamification with other usability attributes may produce different result. (Nielsen & Jakob, 1993) defined usability in correlation with five attributes: efficiency, satisfaction, learnability, memorability, and errors, while the International Organization for Standardization (ISO) identified usability based on effectiveness, efficiency and satisfaction (Jokela et al., 2006). Actually, Efficiency attribute of usability, time that users spent to complete the observation task, for both applications were also recorded. However, due to the difference of activity flow and logic between the applications, the author could not make a meaningful comparison of efficiency. Thus, the efficiency result could not include in the study.

Challenges for Participatory Sensing

Although participant's motivation is a challenge in participatory sensing system, the other remaining problems such as data quality/accuracy and participant's privacy are also the challenges that need to consider thoroughly. Data from participatory sensing tends to be redundant because multiple users might submit similar observations. The participation that allows anyone to contribute data can bring the system to erroneous and malicious contributions (Kanhere, 2011). For instance, participants may send incorrect, low quality or even fake data. On the other hand, faulty measurements are possibly recorded even when users may position their devices inattentively (Tweddle et al., 2009). The matter of dealing with data quality or accuracy is different according to each scenario. (Tweddle et al., 2009) highlighted the importance of training materials, user supports and even direct communication channel for participants to achieve high quality data and minimize the complexity of the tasks. A possible method to ensure quality of data is to compare the measurement collected within a predefined time window to determine the most frequent value, the mean and the standard deviation (Mazzoleni et al., 2015). In this thesis study, there was no data from different users who provided different observation parameters for the same observation location. However, there is no guarantee that this scenario will not happen. Hence, in this lake's ice condition observation, comparing the measurement of observation parameters within a period or geographical range is a promising approach. For instance, if the observation parameters (no ice-covered, partially ice-covered and compactly ice-covered) are different among different users within the approximate geographical coordinates, the values that would take into consideration are the values submitted from the majority of participants.

Participant privacy is also one of the most controversial issues in participatory sensing system. Privacy needs to be addressed carefully in participatory sensing because sensitive information (personal habits, private locations, and protected locations) has been collected. In this context, there is a need to define and respect data ownership, usage rules (limits), and accountability (responsibility for the direct and indirect effects of data usage) (Palacin-Silva et al., 2016).

Even though the subject of interest is environmental-centric, the participatory sensing applications still monitor the context of the participants and thus post a threat to their privacy even the threat are less perceptible than people-centric applications. The trust between the system owner and the participants are extremely important to make the system operate successfully. The system should provide guarantee and capability for participants to have control over their information. In the experiment of this thesis, although participant's privacy is not in the scope of the study, this matter was also considered throughout the study to minimize the threat and any risk to the participants. Participants are asked to sign the consent agreement (appendix 5), and their information was promised to delete once the study is completed. Participants were provided a clear instruction about usage of their information and sensor data, and they were allowed to use fake email address and name for using the application.

Sustainability Analysis of the Application

Sustainability and sustainable development have become more significant in the last few decades. The term **'sustainable development'** is defined as the "*development that would satisfy the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland, Gro, 1985). On 2005 world summit on social development, sustainability was presented as the integration of three important components, known as the three pillars of sustainability, namely economic, social and environmental sustainability.

Since software systems have effects on our lives, supporting sustainability in software engineering would also have significant impacts on making the Earth sustainable as well as enhancing our societies, economies and environment ("Software Engineering for Sustainability (SE4S)," n.d.). Despite having no standard definition of sustainable software engineering, software engineers have been working to topics related to a sustainable impact, such as network optimization, energy efficiency (Owusu & Pattinson, 2012) efficient algorithms, smart grids as the future of our society (Friderikos, Helard, Porras, & Rao, 2014), green IT, agile practices and knowledge management (Penzenstadler et al., 2012).

A sustainability analysis model was proposed by Becker et al. (2016) to assess the systemic effects of a software on the five dimensions of sustainability. This model focuses on the following three core systemic effects defined by Hilty & Aebischer (2015):

- Immediate effects: Direct effects of the entire life cycle of the software system.
- Enabling effects: Appear from the use of the system over a long period.
- Structural effects: *"persistent changes observable at the macro level"* (Hilty & Aebischer, 2015)

The model by Becker et al. (2016) was used to assess the systemic effects of Jarvi on the five sustainability dimensions. The analysis is presented in Figure 30. The arrows represent the enabling relationship of each effect. For example, by providing the information on the state of the lakes, the system can raise environmental awareness of the individual. Once people understand more about environmental problems and sustainability, they will eventually lead a sustainable lifestyle.

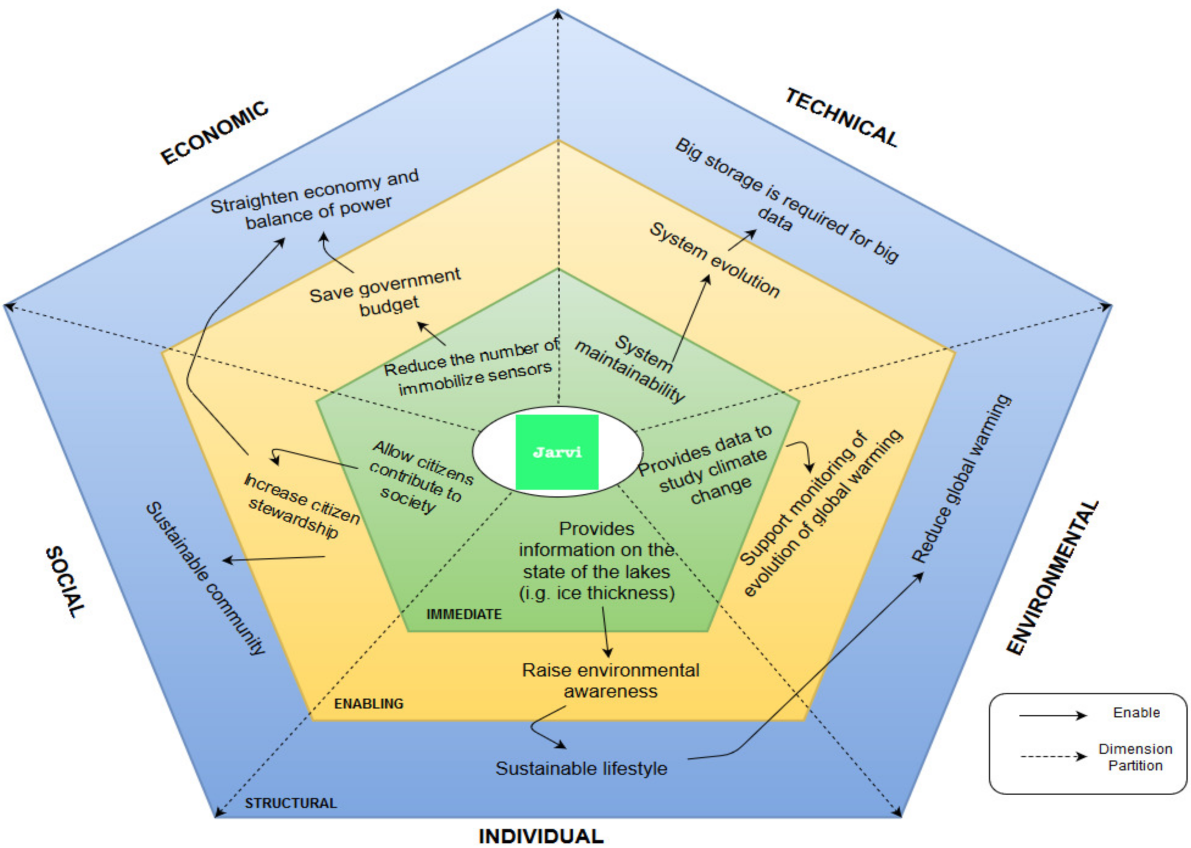


Figure 33: Selected immediate, enabling and structural effects of system Jarvi in five sustainability dimensions adapted from (Becker et al., 2016)

Limitation

This study has a number of limitations such as:

- Field novelty and design: the experiment was carried out in a short period of time with a small sample size (participants). Moreover, since the experiment was conducted within the university environment and had university students as participants, 90% of participants were in the age groups of between 22 and 34 years old. The result could be more meaningful if there were various age group of participants participated in the study.
- Gamification design in the system: the achievement mechanism in gamification can motivate users to complete the task but it can also post a problem of cheating to the system. Thus, cheating prevention is the challenge in implementing gamification to the system. In this experiment, few participants submitted duplicated observations, meaning same photo, observation parameter and location, intentionally or unintentionally. Nevertheless, those duplicate observations were already excluded from the result.

6 CONCLUSION

Participatory sensing has become the prevailing research topic and interest due to the popularity and accessibility of modern smart phones with digital image and GPS coordinate capabilities. Several challenges remain to unleash the full potential of participatory sensing systems, one of which is participants’ motivation. This thesis aimed to solve this challenge by using gamification, game elements in non-game contexts, to motivate and engage users. The mobile application called “Jarvi” with gamified elements embedded was developed. This application enables citizens to monitor the ice condition of lakes, receive safety information and gain awareness of climate change.

To evaluate the impact of gamification on participant’s engagement and usability of the system, an experiment was carried out with 41 participants for 20 days. User engagement was measured by number of observations, number of active users and number of dropouts, and usability was measured by effectiveness, learnability and users’ satisfaction. Among 41 participants, 21 participants used the application with gamification, while the other 20 participants used the application without gamification. The application with gamification scored higher in user engagement than the normal application. However, both applications had similar results in terms of usability. The results from the study suggests that gamification is a promising technique to engage citizens to the system without affecting the usability of the system.

Future work can include the experiment with larger samples (participants) and longer testing period in order to evaluate the effect of gamification on participants’ engagement and application’s usability. Finally, despite being used for lakes observation, this gamified application has potential to be applied in any other domains of participatory sensing.

In order to achieve sustainable development, tools for monitoring the environment and society like “Jarvi” are required. These tools represent an opportunity for large-scale monitoring, balance of powers in society, raising awareness of individuals and communities as well as addressing climate change as we cannot control nor improve what we do not monitor.

REFERENCES

Antin, J., & Cheshire, C. (2008). Designing social psychological incentives for online collective action. *Directions and Implications of Advanced Computing;* Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.359.8814&rep=rep1&type=pdf

Arakawa, Y., & Matsuda, Y. (2016). Gamification Mechanism for Enhancing a Participatory Urban Sensing: Survey and Practical Results. *Journal of Information Processing*, *24*(1), 31–38. https://doi.org/10.2197/ipsjjip.24.31

Bartle, R. a. (1999). Players Who Suit MUDs. *Mud*, 1. https://doi.org/10.1007/s00256-004-0875-6

Batson, C. D., Ahmad, N., & Tsang, J.-A. (2002). Four Motives for Community Involvement. *Journal of Social Issues*, *58*(3), 429–445. https://doi.org/10.1111/1540-4560.00269

Becker, C., Betz, S., Chitchyan, R., Duboc, L., Easterbrook, S. M., Penzenstadler, B., … Venters, C. C. (2016). Requirements: The key to sustainability. *IEEE Software*, *33*(1), 56–65. https://doi.org/10.1109/MS.2015.158

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *BioScience*, *59*(11), 977–984. https://doi.org/10.1525/bio.2009.59.11.9

Brabham, D. C. (2008). Crowdsourcing as a Model for Problem Solving: An Introduction and Cases. *Convergence: The International Journal of Research into New Media Technologies*, *14*(1), 75–90. https://doi.org/10.1177/1354856507084420

Brathwaite, B., & Schreiber, I. (2009). *Challenges for game designers*. Charles River Media, a part of Course Technology. Retrieved from http://dl.acm.org/citation.cfm?id=1481314

Brundtland, Gro, H. (1985). World Commission on environment and development. *Environmental Policy and Law*, *14*(1), 26–30. https://doi.org/10.1016/S0378-777X(85)80040-8

BusinessofApps. (2016). Pokémon GO Usage and Revenue Statistics. Retrieved May 30, 2017, from http://www.businessofapps.com/pokemon-go-usage-revenue-statistics/

Cafazzo, J. A., Casselman, M., Hamming, N., Katzman, D. K., & Palmert, M. R. (2012). Design of an mHealth app for the self-management of adolescent type 1 diabetes: a pilot study. *Journal of Medical Internet Research*, *14*(3), e70.

https://doi.org/10.2196/jmir.2058

Chilvers, J., Lorenzoni, I., Terry, G., Buckley, P., Pinnegar, J. K., & Gelcich, S. (2014). Public engagement with marine climate change issues: (Re)framings, understandings and responses. *Global Environmental Change*, *29*, 165–179. https://doi.org/10.1016/j.gloenvcha.2014.09.006

Christin, D., Reinhardt, A., Kanhere, S. S., & Hollick, M. (2011). A survey on privacy in mobile participatory sensing applications. *Journal of Systems and Software*, *84*(11), 1928–1946. https://doi.org/10.1016/j.jss.2011.06.073

Crowston, K., & Prestopnik, N. R. (2013). Motivation and Data Quality in a Citizen Science Game: A Design Science Evaluation. In *2013 46th Hawaii International Conference on System Sciences* (pp. 450–459). IEEE. https://doi.org/10.1109/HICSS.2013.413

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness. In *Proceedings of the 15th International Academic MindTrek Conference on Envisioning Future Media Environments - MindTrek '11* (p. 9). New York, New York, USA: ACM Press. https://doi.org/10.1145/2181037.2181040

DeviceAtlas. (2016). 16 mobile market statistics you should know in 2016. Retrieved May 30, 2017, from https://deviceatlas.com/blog/16-mobile-market-statistics-you-should-know-2016

Dickinson, J. L., & Bonney, R. (2012). Citizen science: public collaboration in environmental research. Ithaca, NY: Cornell University Press.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., … Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, *10*(6), 291–297. https://doi.org/10.1890/110236

Difference Between Independent and Dependent Variables. (n.d.). Retrieved May 29, 2017, from https://www.thoughtco.com/i-ndpendent-and-dependent-variables-differences-606115

Droege, S. (2007). Just because you paid them doesn't mean their data are better. *Citizen Science Toolkit Conference*, 1–14.

Egenfeldt-Nielsen, S., Smith, J. H., Tosca, S. P., & Egenfeldt-Nielsen, S. (2013). *Understanding video games : the essential introduction*. Routledge. Retrieved from https://books.google.fi/books/about/Understanding_Video_Games.html?id=0tygn2UisUoC&redir_esc=y

Estellés-Arolas, E., & González-Ladrón-de-Guevara, F. (2012). Towards an integrated crowdsourcing definition. *Journal of Information Science*, *38*(2), 189–200. https://doi.org/10.1177/0165551512437638

Estrin, D. (2010). Participatory sensing: applications and architecture [Internet Predictions]. *IEEE Internet Computing*, *14*(1), 12–42. https://doi.org/10.1109/MIC.2010.12

Finnish Environment Institute. (2013). Hydrological situation and forecasts. Retrieved May 29, 2017, from http://www.tulvakeskus.fi/en-US/Waters/Hydrological_situation_and_forecasts/Hydrological_situation_and_forecasts

Friderikos, V., Helard, M., Porras, J., & Rao, T. R. (2014). Toward a Smart, Fully Connected Society: An Overview of the 32nd Meeting of the Wireless World Research Forum [From the Guest Editors]. *IEEE Vehicular Technology Magazine*, *9*(3), 24–26. https://doi.org/10.1109/MVT.2014.2335392

Goldman, J., Shilton, K., Burke, J., Estrin, D., Hansen, M., Ramanathan, N., … Samanta, V. (2009). Participatory Sensing: A citizen-powered approach to illuminating the patterns that shape our world. *Office*, *14*(May), 1–15. https://doi.org/10.1109/MIC.2010.12

Guo, B., Wang, Z., Yu, Z., Wang, Y., Yen, N. Y., Huang, R., & Zhou, X. (2015). Mobile Crowd Sensing and Computing. *ACM Computing Surveys*, *48*(1), 1–31. https://doi.org/10.1145/2794400

Gustafsson, A., Katzeff, C., & Bang, M. (2009). Evaluation of a pervasive game for domestic energy engagement among teenagers. *Computers in Entertainment*, *7*(4), 1. https://doi.org/10.1145/1658866.1658873

Heggen, S. (2013). Participatory sensing. *Interactions*, *20*(1), 18. https://doi.org/10.1145/2405716.2405722

Hilty, L. M., & Aebischer, B. (2015). ICT for Sustainability: An Emerging Research Field. Retrieved from http://publicationslist.org/data/lorenz.hilty/ref-225/2014_Hilty_Aebischer_ICT_for_Sustainability.pdf

Howe, J. (2006). Crowdsourcing: A definition. *Crowdsourcing: Tracking the Rise of the Amateur*. Retrieved from https://scholar.google.com/scholar?cluster=18013007550735437827&hl=en&oi=scholarr

ISO 9241-11:1998(en), Ergonomic requirements for office work with visual display terminals (VDTs) — Part 11: Guidance on usability. (n.d.). Retrieved May 29, 2017, from https://www.iso.org/obp/ui/#iso:std:16883:en

Johannesson, P., & Perjons, E. (2014). *An Introduction to Design Science*. *Springer International Publishing Switzerland*. https://doi.org/10.1007/978-3-319-10632-8

Jokela, T., Koivumaa, J., Pirkola, J., Salminen, P., & Kantola, N. (2006). Methods for quantitative usability requirements: A case study on the development of the user interface of a mobile phone. *Personal and Ubiquitous Computing*, *10*(6), 345–355. https://doi.org/10.1007/s00779-005-0050-7

Kanhere, S. S. (2011). Participatory Sensing: Crowdsourcing Data from Mobile Smartphones in Urban Spaces. In *2011 IEEE 12th International Conference on Mobile Data Management* (pp. 3–6). IEEE. https://doi.org/10.1109/MDM.2011.16

Khan, Z., Kiani, S. L., & Soomro, K. (2014). A framework for cloud-based context-aware information services for citizens in smart cities. *Journal of Cloud Computing*, *3*(1), 14. https://doi.org/10.1186/s13677-014-0014-4

Kim, Y., & Cho, S.-B. (2009). A ringtone recommendation agent based on a Bayesian model of user emotion. In *2009 IEEE International Conference on Intelligent Computing and Intelligent Systems* (pp. 542–546). IEEE. https://doi.org/10.1109/ICICISYS.2009.5357783

Klimova, A., Rondeau, E., Andersson, K., Porras, J., Rybin, A., & Zaslavsky, A. (2016). An international Master's program in green ICT as a contribution to sustainable development. *Journal of Cleaner Production*, *135*, 223–239. https://doi.org/10.1016/j.jclepro.2016.06.032

Koufaris, M. (2002). Applying the Technology Acceptance Model and Flow Theory to Online Consumer Behavior. *Journal of Information Systems Research*, *13*(2), 205–223. https://doi.org/10.1287/isre.13.2.205.83

Lazzaro, N. (2004). Why We Play Games: Four Keys to More Emotion Without Story. *Game Developer Conference (GDC)*, 1–8. https://doi.org/10.1111/j.1464-410X.2004.04896.x

Lewandowsky, S., Oberauer, K., & Gignac, G. E. (2013). NASA Faked the Moon Landing—Therefore, (Climate) Science Is a Hoax. *Psychological Science*, *24*(5), 622–633. https://doi.org/10.1177/0956797612457686

Marczewski, A. (n.d.). *Gamification : a simple introduction & a bit more*. Retrieved from https://books.google.fi/books/about/Gamification_A_Simple_Introduction.html?id=IOu9kPjlndYC&redir_esc=y

Mazzoleni, M., Verlaan, M., Alfonso, L., Monego, M., Norbiato, D., Ferri, M., & Solomatine, D. P. (2015). Can assimilation of crowdsourced streamflow observations in hydrological modelling improve flood prediction? *Hydrology and Earth System Sciences Discussions*, *12*(11), 11371–11419. https://doi.org/10.5194/hessd-12-11371-2015

Meurisch, C., Planz, K., Schäfer, D., & Schweizer, I. (2013). Noisemap: Discussing Scalability in Participatory Sensing. *Proceedings of First International Workshop on Sensing and Big Data Mining - SENSEMINE'13*, 1–6. https://doi.org/10.1145/2536714.2536720

Moraes, A. L. D., Fonseca, F., Esteves, M. G. P., Schneider, D., & de Souza, J. M. (2014). A meta-model for crowdsourcing platforms in Data Collection and Participatory Sensing. In *Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (pp. 429–434). IEEE. https://doi.org/10.1109/CSCWD.2014.6846883

NASA: Climate Change and Global Warming. (n.d.). Retrieved May 22, 2017, from https://climate.nasa.gov/

Nielsen, J., & Jakob. (1993). *Usability engineering*. Academic Press. Retrieved from http://dl.acm.org/citation.cfm?id=529793

Ogie, R. I. (2016). *Adopting incentive mechanisms for large-scale participation in mobile crowdsensing: from literature review to a conceptual framework. Human-centric Computing and Information Sciences* (Vol. 6). Springer Berlin Heidelberg. https://doi.org/10.1186/s13673-016-0080-3

Owusu, F., & Pattinson, C. (2012). The Current State of Understanding of the Energy Efficiency of Cloud Computing. In *2012 IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications* (pp. 1948–1953). IEEE. https://doi.org/10.1109/TrustCom.2012.270

Oxford English Dictionary. (2014). New words list June 2014. Retrieved May 30, 2017, from http://public.oed.com/the-oed-today/recent-updates-to-the-oed/previous updates/june-2014-update/new-words-list-june-2014/

Palacin-Silva, M., Seffah, A., Heikkinen, K., Porras, J., Pyhälahti, T., Sucksdorff, Y., … Junttila, S. (2016). State-of-the Art Study in Citizen Observatories: Technological Trends, Development Challenges and Research Avenues. Retrieved from https://helda.helsinki.fi/handle/10138/164810

Palmer, T. S. (1917). In Memoriam: Wells Woodbridge Cooke. Born Jan. 25, 1858 - Died March 30, 1916. *The Auk*, *34*(2), 119–132. https://doi.org/10.2307/4072477

Participation, P., Potential, A. I., & Education, I. S. (2009). Research : Defining the Field and Science Education. *Science Education*, (July).

Paul, K., Quinn, M. S., Huijser, M. P., Graham, J., & Broberg, L. (2014). An evaluation of a citizen science data collection program for recording wildlife observations along a highway. *Journal of Environmental Management*, *139*, 180–187. https://doi.org/10.1016/j.jenvman.2014.02.018

Penzenstadler, B., Bauer, V., Calero, C., & Franch, X. (2012). Sustainability in software engineering: a systematic literature review. In *16th International Conference on Evaluation & Assessment in Software Engineering (EASE 2012)* (pp. 32–41). IET. https://doi.org/10.1049/ic.2012.0004

Porras, J., Seffah, A., Rondeau, E., Andersson, K., & Alexandra, K. (2016). PERCCOM: A Master Program in Pervasive Computing and COMmunications for Sustainable Development. https://doi.org/10.1109/CSEET.2016.39

Pyhalahti, T., Toivanen, T., Kallio, K. Y., Jarvinen, M., Molinier, M., Koponen, S., … Lindholm, M. (2015). Advances in combining optical citizen observations on water quality with satellite observations as part of an environmental monitoring system. *International Geoscience and Remote Sensing Symposium (IGARSS)*, *2015–Novem*, 5395–5398. https://doi.org/10.1109/IGARSS.2015.7327055

Raddick, M. J., Bracey, G., Gay, P. L., Lintott, C. J., Murray, P., Schawinski, K., … Vandenberg, J. (2009). Galaxy Zoo: Exploring the Motivations of Citizen Science Volunteers. https://doi.org/10.3847/AER2009036

Resnik, D. B., Elliott, K. C., & Miller, A. K. (2015). A framework for addressing ethical issues in citizen science. *Environmental Science and Policy*, *54*, 475–481. https://doi.org/10.1016/j.envsci.2015.05.008

Restuccia, F., Das, S. K., & Payton, J. (2015). Incentive Mechanisms for Participatory Sensing: Survey and Research Challenges, *V*(212), 1–38. https://doi.org/10.1145/2888398

Ritterfeld, U., Cody, M. J., & Vorderer, P. (2009). *Serious games: mechanisms and effects*. Routledge. Retrieved from https://books.google.fi/books/about/Serious_Games.html?id=GwPf7tbO5mgC&redir_esc=y

Rollings, A., & Adams, E. (Ernest W. . (2003). *Andrew Rollings and Ernest Adams on game design*. New Riders. Retrieved from http://dl.acm.org/citation.cfm?id=1213088

Schnoor, J. L. (2007). *Citizen science. Environmental science & technology* (Vol. 41). https://doi.org/10.1353/eco.2007.0002

Sharma, S., Magnuson, J. J., Batt, R. D., Winslow, L. A., Korhonen, J., & Aono, Y. (2016). Direct observations of ice seasonality reveal changes in climate over the past 320–570 years. *Scientific Reports*, *6*(April), 25061. https://doi.org/10.1038/srep25061

Snyder, M., & Omoto, A. M. (2001). Basic research and practical problems: Volunteerism and the psychology of individual and collective action.

Socientize Project. (2013). Green paper on Citizen Science. Citizen Science for Europe: Towards a society of empowered citizens and enhanced research. *Socientize*, 1–54.

Software Engineering for Sustainability (SE4S). (n.d.). Retrieved May 22, 2017, from http://se4s.ics.uci.edu/

Tweddle, J.C.; Robinson, L.D.; Pocock, M.J.O.& Roy, H. E. (2009a). *Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. https://doi.org/10.1002/biuz.201710611

Tweddle, J.C.; Robinson, L.D.; Pocock, M.J.O.& Roy, H. E. (2009b). *Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. https://doi.org/10.1002/biuz.201710611

Wang, R. Y., & Strong, D. M. (1996). Beyond Accuracy: What Data Quality Means to Data Consumers. *Journal of Management Information Systems*, *12*(4), 5–33. https://doi.org/10.1080/07421222.1996.11518099

Wang, Y., Jia, X., Jin, Q., & Ma, J. (2016). QuaCentive: a quality-aware incentive mechanism in mobile crowdsourced sensing (MCS). *The Journal of Supercomputing*, *72*(8), 2924–2941. https://doi.org/10.1007/s11227-015-1395-y

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., & Wesslén, A. (2012). *Experimentation in Software Engineering*. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-29044-2

Zichermann, G., & Cunningham, C. (2011). *Gamification by design : implementing game mechanics in web and mobile apps*. O'Reilly Media.

Antin, J., & Cheshire, C. (2008). Designing social psychological incentives for online collective action. *Directions and Implications of Advanced Computing;* Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.359.8814&rep=rep1&type=pdf

Arakawa, Y., & Matsuda, Y. (2016). Gamification Mechanism for Enhancing a Participatory Urban Sensing: Survey and Practical Results. *Journal of Information Processing*, *24*(1), 31–38. https://doi.org/10.2197/ipsjjip.24.31

Bartle, R. a. (1999). Players Who Suit MUDs. *Mud*, 1. https://doi.org/10.1007/s00256-004-0875-6

Batson, C. D., Ahmad, N., & Tsang, J.-A. (2002). Four Motives for Community Involvement. *Journal of Social Issues*, *58*(3), 429–445. https://doi.org/10.1111/1540-4560.00269

Becker, C., Betz, S., Chitchyan, R., Duboc, L., Easterbrook, S. M., Penzenstadler, B., … Venters, C. C. (2016). Requirements: The key to sustainability. *IEEE Software*, *33*(1), 56–65. https://doi.org/10.1109/MS.2015.158

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *BioScience*, *59*(11), 977–984. https://doi.org/10.1525/bio.2009.59.11.9

Brabham, D. C. (2008). Crowdsourcing as a Model for Problem Solving: An Introduction and Cases. *Convergence: The International Journal of Research into New Media Technologies*, *14*(1), 75–90. https://doi.org/10.1177/1354856507084420

Brathwaite, B., & Schreiber, I. (2009). *Challenges for game designers*. Charles River Media, a part of Course Technology. Retrieved from http://dl.acm.org/citation.cfm?id=1481314

Brundtland, Gro, H. (1985). World Commission on environment and development. *Environmental Policy and Law*, *14*(1), 26–30. https://doi.org/10.1016/S0378-777X(85)80040-8

BusinessofApps. (2016). Pokémon GO Usage and Revenue Statistics. Retrieved May 30, 2017, from http://www.businessofapps.com/pokemon-go-usage-revenue-statistics/

Cafazzo, J. A., Casselman, M., Hamming, N., Katzman, D. K., & Palmert, M. R. (2012). Design of an mHealth app for the self-management of adolescent type 1 diabetes: a pilot study. *Journal of Medical Internet Research*, *14*(3), e70. https://doi.org/10.2196/jmir.2058

Chilvers, J., Lorenzoni, I., Terry, G., Buckley, P., Pinnegar, J. K., & Gelcich, S. (2014). Public engagement with marine climate change issues: (Re)framings, understandings and responses. *Global Environmental Change*, *29*, 165–179. https://doi.org/10.1016/j.gloenvcha.2014.09.006

Christin, D., Reinhardt, A., Kanhere, S. S., & Hollick, M. (2011). A survey on privacy in mobile participatory sensing applications. *Journal of Systems and Software*, *84*(11), 1928–1946. https://doi.org/10.1016/j.jss.2011.06.073

Crowston, K., & Prestopnik, N. R. (2013). Motivation and Data Quality in a Citizen Science Game: A Design Science Evaluation. In *2013 46th Hawaii International Conference on System Sciences* (pp. 450–459). IEEE. https://doi.org/10.1109/HICSS.2013.413

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness. In *Proceedings of the 15th International Academic MindTrek Conference on Envisioning Future Media Environments - MindTrek '11* (p. 9). New York, New

York, USA: ACM Press. https://doi.org/10.1145/2181037.2181040

DeviceAtlas. (2016). 16 mobile market statistics you should know in 2016. Retrieved May 30, 2017, from https://deviceatlas.com/blog/16-mobile-market-statistics-you-should-know-2016

Dickinson, J. L., & Bonney, R. (2012). Citizen science: public collaboration in environmental research. Ithaca, NY: Cornell University Press.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., … Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, *10*(6), 291–297. https://doi.org/10.1890/110236

Difference Between Independent and Dependent Variables. (n.d.). Retrieved May 29, 2017, from https://www.thoughtco.com/i-ndpendent-and-dependent-variables-differences-606115

Droege, S. (2007). Just because you paid them doesn't mean their data are better. *Citizen Science Toolkit Conference*, 1–14.

Egenfeldt-Nielsen, S., Smith, J. H., Tosca, S. P., & Egenfeldt-Nielsen, S. (2013). *Understanding video games : the essential introduction*. Routledge. Retrieved from https://books.google.fi/books/about/Understanding_Video_Games.html?id=0tygn2UisUoC&redir_esc=y

Estellés-Arolas, E., & González-Ladrón-de-Guevara, F. (2012). Towards an integrated crowdsourcing definition. *Journal of Information Science*, *38*(2), 189–200. https://doi.org/10.1177/0165551512437638

Estrin, D. (2010). Participatory sensing: applications and architecture [Internet Predictions]. *IEEE Internet Computing*, *14*(1), 12–42. https://doi.org/10.1109/MIC.2010.12

Finnish Environment Institute. (2013). Hydrological situation and forecasts. Retrieved May 29, 2017, from http://www.tulvakeskus.fi/en-US/Waters/Hydrological_situation_and_forecasts/Hydrological_situation_and_forecasts

Friderikos, V., Helard, M., Porras, J., & Rao, T. R. (2014). Toward a Smart, Fully Connected Society: An Overview of the 32nd Meeting of the Wireless World Research Forum [From the Guest Editors]. *IEEE Vehicular Technology Magazine*, *9*(3), 24–26. https://doi.org/10.1109/MVT.2014.2335392

Goldman, J., Shilton, K., Burke, J., Estrin, D., Hansen, M., Ramanathan, N., … Samanta, V. (2009). Participatory Sensing: A citizen-powered approach to illuminating the patterns that shape our world. *Office*, *14*(May), 1–15. https://doi.org/10.1109/MIC.2010.12

Guo, B., Wang, Z., Yu, Z., Wang, Y., Yen, N. Y., Huang, R., & Zhou, X. (2015). Mobile Crowd Sensing and Computing. *ACM Computing Surveys*, *48*(1), 1–31. https://doi.org/10.1145/2794400

Gustafsson, A., Katzeff, C., & Bang, M. (2009). Evaluation of a pervasive game for domestic energy engagement among teenagers. *Computers in Entertainment*, *7*(4), 1. https://doi.org/10.1145/1658866.1658873

Heggen, S. (2013). Participatory sensing. *Interactions*, *20*(1), 18. https://doi.org/10.1145/2405716.2405722

Hilty, L. M., & Aebischer, B. (2015). ICT for Sustainability: An Emerging Research Field. Retrieved from http://publicationslist.org/data/lorenz.hilty/ref-225/2014_Hilty_Aebischer_ICT_for_Sustainability.pdf

Howe, J. (2006). Crowdsourcing: A definition. *Crowdsourcing: Tracking the Rise of the Amateur*. Retrieved from https://scholar.google.com/scholar?cluster=18013007550735437827&hl=en&oi=scholarr

ISO 9241-11:1998(en), Ergonomic requirements for office work with visual display terminals (VDTs) — Part 11: Guidance on usability. (n.d.). Retrieved May 29, 2017, from https://www.iso.org/obp/ui/#iso:std:16883:en

Johannesson, P., & Perjons, E. (2014). *An Introduction to Design Science*. *Springer International Publishing Switzerland*. https://doi.org/10.1007/978-3-319-10632-8

Jokela, T., Koivumaa, J., Pirkola, J., Salminen, P., & Kantola, N. (2006). Methods for quantitative usability requirements: A case study on the development of the user interface of a mobile phone. *Personal and Ubiquitous Computing*, *10*(6), 345–355. https://doi.org/10.1007/s00779-005-0050-7

Kanhere, S. S. (2011). Participatory Sensing: Crowdsourcing Data from Mobile Smartphones in Urban Spaces. In *2011 IEEE 12th International Conference on Mobile Data Management* (pp. 3–6). IEEE. https://doi.org/10.1109/MDM.2011.16

Khan, Z., Kiani, S. L., & Soomro, K. (2014). A framework for cloud-based context-aware information services for citizens in smart cities. *Journal of Cloud Computing*, *3*(1), 14. https://doi.org/10.1186/s13677-014-0014-4

Kim, Y., & Cho, S.-B. (2009). A ringtone recommendation agent based on a Bayesian model of user emotion. In *2009 IEEE International Conference on Intelligent Computing and Intelligent Systems* (pp. 542–546). IEEE. https://doi.org/10.1109/ICICISYS.2009.5357783

Klimova, A., Rondeau, E., Andersson, K., Porras, J., Rybin, A., & Zaslavsky, A. (2016). An international Master's program in green ICT as a contribution to sustainable development. *Journal of Cleaner Production*, *135*, 223–239. https://doi.org/10.1016/j.jclepro.2016.06.032

Koufaris, M. (2002). Applying the Technology Acceptance Model and Flow Theory to Online Consumer Behavior. *Journal of Information Systems Research*, *13*(2), 205–223. https://doi.org/10.1287/isre.13.2.205.83

Lazzaro, N. (2004). Why We Play Games: Four Keys to More Emotion Without Story. *Game Developer Conference (GDC)*, 1–8. https://doi.org/10.1111/j.1464-410X.2004.04896.x

Lewandowsky, S., Oberauer, K., & Gignac, G. E. (2013). NASA Faked the Moon Landing—Therefore, (Climate) Science Is a Hoax. *Psychological Science*, *24*(5), 622–633. https://doi.org/10.1177/0956797612457686

Marczewski, A. (n.d.). *Gamification : a simple introduction & a bit more*. Retrieved from https://books.google.fi/books/about/Gamification_A_Simple_Introduction.html?id=IOu9kPjlndYC&redir_esc=y

Mazzoleni, M., Verlaan, M., Alfonso, L., Monego, M., Norbiato, D., Ferri, M., & Solomatine, D. P. (2015). Can assimilation of crowdsourced streamflow observations in hydrological modelling improve flood prediction? *Hydrology and Earth System Sciences Discussions*, *12*(11), 11371–11419. https://doi.org/10.5194/hessd-12-11371-2015

Meurisch, C., Planz, K., Schäfer, D., & Schweizer, I. (2013). Noisemap: Discussing Scalability in Participatory Sensing. *Proceedings of First International Workshop on Sensing and Big Data Mining - SENSEMINE'13*, 1–6. https://doi.org/10.1145/2536714.2536720

Moraes, A. L. D., Fonseca, F., Esteves, M. G. P., Schneider, D., & de Souza, J. M. (2014). A meta-model for crowdsourcing platforms in Data Collection and Participatory Sensing. In *Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (pp. 429–434). IEEE. https://doi.org/10.1109/CSCWD.2014.6846883

NASA: Climate Change and Global Warming. (n.d.). Retrieved May 22, 2017, from https://climate.nasa.gov/

Nielsen, J., & Jakob. (1993). *Usability engineering*. Academic Press. Retrieved from http://dl.acm.org/citation.cfm?id=529793

Ogie, R. I. (2016). *Adopting incentive mechanisms for large-scale participation in mobile* *crowdsensing: from literature review to a conceptual framework. Human-centric Computing and Information Sciences* (Vol. 6). Springer Berlin Heidelberg. https://doi.org/10.1186/s13673-016-0080-3

Owusu, F., & Pattinson, C. (2012). The Current State of Understanding of the Energy Efficiency of Cloud Computing. In *2012 IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications* (pp. 1948–1953). IEEE. https://doi.org/10.1109/TrustCom.2012.270

Oxford English Dictionary. (2014). New words list June 2014. Retrieved May 30, 2017, from http://public.oed.com/the-oed-today/recent-updates-to-the-oed/previous updates/june-2014-update/new-words-list-june-2014/

Palacin-Silva, M., Seffah, A., Heikkinen, K., Porras, J., Pyhälahti, T., Sucksdorff, Y., … Junttila, S. (2016). State-of-the Art Study in Citizen Observatories: Technological Trends, Development Challenges and Research Avenues. Retrieved from https://helda.helsinki.fi/handle/10138/164810

Palmer, T. S. (1917). In Memoriam: Wells Woodbridge Cooke. Born Jan. 25, 1858 - Died March 30, 1916. *The Auk*, *34*(2), 119–132. https://doi.org/10.2307/4072477

Participation, P., Potential, A. I., & Education, I. S. (2009). Research : Defining the Field and Science Education. *Science Education*, (July).

Paul, K., Quinn, M. S., Huijser, M. P., Graham, J., & Broberg, L. (2014). An evaluation of a citizen science data collection program for recording wildlife observations along a highway. *Journal of Environmental Management*, *139*, 180–187. https://doi.org/10.1016/j.jenvman.2014.02.018

Penzenstadler, B., Bauer, V., Calero, C., & Franch, X. (2012). Sustainability in software engineering: a systematic literature review. In *16th International Conference on Evaluation & Assessment in Software Engineering (EASE 2012)* (pp. 32–41). IET. https://doi.org/10.1049/ic.2012.0004

Porras, J., Seffah, A., Rondeau, E., Andersson, K., & Alexandra, K. (2016). PERCCOM: A Master Program in Pervasive Computing and COMmunications for Sustainable Development. https://doi.org/10.1109/CSEET.2016.39

Pyhalahti, T., Toivanen, T., Kallio, K. Y., Jarvinen, M., Molinier, M., Koponen, S., … Lindholm, M. (2015). Advances in combining optical citizen observations on water quality with satellite observations as part of an environmental monitoring system. *International Geoscience and Remote Sensing Symposium (IGARSS)*, *2015–Novem*, 5395–5398. https://doi.org/10.1109/IGARSS.2015.7327055

Raddick, M. J., Bracey, G., Gay, P. L., Lintott, C. J., Murray, P., Schawinski, K., … Vandenberg, J. (2009). Galaxy Zoo: Exploring the Motivations of Citizen Science Volunteers. https://doi.org/10.3847/AER2009036

Resnik, D. B., Elliott, K. C., & Miller, A. K. (2015). A framework for addressing ethical issues in citizen science. *Environmental Science and Policy*, *54*, 475–481. https://doi.org/10.1016/j.envsci.2015.05.008

Restuccia, F., Das, S. K., & Payton, J. (2015). Incentive Mechanisms for Participatory Sensing: Survey and Research Challenges, *V*(212), 1–38. https://doi.org/10.1145/2888398

Ritterfeld, U., Cody, M. J., & Vorderer, P. (2009). *Serious games: mechanisms and effects*. Routledge. Retrieved from https://books.google.fi/books/about/Serious_Games.html?id=GwPf7tbO5mgC&redir_esc=y

Rollings, A., & Adams, E. (Ernest W. . (2003). *Andrew Rollings and Ernest Adams on game design*. New Riders. Retrieved from http://dl.acm.org/citation.cfm?id=1213088

Schnoor, J. L. (2007). *Citizen science. Environmental science & technology* (Vol. 41). https://doi.org/10.1353/eco.2007.0002

Sharma, S., Magnuson, J. J., Batt, R. D., Winslow, L. A., Korhonen, J., & Aono, Y. (2016). Direct observations of ice seasonality reveal changes in climate over the past 320–570 years. *Scientific Reports*, *6*(April), 25061. https://doi.org/10.1038/srep25061

Snyder, M., & Omoto, A. M. (2001). Basic research and practical problems: Volunteerism and the psychology of individual and collective action.

Socientize Project. (2013). Green paper on Citizen Science. Citizen Science for Europe: Towards a society of empowered citizens and enhanced research. *Socientize*, 1–54.

Software Engineering for Sustainability (SE4S). (n.d.). Retrieved May 22, 2017, from http://se4s.ics.uci.edu/

Tweddle, J.C.; Robinson, L.D.; Pocock, M.J.O.& Roy, H. E. (2009a). *Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. https://doi.org/10.1002/biuz.201710611

Tweddle, J.C.; Robinson, L.D.; Pocock, M.J.O.& Roy, H. E. (2009b). *Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. https://doi.org/10.1002/biuz.201710611

Wang, R. Y., & Strong, D. M. (1996). Beyond Accuracy: What Data Quality Means to Data Consumers. *Journal of Management Information Systems*, *12*(4), 5–33.

https://doi.org/10.1080/07421222.1996.11518099

Wang, Y., Jia, X., Jin, Q., & Ma, J. (2016). QuaCentive: a quality-aware incentive mechanism in mobile crowdsourced sensing (MCS). *The Journal of Supercomputing*, *72*(8), 2924–2941. https://doi.org/10.1007/s11227-015-1395-y

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., & Wesslén, A. (2012). *Experimentation in Software Engineering*. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-29044-2

Zichermann, G., & Cunningham, C. (2011). *Gamification by design : implementing game mechanics in web and mobile apps*. O'Reilly Media.

Antin, J., & Cheshire, C. (2008). Designing social psychological incentives for online collective action. *Directions and Implications of Advanced Computing;* Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.359.8814&rep=rep1&type=pdf

Arakawa, Y., & Matsuda, Y. (2016). Gamification Mechanism for Enhancing a Participatory Urban Sensing: Survey and Practical Results. *Journal of Information Processing*, *24*(1), 31–38. https://doi.org/10.2197/ipsjjip.24.31

Bartle, R. a. (1999). Players Who Suit MUDs. *Mud*, 1. https://doi.org/10.1007/s00256-004-0875-6

Batson, C. D., Ahmad, N., & Tsang, J.-A. (2002). Four Motives for Community Involvement. *Journal of Social Issues*, *58*(3), 429–445. https://doi.org/10.1111/1540-4560.00269

Becker, C., Betz, S., Chitchyan, R., Duboc, L., Easterbrook, S. M., Penzenstadler, B., … Venters, C. C. (2016). Requirements: The key to sustainability. *IEEE Software*, *33*(1), 56–65. https://doi.org/10.1109/MS.2015.158

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *BioScience*, *59*(11), 977–984. https://doi.org/10.1525/bio.2009.59.11.9

Brabham, D. C. (2008). Crowdsourcing as a Model for Problem Solving: An Introduction and Cases. *Convergence: The International Journal of Research into New Media Technologies*, *14*(1), 75–90. https://doi.org/10.1177/1354856507084420

Brathwaite, B., & Schreiber, I. (2009). *Challenges for game designers*. Charles River Media, a part of Course Technology. Retrieved from http://dl.acm.org/citation.cfm?id=1481314

Brundtland, Gro, H. (1985). World Commission on environment and development. *Environmental Policy and Law*, *14*(1), 26–30. https://doi.org/10.1016/S0378-

777X(85)80040-8

BusinessofApps. (2016). Pokémon GO Usage and Revenue Statistics. Retrieved May 30, 2017, from http://www.businessofapps.com/pokemon-go-usage-revenue-statistics/

Cafazzo, J. A., Casselman, M., Hamming, N., Katzman, D. K., & Palmert, M. R. (2012). Design of an mHealth app for the self-management of adolescent type 1 diabetes: a pilot study. *Journal of Medical Internet Research*, *14*(3), e70. https://doi.org/10.2196/jmir.2058

Chilvers, J., Lorenzoni, I., Terry, G., Buckley, P., Pinnegar, J. K., & Gelcich, S. (2014). Public engagement with marine climate change issues: (Re)framings, understandings and responses. *Global Environmental Change*, *29*, 165–179. https://doi.org/10.1016/j.gloenvcha.2014.09.006

Christin, D., Reinhardt, A., Kanhere, S. S., & Hollick, M. (2011). A survey on privacy in mobile participatory sensing applications. *Journal of Systems and Software*, *84*(11), 1928–1946. https://doi.org/10.1016/j.jss.2011.06.073

Crowston, K., & Prestopnik, N. R. (2013). Motivation and Data Quality in a Citizen Science Game: A Design Science Evaluation. In *2013 46th Hawaii International Conference on System Sciences* (pp. 450–459). IEEE. https://doi.org/10.1109/HICSS.2013.413

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness. In *Proceedings of the 15th International Academic MindTrek Conference on Envisioning Future Media Environments - MindTrek '11* (p. 9). New York, New York, USA: ACM Press. https://doi.org/10.1145/2181037.2181040

DeviceAtlas. (2016). 16 mobile market statistics you should know in 2016. Retrieved May 30, 2017, from https://deviceatlas.com/blog/16-mobile-market-statistics-you-should-know-2016

Dickinson, J. L., & Bonney, R. (2012). Citizen science: public collaboration in environmental research. Ithaca, NY: Cornell University Press.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., … Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, *10*(6), 291–297. https://doi.org/10.1890/110236

Difference Between Independent and Dependent Variables. (n.d.). Retrieved May 29, 2017, from https://www.thoughtco.com/i-ndpendent-and-dependent-variables-differences-606115

Droege, S. (2007). Just because you paid them doesn't mean their data are better. *Citizen*

Science Toolkit Conference, 1–14.

Egenfeldt-Nielsen, S., Smith, J. H., Tosca, S. P., & Egenfeldt-Nielsen, S. (2013). *Understanding video games : the essential introduction*. Routledge. Retrieved from https://books.google.fi/books/about/Understanding_Video_Games.html?id=0tygn2UisUoC&redir_esc=y

Estellés-Arolas, E., & González-Ladrón-de-Guevara, F. (2012). Towards an integrated crowdsourcing definition. *Journal of Information Science*, *38*(2), 189–200. https://doi.org/10.1177/0165551512437638

Estrin, D. (2010). Participatory sensing: applications and architecture [Internet Predictions]. *IEEE Internet Computing*, *14*(1), 12–42. https://doi.org/10.1109/MIC.2010.12

Finnish Environment Institute. (2013). Hydrological situation and forecasts. Retrieved May 29, 2017, from http://www.tulvakeskus.fi/en-US/Waters/Hydrological_situation_and_forecasts/Hydrological_situation_and_forecasts

Friderikos, V., Helard, M., Porras, J., & Rao, T. R. (2014). Toward a Smart, Fully Connected Society: An Overview of the 32nd Meeting of the Wireless World Research Forum [From the Guest Editors]. *IEEE Vehicular Technology Magazine*, *9*(3), 24–26. https://doi.org/10.1109/MVT.2014.2335392

Goldman, J., Shilton, K., Burke, J., Estrin, D., Hansen, M., Ramanathan, N., … Samanta, V. (2009). Participatory Sensing: A citizen-powered approach to illuminating the patterns that shape our world. *Office*, *14*(May), 1–15. https://doi.org/10.1109/MIC.2010.12

Guo, B., Wang, Z., Yu, Z., Wang, Y., Yen, N. Y., Huang, R., & Zhou, X. (2015). Mobile Crowd Sensing and Computing. *ACM Computing Surveys*, *48*(1), 1–31. https://doi.org/10.1145/2794400

Gustafsson, A., Katzeff, C., & Bang, M. (2009). Evaluation of a pervasive game for domestic energy engagement among teenagers. *Computers in Entertainment*, *7*(4), 1. https://doi.org/10.1145/1658866.1658873

Heggen, S. (2013). Participatory sensing. *Interactions*, *20*(1), 18. https://doi.org/10.1145/2405716.2405722

Hilty, L. M., & Aebischer, B. (2015). ICT for Sustainability: An Emerging Research Field. Retrieved from http://publicationslist.org/data/lorenz.hilty/ref-225/2014_Hilty_Aebischer_ICT_for_Sustainability.pdf

Howe, J. (2006). Crowdsourcing: A definition. *Crowdsourcing: Tracking the Rise of the Amateur*. Retrieved from https://scholar.google.com/scholar?cluster=18013007550735437827&hl=en&oi=scholar

r

ISO 9241-11:1998(en), Ergonomic requirements for office work with visual display terminals (VDTs) — Part 11: Guidance on usability. (n.d.). Retrieved May 29, 2017, from https://www.iso.org/obp/ui/#iso:std:16883:en

Johannesson, P., & Perjons, E. (2014). *An Introduction to Design Science*. *Springer International Publishing Switzerland*. https://doi.org/10.1007/978-3-319-10632-8

Jokela, T., Koivumaa, J., Pirkola, J., Salminen, P., & Kantola, N. (2006). Methods for quantitative usability requirements: A case study on the development of the user interface of a mobile phone. *Personal and Ubiquitous Computing*, *10*(6), 345–355. https://doi.org/10.1007/s00779-005-0050-7

Kanhere, S. S. (2011). Participatory Sensing: Crowdsourcing Data from Mobile Smartphones in Urban Spaces. In *2011 IEEE 12th International Conference on Mobile Data Management* (pp. 3–6). IEEE. https://doi.org/10.1109/MDM.2011.16

Khan, Z., Kiani, S. L., & Soomro, K. (2014). A framework for cloud-based context-aware information services for citizens in smart cities. *Journal of Cloud Computing*, *3*(1), 14. https://doi.org/10.1186/s13677-014-0014-4

Kim, Y., & Cho, S.-B. (2009). A ringtone recommendation agent based on a Bayesian model of user emotion. In *2009 IEEE International Conference on Intelligent Computing and Intelligent Systems* (pp. 542–546). IEEE. https://doi.org/10.1109/ICICISYS.2009.5357783

Klimova, A., Rondeau, E., Andersson, K., Porras, J., Rybin, A., & Zaslavsky, A. (2016). An international Master's program in green ICT as a contribution to sustainable development. *Journal of Cleaner Production*, *135*, 223–239. https://doi.org/10.1016/j.jclepro.2016.06.032

Koufaris, M. (2002). Applying the Technology Acceptance Model and Flow Theory to Online Consumer Behavior. *Journal of Information Systems Research*, *13*(2), 205–223. https://doi.org/10.1287/isre.13.2.205.83

Lazzaro, N. (2004). Why We Play Games: Four Keys to More Emotion Without Story. *Game Developer Conference (GDC)*, 1–8. https://doi.org/10.1111/j.1464-410X.2004.04896.x

Lewandowsky, S., Oberauer, K., & Gignac, G. E. (2013). NASA Faked the Moon Landing—Therefore, (Climate) Science Is a Hoax. *Psychological Science*, *24*(5), 622–633. https://doi.org/10.1177/0956797612457686

Marczewski, A. (n.d.). *Gamification : a simple introduction & a bit more*. Retrieved from https://books.google.fi/books/about/Gamification_A_Simple_Introduction.html?id=IOu9kPjlndYC&redir_esc=y

Mazzoleni, M., Verlaan, M., Alfonso, L., Monego, M., Norbiato, D., Ferri, M., & Solomatine, D. P. (2015). Can assimilation of crowdsourced streamflow observations in hydrological modelling improve flood prediction? *Hydrology and Earth System Sciences Discussions*, *12*(11), 11371–11419. https://doi.org/10.5194/hessd-12-11371-2015

Meurisch, C., Planz, K., Schäfer, D., & Schweizer, I. (2013). Noisemap: Discussing Scalability in Participatory Sensing. *Proceedings of First International Workshop on Sensing and Big Data Mining - SENSEMINE'13*, 1–6. https://doi.org/10.1145/2536714.2536720

Moraes, A. L. D., Fonseca, F., Esteves, M. G. P., Schneider, D., & de Souza, J. M. (2014). A meta-model for crowdsourcing platforms in Data Collection and Participatory Sensing. In *Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (pp. 429–434). IEEE. https://doi.org/10.1109/CSCWD.2014.6846883

NASA: Climate Change and Global Warming. (n.d.). Retrieved May 22, 2017, from https://climate.nasa.gov/

Nielsen, J., & Jakob. (1993). *Usability engineering*. Academic Press. Retrieved from http://dl.acm.org/citation.cfm?id=529793

Ogie, R. I. (2016). *Adopting incentive mechanisms for large-scale participation in mobile crowdsensing: from literature review to a conceptual framework*. *Human-centric Computing and Information Sciences* (Vol. 6). Springer Berlin Heidelberg. https://doi.org/10.1186/s13673-016-0080-3

Owusu, F., & Pattinson, C. (2012). The Current State of Understanding of the Energy Efficiency of Cloud Computing. In *2012 IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications* (pp. 1948–1953). IEEE. https://doi.org/10.1109/TrustCom.2012.270

Oxford English Dictionary. (2014). New words list June 2014. Retrieved May 30, 2017, from http://public.oed.com/the-oed-today/recent-updates-to-the-oed/previous updates/june-2014-update/new-words-list-june-2014/

Palacin-Silva, M., Seffah, A., Heikkinen, K., Porras, J., Pyhälahti, T., Sucksdorff, Y., … Junttila, S. (2016). State-of-the Art Study in Citizen Observatories: Technological Trends, Development Challenges and Research Avenues. Retrieved from https://helda.helsinki.fi/handle/10138/164810

Palmer, T. S. (1917). In Memoriam: Wells Woodbridge Cooke. Born Jan. 25, 1858 - Died March 30, 1916. *The Auk*, *34*(2), 119–132. https://doi.org/10.2307/4072477

Participation, P., Potential, A. I., & Education, I. S. (2009). Research : Defining the Field and Science Education. *Science Education*, (July).

Paul, K., Quinn, M. S., Huijser, M. P., Graham, J., & Broberg, L. (2014). An evaluation of a citizen science data collection program for recording wildlife observations along a highway. *Journal of Environmental Management*, *139*, 180–187. https://doi.org/10.1016/j.jenvman.2014.02.018

Penzenstadler, B., Bauer, V., Calero, C., & Franch, X. (2012). Sustainability in software engineering: a systematic literature review. In *16th International Conference on Evaluation & Assessment in Software Engineering (EASE 2012)* (pp. 32–41). IET. https://doi.org/10.1049/ic.2012.0004

Porras, J., Seffah, A., Rondeau, E., Andersson, K., & Alexandra, K. (2016). PERCCOM: A Master Program in Pervasive Computing and COMmunications for Sustainable Development. https://doi.org/10.1109/CSEET.2016.39

Pyhalahti, T., Toivanen, T., Kallio, K. Y., Jarvinen, M., Molinier, M., Koponen, S., … Lindholm, M. (2015). Advances in combining optical citizen observations on water quality with satellite observations as part of an environmental monitoring system. *International Geoscience and Remote Sensing Symposium (IGARSS)*, *2015–Novem*, 5395–5398. https://doi.org/10.1109/IGARSS.2015.7327055

Raddick, M. J., Bracey, G., Gay, P. L., Lintott, C. J., Murray, P., Schawinski, K., … Vandenberg, J. (2009). Galaxy Zoo: Exploring the Motivations of Citizen Science Volunteers. https://doi.org/10.3847/AER2009036

Resnik, D. B., Elliott, K. C., & Miller, A. K. (2015). A framework for addressing ethical issues in citizen science. *Environmental Science and Policy*, *54*, 475–481. https://doi.org/10.1016/j.envsci.2015.05.008

Restuccia, F., Das, S. K., & Payton, J. (2015). Incentive Mechanisms for Participatory Sensing: Survey and Research Challenges, *V*(212), 1–38. https://doi.org/10.1145/2888398

Ritterfeld, U., Cody, M. J., & Vorderer, P. (2009). *Serious games: mechanisms and effects*. Routledge. Retrieved from https://books.google.fi/books/about/Serious_Games.html?id=GwPf7tbO5mgC&redir_esc=y

Rollings, A., & Adams, E. (Ernest W. . (2003). *Andrew Rollings and Ernest Adams on game* *design*. New Riders. Retrieved from http://dl.acm.org/citation.cfm?id=1213088

Schnoor, J. L. (2007). *Citizen science. Environmental science & technology* (Vol. 41). https://doi.org/10.1353/eco.2007.0002

Sharma, S., Magnuson, J. J., Batt, R. D., Winslow, L. A., Korhonen, J., & Aono, Y. (2016). Direct observations of ice seasonality reveal changes in climate over the past 320–570 years. *Scientific Reports*, *6*(April), 25061. https://doi.org/10.1038/srep25061

Snyder, M., & Omoto, A. M. (2001). Basic research and practical problems: Volunteerism and the psychology of individual and collective action.

Socientize Project. (2013). Green paper on Citizen Science. Citizen Science for Europe: Towards a society of empowered citizens and enhanced research. *Socientize*, 1–54.

Software Engineering for Sustainability (SE4S). (n.d.). Retrieved May 22, 2017, from http://se4s.ics.uci.edu/

Tweddle, J.C.; Robinson, L.D.; Pocock, M.J.O.& Roy, H. E. (2009a). *Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. https://doi.org/10.1002/biuz.201710611

Tweddle, J.C.; Robinson, L.D.; Pocock, M.J.O.& Roy, H. E. (2009b). *Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. https://doi.org/10.1002/biuz.201710611

Wang, R. Y., & Strong, D. M. (1996). Beyond Accuracy: What Data Quality Means to Data Consumers. *Journal of Management Information Systems*, *12*(4), 5–33. https://doi.org/10.1080/07421222.1996.11518099

Wang, Y., Jia, X., Jin, Q., & Ma, J. (2016). QuaCentive: a quality-aware incentive mechanism in mobile crowdsourced sensing (MCS). *The Journal of Supercomputing*, *72*(8), 2924–2941. https://doi.org/10.1007/s11227-015-1395-y

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., & Wesslén, A. (2012). *Experimentation in Software Engineering*. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-29044-2

Zichermann, G., & Cunningham, C. (2011). *Gamification by design : implementing game mechanics in web and mobile apps*. O'Reilly Media.

APPENDIX 1. System Requirements

Participatory Sensing/Crowdsensing Application

Stakeholders

Participants: a participant can be a general citizen who registers on the platform to contribute his or her sensing data through observation.

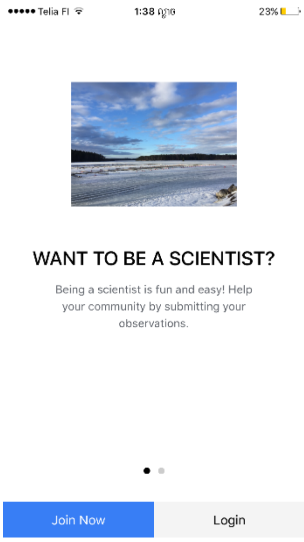
Functional Requirements

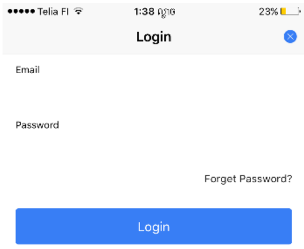
No	Description
1	The application shall accept and register users
2	The application shall require only necessary data from both requesters and participants respectively
3	The application shall allow users to manage their profiles
4	The application shall list all the observation tasks submitted by requesters
5	The application shall allow participants to submit observation by using camera, photo library and GPS location
6	The application shall provide points to participants after each submission
7	The application shall allow participants to view their total scores and ranking
8	The application shall display participants' activities
9	The application shall provide information about observation for participants

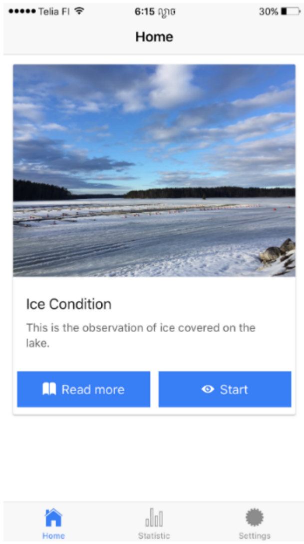
Non-Functional Requirements

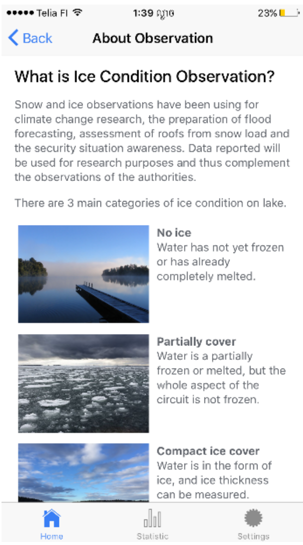
No	Description
10	The application shall have a user-friendly and simple interface
11	The application shall be compatible with all phone operating system
12	The system shall be secure

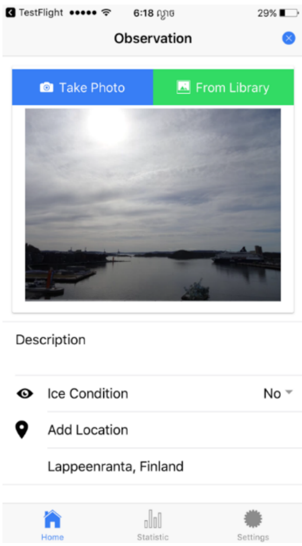
APPENDIX 2. Jarvida (non-gamified application) Screenshots

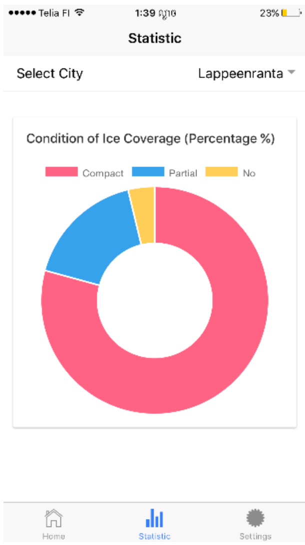


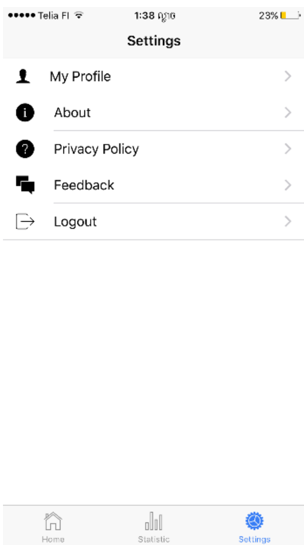


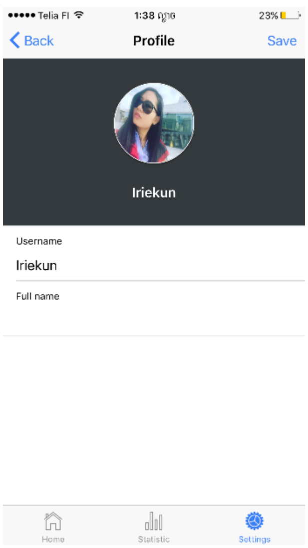




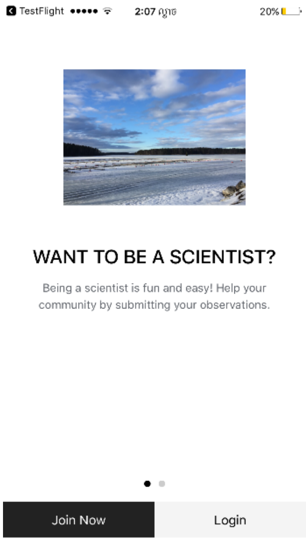


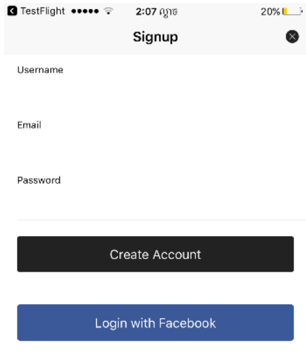


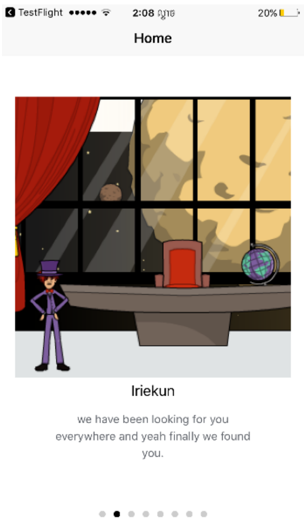


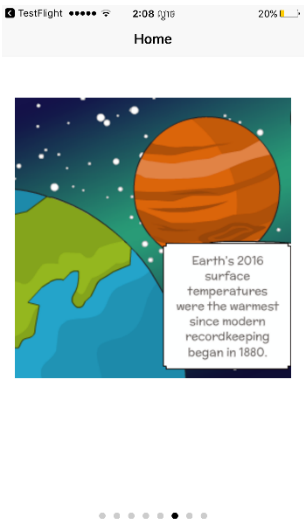


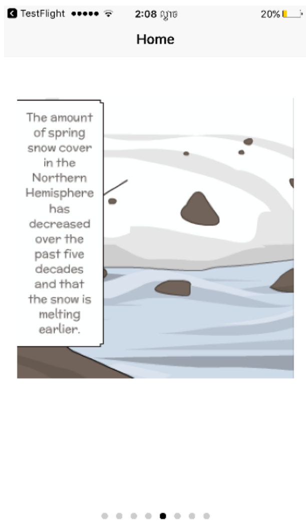
APPENDIX 3. Jarvi (gamified application) Screenshots

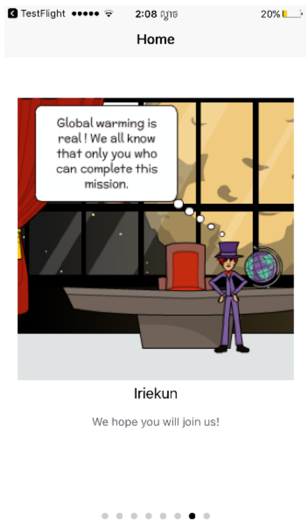




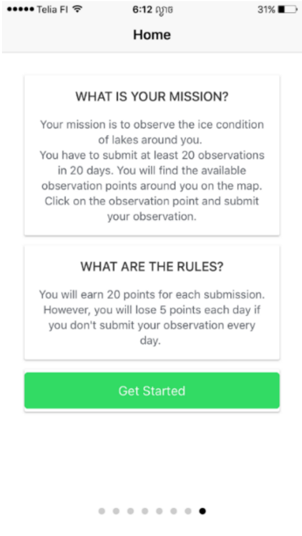


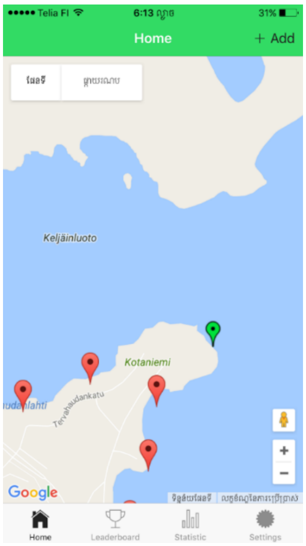


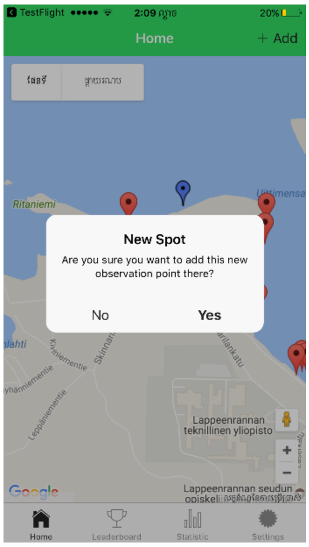


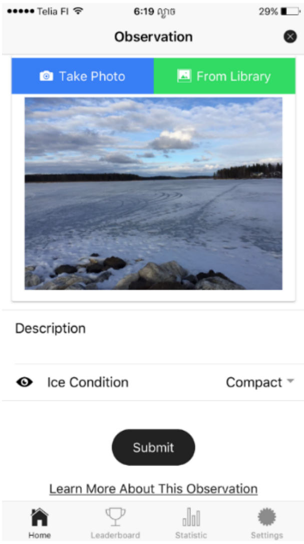


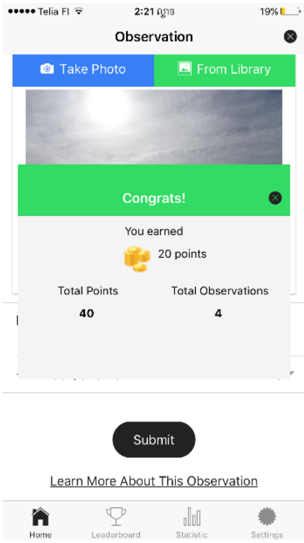
APPENDIX 3. (continues)

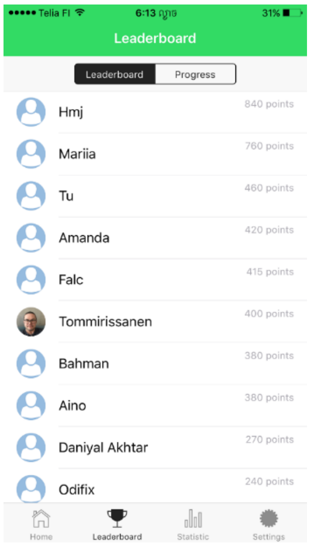


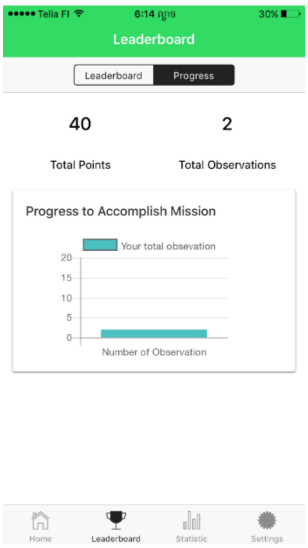


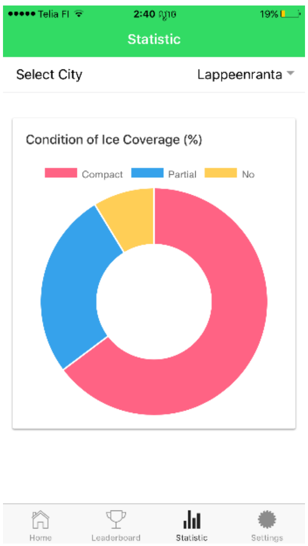


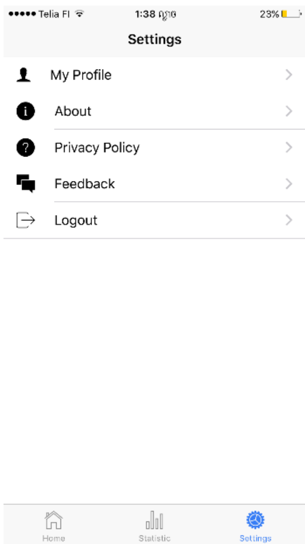












APPENDIX 4. Pre-Survey

Jarvi: Pre- Survey

Jarvi is a gamified mobile application to monitor lakes across Finland. Jarvi invites you to observe the progress of spring in the lakes by reporting changes in the snow and ice during 20 days from 24 March to 12 April via a mobile application. The observations are being collected for research purposes to help study the opportunities for engaging citizens in climate change mitigation. All collected data will be handled and stored confidentially and, no data will be released for the use of any third party, with the exception of anonymized analysis as research results. From these published results, it will be impossible to deduct any information on names, products or answers from any individual participant.

More information available from MSc Maria Palacin-Silva (maria.palacin.silva@lut.fi)

1. Which application did you use? *

- ◯ Jarvigo
- ◯ Jarvida

2. Select your your age range *

- ◯ 21 and Under
- ◯ 22 to 34
- ◯ 35 to 44
- ◯ 45 to 54
- ◯ 55 to 64
- ◯ 65 and Over

3. In a typical week and month, how often do you go to lakes? (Passing by also counts) *

- ◯ Never
- ◯ 1 to 2 times per month
- ◯ More than 3 times a month
- ◯ 1 to 2 times per week
- ◯ More than 3 times a week

4. Having used Jarvi for first time. Please, rate the following statements in the scale from strongly disagree, somewhat disagree, neutral, somewhat agree to strongly agree. *

	strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree
I thought there was too much inconsistency in this system	◯	◯	◯	◯	◯
I found the system unnecessarily complex	◯	◯	◯	◯	◯
I would imagine that most people would learn to use this system very quickly	◯	◯	◯	◯	◯
I felt very confident using the system	◯	◯	◯	◯	◯
I needed to learn a lot of things before I could get going with this system	◯	◯	◯	◯	◯
I think that I would like to use this system frequently	◯	◯	◯	◯	◯
I found the various functions in this system were well integrated	◯	◯	◯	◯	◯
I thought the system was easy to use	◯	◯	◯	◯	◯
I found the system very hard to use	◯	◯	◯	◯	◯

5. Do you know the ice condition observation can help to study the climate change, flood forecasting, and security situation awareness? *

- ◯ Yes
- ◯ No
- ◯ I knew it partially

Next -->

APPENDIX 4. (continues)

6. Please, match the images of the lake with the description about water status

No ice: water has not yet frozen or has already melted

Partially covered: water is partially frozen or melted, but the whole aspect of the circuit is not frozen

Compact ice: water is in the form of ice and ice thickness can be measured

Reset pictures

<-- Previous | Submit

APPENDIX 5. Post-Survey

Jarvi: Post_Survey

1. Which application did you use? *

- Jarvigo
- Jarvida

Next -->

Section I: Features and Usage

2. Rate the following statements about Jarvi features in the scale from strongly disagree, somewhat disagree, neutral, somewhat agree to strongly agree.

	strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree
I achieved my challenge (20 observations in 20 days)					
Seeing my name in the leaderboard motivated me to submit more observations					
Seeing my points reduced motivated me to submit new observations					
I learned about global warming with the storyboard					
I followed my progress on the activity tab					

<-- Previous Next -->

Section I: Features and Usage

3. Rate the following statements on usage habits in the scale from strongly disagree, somewhat disagree, neutral, somewhat agree to strongly agree. *

	strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree
I was motivated to use the system regularly					
I was motivated to submit many observations					
I learned about global warming during the use of the program					

<-- Previous Next -->

Section II: Use and Attitude

4. Having used Jarvi for first time. Please, rate the following statements about the ease of use in the scale from strongly disagree, somewhat disagree, neutral, somewhat agree to strongly agree. *

	strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree
I think that I would like to use this system frequently					
I found the system unnecessarily complex					
I thought the system was easy to use					
I think that I would need the support of a technical person to be able to use this system					
I found the various functions in this system were well integrated					
I thought there was too much inconsistency in this system					
I would imagine that most people would learn to use this system very quickly					
I found the system very clumsy or difficult to use					
I felt very confident using the system					
I needed to learn a lot of things before I could get going with this system					
I find it easy to get the system to do what I want it to do					
Overall, I am satisfied with how easy it was to use the system					

APPENDIX 5. (continues)

5. Rate the following statements about the enjoyment in the scale from strongly disagree, somewhat disagree, neutral, somewhat agree to strongly agree. *

	strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree
Using the mobile software for measurement is a good idea	◯	◯	◯	◯	◯
The program makes measuring tasks more interesting	◯	◯	◯	◯	◯
Working with the program is fun	◯	◯	◯	◯	◯
I like using the program to measure lakes	◯	◯	◯	◯	◯
I found using the system to be enjoyable	◯	◯	◯	◯	◯
The actual process of using the system is pleasant	◯	◯	◯	◯	◯

Section III: Awareness

7. Order the following statements according to their importance in your opinion (drag and drop): *

Lakes observation is useful for...

1	Understanding the long-term effects of climate change.
2	Understanding natural phenomena
3	Complement data from satellites
4	Provide safety information e.g. ice thickness
5	Understand the condition of the lakes
6	Predict future changes in nature

Reset pictures

APPENDIX 6. Consent Agreement

Consent agreement for participation in Jarvi experimental study

Dear Participant,

The following information is provided for you to decide whether you wish to participant in the present study. You should be aware that you are free to decide to not participate or to withdraw at any time without affecting your relationship with this department, the investigator or the Lappeenranta University of Technology.

The purpose of this study is to understand the opportunities for engaging citizens in lakes monitoring via mobile applications. The procedure will be an experimental study where participants are asked to observe the progress of spring in the Finnish lakes by reporting changes in the snow and ice during 20 days from March 24th to April 12th. Participants, will be using the application and submitting observations of the lake in photo or text form at any time. Data collection involve, usage monitoring surveys and small surveys at the beginning and end of the study.

Do not hesitate to ask any questions about the study either before participating or during the time that you are participating. We would be happy to share our findings with you after the research is completed. However, your name will not be associated with the research findings in any way, and your identity as participant will be known only to the researchers.

There are no known risks and/or discomforts associated with this study. The expected benefits associated with your participation are the opportunity to participate in a empirical research study and the learning about nature monitoring relevance for climate change mitigation. If submitted for publication, a byline will indicate the respective acknowledgements.

Please, sign your consent with full knowledge of the nature and purpose of the procedures. A copy of this consent form will be given to you to keep.

Name and signature
Date

Maria V. Palacin-Silva.
Principal Investigator.
Lappeenranta University of Technology.