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Evaluating Mobile-Based Citizen Science in Increasing Citizen Participants in Environmental Management

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EVALUATING MOBILE-BASED CITIZEN SCIENCE IN INCREASING CITIZEN PARTICIPANTS IN ENVIRONMENTAL MANAGEMENT

by

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Mobile-based citizen science as thriving citizen education tool increases the non-expert citizen involvement in the scientific world by encouraging the public upload nature observation to assist scientific research while learning scientific knowledge. Mobile-base citizen science as social media has potential to facilitate citizen engagement in the environmental management. Based on the conceptual framework of citizen science incorporation with environmental management, large users in the program foster the citizen involvement in the environmental management. Research here applies SWOT (Strength, Weakness, Opportunity, Threats) analysis to evaluate mobile based citizen science regarding data management, citizen participation, and partnership. It revealed the current status of mobile-based citizen including advantages and disadvantages. The simplicity of observation collection, public data accessibility, communication channel provided for participants and strong supporter or collaborative partners are effective in making citizen science strong candidate in engaging citizen into environmental management. However, there are absent of data quality filter, privacy protection and the fact that large registered users and data submission doesn't lead to high citizen participation impede the development of mobile-based citizen science. Therefore, the

suggestion for current programs is to obtain investment from other organizations or agencies to develop more effective strategies to keep and maintain participants. The results of this study proves that mobile-based citizen science has potential to engage citizens in environmental management, but they need the improvement of sustaining strengths and opportunity and removing weakness and threats.

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CHAPTER 1 INTRODUCTION

Citizen participation is a pivotal parts in environmental management, and the level of engagement and the approaches to getting involved vary greatly. Hill (2012) classified citizen involvement in environmental management to three typologies including powering distribution, participation and intellectual purpose. Power sharing refers to citizen involvement in decision-making, rules definition, resource values and property rights. Participation is the engagement in the participatory process and the ways an organization engages and coordinates within this process. Intellectual purpose implies public involvement in environmental management, citizen engagement, local development and capacity building.

All typologies were proved to be effective to optimize contribution from the indigenous public. Indigenous public participation in environmental management and bolsters cultural diversity by superimposing Indigenous Ecological Knowledge (IEK) and Western science (Hill et al., 2012). The motivation of citizen commitment into environmental management is driven by many factors such as personal awareness and social incentives. Citizen engagement in environment management significantly helps solve the complex and dynamic nature of environmental problems. There is growing evidence that shows the citizen participation could strengthen the quality of environmental decision-making process due to the various input (Reed, 2008). Future research studies have been conducted to show the importance of public commitment in the environmental management and public involvement. For example, there was a discussion about the United States EPA (Environmental Protection Agency) framework which showed that absence of meaningful stakeholder input acted as an impediment for

environmental management to become fruitful and productive (Wagenet & Pfeffer, 2009). In addition, study conducted by Irvin and Stansbury (2009) listed the benefits of public involvement in government decision-making regarding participants and government, which both resulted in mutual benefit. This was accomplished through citizen awareness of environmental knowledge via collaborative participation with the government representatives via the collaborative process in the environmental management increase the citizen awareness of environmental knowledge. The government was enlightened by the citizen as well. Therefore, facilitating citizen involvement is the challenge for the decision maker in environmental management.

Randolph (2012) demonstrated the environmental management revolution from the early 20th Century to today. Citizen engagement in the environmental sector has improved since pre-1960 where the power fell into the hands of local elected officials. From the 1960s to 1970s, public participation caught attention from the government with social unrest, but citizen engagement became outsider from constituents due to conflicting demands and opinions between various public input workshops and advisory committees. During the 1970s and 1980s, participatory planning revealed methods to create the win-win situation to solve the conflict of different interests among stakeholders. In the 1990s, there were more collaborative means to reduce stakeholder's conflict, and interested parties started to have the authority in order to achieve plans and decisions that would be made. Citizen groups were organized. Diversity, interdependent participants were capable of developing a shared vision, decreasing conflict, building consensus and systemizing inspired plan. The last generation of collaborative learning and co-management realized that it is still needed another transition in order to limit

conflict and achieve consensus within different stakeholders groups to encourages input knowledge through joint learning (Randolph, 2012). In spite of conflict within management, citizen engagement still fosters environmental management. Generally speaking, the major shift from a top-down approach to a system that bridged the gap between government leaders and the general public can be attributed to the international trend in availability of thriving communications technologies such as mobile devices and the Internet. This shift was fueled by the change of governance, the political economy, the demand to distribute obligation of resolving environmental issues to the citizen, and the regional politics of social, economic and environmental programs (Head, 2007).

Citizen science had been palmy in archaeology, astronomy and natural history where observational skills are more appreciated than sophisticated and costly scientific equipment (Silvertown, 2009). Citizen science is unpaid volunteers who cooperate with the scientist as filed assistant monitor environmental change. For instance, the citizen in Finland observed wild-birds migration and recorded the timing and direction in 1974 (Greenwood, 2007). Current scientists completed data collection with the help of the citizens who admires the outdoors observations or concerned about the environmental problems and willing to devote time and energy to participate in environmental events. Citizen science programs were a channel that assisted the non-professional citizen to take part in scientific research or environmental management (Conh, 2008).

The mobile technology boosted in the 20th century, and it promoted diversity of data collection, and citizen communication approaches with digital communication and the social web. Currently, the mobile device is prevalent in the world. The article of Pew Research (2016) entitled “Smartphone Ownership and Internet Usage Continues to

Climb in Emerging Economies" surveyed about the popularity of smartphone around the globe. This report showed the percentage of owning a smartphone and using the Internet occasionally was 45% in over 21 emerging and developing countries in 2013. The result also showed that 87% of people are internet users across 11 advanced economies including the U.S., Canada, Western European nations, developed Pacific nations including Australia, Japan, South Korea and Israel (Poushter,2016). Existing internet-based mobile technologies is an integral part of mobile-based citizen science expansion because it makes information dissemination and generation effortless. Mobile computing contributes to scientific research mainly as well as the smartphone, and it allows users to obtain and process environmental data as scientific inquiry via the Internet-based mobile device (Silvertown, 2009). Mobile-based citizen science used as the environmental monitor sensor that positioned it the notable data contributor to environmental science. Hence, the smartphone as a favorite device today have an additional function as "online mobile measurement instrument" in environmental science or management. The compatibility of the mobile device and citizen science facilitate the development of mobile-based citizen science programs. Currently, there are a series of models to develop a systematic mobile based citizen science program. For example, Cornell Lab of Ornithology (CLO) has been implementing citizen science programs varied with size and participants to motivate the public to learn about wild birds, and they were all incredibly profitable. Developing mobile based citizen science programs needs considerable effort from many experts specialized in different areas. The process of a model building consists of choosing a scientific question, developing teams, recruiting participants, training participants, designing data processing including receiving, editing and

displaying, analyzing, interpreting, disseminating results and outcome measurement (Bonney et al.,2009).

At this point, using social media in the smartphone to accomplish citizen science data collection was prevalent, and the fast development of citizen science credits with frequently updating of the mobile device. Multifunctional design of the smartphone such as information storage, GPS, and Bluetooth optimizes data or information storage, collection, uploading and sharing of mobile-based citizen science. The Mobile personal communication device (MPCD) mentioned in Ferster and Coops' journal (2013) that as a recent progressive device with the essential function of obtaining necessary and timely measurements has been used for the Earth observation since 2010 to gather planet information including physical, chemical and biological data from the citizen. Also, Papenfuss et al. (2015) researched based on the information on a well-known mobile-based fishing application in Alberta Canada to reveal the behavior of anglers. The capability of predicting angler's behavior provides valuable insight for fishers and wildlife research. Distribution and magnitude of fishers within a particular area rely on anglers and angler regulations. Also, mobile-based citizen science projects expand the data range spatially and temporally, because data generated and submitted by the citizen distributed in the large range of regions and time zone distribution via the on-time Internet. Citizen science is significant in society today due to the efficient data generation with free-cost in environmental monitoring. Citizen participates scientific research and provides data via participatory sensing in the mobile device. Mobile-based approaches in citizen science are developed to simplify citizen data collection and more and more updates occur in the mobile device to assist the process. Dunlap, Tang, and Greenberg

performed research (2015) about applying geocaching that guides people to the particular site to achieve their accomplishment by providing equipment, and infrastructure to advance community environmental monitoring (Dunlap et al.,2015).

Application of mobile-based citizen science in environmental management is thriving in both scientific research and environmental management. The topics about citizen engagement via social media foster citizen participation were under research frequently (Clark, 2014). Mobile-based citizen science not only obtained environmental information from the local citizen can influence public policy, but also provides the additional communication channel among groups with different interest for building consensus. Besides, mobile device hasten citizen engagement by simplifying online information sharing to bring significant public input and involvement to the environmental management. Therefore, the capability of the mobile-based citizen to influence the public has potential to enlarge the public participation in environmental management.

There are a series of literature apropos mobile-based citizen science project forms the connection between the public and the professional science, and many types of researchers have been conducted to address various kinds of internal issues in mobile-based citizen science such as data quality, data application, and privacy protection. People constantly discuss the scientific impact of community-based environmental monitoring via citizen science. However, few study appears to disclose the mobile-based citizen science effect on public involvement in environmental management. When environmental awareness of citizen increased, they tend to engage in environmental activities and devote to environmental management. The gap of research here is to define

the ideal mobile-based citizen science that positive influence public and reveal the factors that restrict the application in the environmental management. Therefore, cases analysis is indispensable to reveal the internal elements and the external environment that impact the development of mobile-based citizen science.

Research goal here is to applying SWOT (Strengths, Weakness, Opportunity, Threats) analysis to evaluate data management, user participation, and partnership in mobile-based citizen science projects. Cases are selected based on the certain criteria. Results will illustrate the current status of mobile-based citizen science, its advantages and shortcomings. Based on results, the research provides the suggestions for improving mobile-based citizen science to engage the citizen in the environmental management.

CHAPTER 2 CONCEPTUAL FRAMEWORK

Background information above described the significance of citizen input to the environmental management, the evolution of environmental management, the impact of the rapid development of mobile device technology on citizen science and recent research of mobile-based citizen science in scientific research. Based on the research question, discussion of current mobile based citizen science impact on citizen engagement in environmental management is necessary, and the variables used to evaluate need to be defined. Therefore, the paths of mobile-based citizen science incorporate with environmental management provides the rationale to identify variables of the case analysis. Conceptual framework demonstrated below can help to develop evaluation methods and variables to perform research.

A conceptual framework is a theoretical model where visually express the relationship among various subjects, so it plays an essential role in scientific research. It

enhances the understanding by conveying information through visual communication. Wiggis (2010) developed an organization design-oriented conceptual framework of the process of citizen science virtual organization producing scientific knowledge to establish theory development process and discussed the application of the framework to an exploratory study while supports process model by investigating the impact of the design of scientific knowledge production. Therefore, the paths of citizen science incorporation with environmental management was based on figure 1 in McKinley et al. (2017). It illustrates the different paths of incorporation of mobile-based citizen science to the environmental management to extrapolate the key element that helps the mobile-based citizen science to involve the large citizen engagement in environmental management.

2.1 Framework Description

Figure 1 below express two main ways of how citizen science is integrating into environmental management. The outcome of citizen science profoundly impacts citizen user engagement in environmental management, and environmental management influences on citizen science as well. (1) Path one: It demonstrates a path that citizen science impart scientific knowledge to the public. Non-expert public assist data collection for environmental scientists, environmental managers or decision maker. Scientific information applied in the environmental management helps the decision makers to make objective judgment. (2) Path Two: It implies that an indirect approach that citizen science was an online education tool that allows the citizen to learn environmental knowledge when providing essential information to the program. The mobile-based citizen science also increase citizen awareness that stimulates citizen to make the public input including participating environmental activities, advocate for environmental conservation or

promulgate to make public input within their communities. Meanwhile, citizen can directly apply what they acquire from the citizen science to the environmental management. For instance, citizen is able to provide feedback or comments on implemented policy. Two different paths reinforce and synergy to affect citizen engagement in the environmental management mutually in the most citizen science project and converge in citizen science. In figure 1, environmental management contributes to citizen science via policy implementation and evolution, so the entire framework becomes a closed loop of citizen science and environmental management.

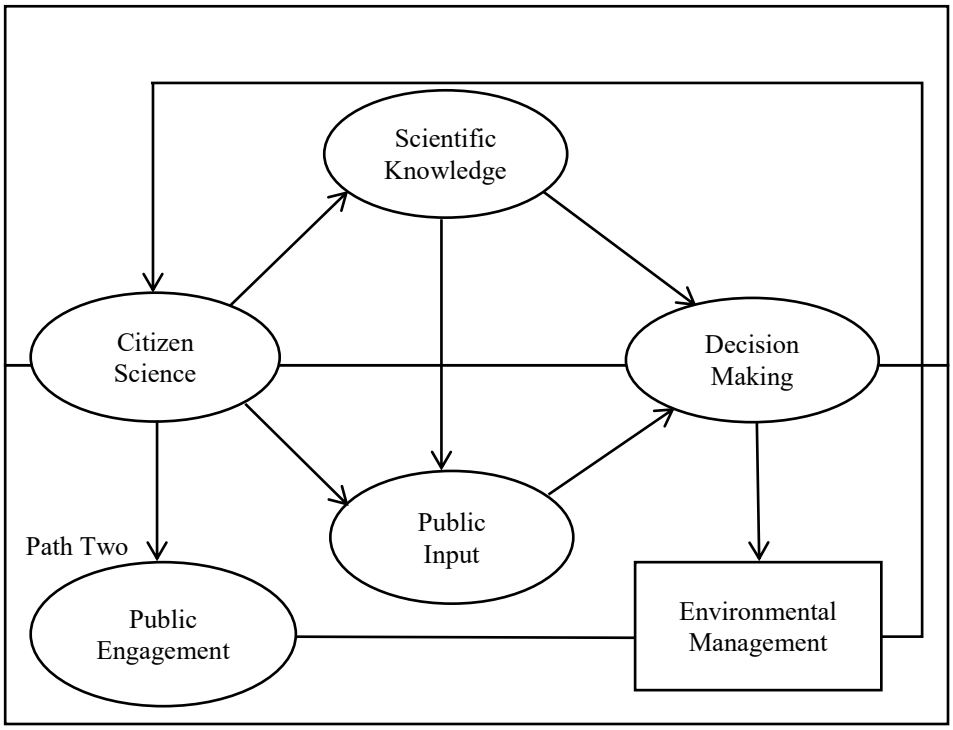

Figure 1 Citizen Science Incorporation in Environmental Management

Fig. 1. The two pathways that citizen science can influence citizen environmental management by imparting environmental science to citizen and fostering direct (Path one) and indirect (Path Two) public involvement in environmental management. Solid arrows in the figure refer to the impacts of one objects to another. Two paths converge in “Citizen Science” and can be strengthened and cooperate mutually.

2.2 Variables

Tang and Liu (2015) proposed three objectives (information, site use and user) from poor condition to excellent condition to clarify ideal conditions for an Internet-based PPGIS (Internet-based Public Participation GIS) site to foster public involvement in environmental planning and management in the conceptual framework. The three variables (information, site use and user) concluded from conceptual are evaluated to accomplish the research goal to present the current status of PPGIS cases. Accordingly, the conceptual framework of citizen science incorporating with environmental management here as well shows assessable and accessible variables in the mobile-based citizen science case evaluation. Following the research goal described in chapter one, enticements of citizen engagement in environmental management are the core of the entire cases analysis. Public input, public engagement, and scientific knowledge are channels connect the environmental management via citizen activities in the conceptual framework. The sub-section below clarify the process of variables determination.

2.2.1 User Participation

Meanwhile, the public influence and education purpose of citizen science determine the citizen motivation of contributing to the environmental management. Data output and the influence on citizen lead to public engagement in the environmental management. Jordan, Ballard, and Phillips (2012) presented three basic issues and methods for evaluating learning outcome of citizen science. Individual learning outcomes, programmatic outcomes, and community-level outcome are three types of evaluation. Individual learning outcomes refer to attitude change towards environmental conservation such as fully understanding ecosystem or science process, having the motivation to participate in natural science activities and inquiry skill and performing

environmental stewardship behaviors. Examining individual outcome needs to evaluate citizen engagement in citizen science. The great quantity of use participation in mobile-based citizen science will influence more people to participate in environmental management.

2.2.2 Data Management

Programmatic outcomes require the examination of the application of data in environmental management such as in scientific research and environmental management decision-making. Data quality determines programmatic outcome evaluation. Therefore, community-based data quality in citizen science matters in case research because of its potential application during decision-making process. Quality and quantity of volunteer submission affect the environmental management. The data management within the program thus associates with the effectiveness of user engagement in the environmental management and determines. Data management design aims to minimize errors while efficiently generating the maximum amount of numbers.

2.2.3 Partnership

Community-level outcome assessment tests if citizen science can enhance social capital, community capacity or impact economy. Social implication relies on encouragement from the partnership, for example, local environmental agencies to expand positive influence to the community. External source to support the development of capacity is significant. When the program has the social influence, there will be more citizen engagement in the mobile-based citizen science and the environmental management.

Data management, citizen participation and partnership are three objectives capable to indicate effectiveness of mobile based citizen science develop citizen involvement in environmental management.

CHAPTER 3 CRITERIA AND CASE DESCRIPTION

The conceptual model summaries three variables for the cases analysis. When variables confirmed, the research here will evaluate each mobile based citizen science cases. Hence, it is necessary to establish criteria to choose cases. The section below will demonstrate case selection criteria and cases description

3.1 Criteria

Case selection complies with criteria. There are three critical criteria for the cases selection. (1) Objective: Main research objective is the application of mobile-based citizen science in environmental management, so target citizen observation of mobile-based citizen science need to be environmental related to promote citizen engagement in the environmental management. (2) Methodology: As research goal stated previously, cases are expected to address the environmental issues in environmental management and help users participate environmental management. Thus, the main data source of each case from the public. Having public input in citizen science potentially connects citizen with environmental management. (3) Platform: Mobile device provides the channel for the public to convey the environmental information. Selected cases thus need to be mobile device based and behave like the public information generation tool. Also, official program website with data display is necessary to assist data upload and download.

Based on above three criteria, five cases selected in the research: eBird, iNaturalist, Project Noah, Galaxy Zoo and What’s Invasive!.

3.2 Case Description

eBird, iNaturalist, Project Noah, Galaxy Zoo and What's Invasive! are five mobile-based citizen science projects are selected. Table 1 below lists general information including founder, observations, platform and data collection methods of each case.

eBird, iNaturalist, Project Noah, Galaxy zoo have coverage of all around the world, but What's Invasive present data from 110 parks in the United States. The general objective of these five cases is encouraging the public to use the internet based mobile device to collect environmental data including wild species, wild bird galaxy classification, and invasive species to assist scientific research. Five of them have mobile phone application and official web-interface data management system. The primary data source for selected cases is from the public submission. However, selected cases are varied with spatial and temporal scale, user number and observation, it caused inaccuracy when performing analysis and evaluation. So, the result might have the low accuracy to represent all mobile-based citizen science currently.

3.3 Data Source

Total users and total data submission with the time range from when the program was found to November 2016. All descriptive and statistical information are gained from cases official websites or confirmed by the valid workers of the programs. Table 2 below shows the data source including the URL of case website where the data information display and the name of the project technician who provided the data.

CHAPTER 4 METHODOLOGY

Data management, user participation level, and partnership discussed from above, provide a conceptual framework for three variables that specify the abilities of cases to motivate citizens to participate in the environment. They provide descriptive information of cases to evaluate through SWOT (Strength, Weakness, Opportunity, Threats). Case study elucidates data management, participation level, and partnership status and reveals the advantages and shortcomings.

Table 1. Selected Case Description

Name	Founder	Observations	Platform	Data Collection	Establishment Time
iNaturalist	Nate Agrin, Jessica Kline Ken-ichi Ueda	Wild Species	Mobile APP Web-Interface	Volunteer Submission	Mar-2008
Project Noah	New York University's Interactive Telecommunication Program	Wild Species	Mobile APP Web-interface	Volunteer Submission	Early 2010
E-Bird	Cornell Lab of Ornithology and National Audubon Society	Wild Birds	Mobile APP Web-interface	Volunteer Submission	2002
Galaxy Zoo	Chris Lintott Karen Masters Kevin Schawinski	Galaxy Morphological Classification	Mobile APP Web-interface	Volunteer Submission	Jul-2007
What's Invasive!	University of California-Los Angeles The Santa Monica Mountains National Recreation Area EDDMaps	Invasive Species	Mobile Application Web-interface	Volunteer Submission	2006

4.1 SWOT Analysis

SWOT analysis is widely used methodology of evaluation in diverse projects or other cases where the leaders need to make the decision. Before summarizing the development suggestions to selected cases, SWOT analysis identifies and evaluates the factors by assisting or styming the mobile-based citizen science to accomplish its

potentials (Houben et al.,1999). It assesses strengths and weakness as internal factors that can boost and decrease the development of mobile-based citizen science project help the citizen engage in the environmental management. On the contract, assessment of external factors opportunity and threats that influence the cases is unavoidable as well. Result of SWOT analysis manifest the present factors that either hinder or facilitate mobile based citizen science in encouraging citizen to participate environmental management. It lay out the foundation of more improvement in the future. Three section below details descriptions of each variable of evaluation.

Table 2 Case Data Source

Data Source	**Total User**	**Total Submission**
iNaturalist	Ken-ichi	http://www.inaturalist.org/stats
eBird	http://ebird.org/ebird/places	http://ebird.org/ebird/places
Project Noah	https://www.projectnoah.org/organisms	https://www.projectnoah.org/organisms
Galaxy Zoo	https://data.galaxyzoo.org/	https://data.galaxyzoo.org/
What's Invasive	https://www.whatsinvasive.org/	https://www.whatsinvasive.org/

4.2 Data management

Data submitted by the user is important in mobile-based citizen science. Ferster et al. (2013) conducted a literature review to discuss the considerations of MPCDs (Mobile Personal Communication Device) in data collection including field measurement, sample strategies, privacy, data quality, analyzing datasets covering broad spatial extents and sharing dataset. This method developed a practical framework to minimize biases and error during data processes. Here, the data management consists of multiple critical items in cases evaluation. The research here evaluate the data management including the entire

mechanism such as data collection, data processing and sharing. It is primarily determined and designed by the technical system within the program. Data management evaluation here covers data sampling scheme, quality control approaches, and data accessibility and user authorization of data sharing. (1) Collection: This research will examine whether the cases share professional protocols or guideline to the novice users or not. Meanwhile, the accessibility of "help" section, Q & A sections and online technician helper to the general public for data or sample collection is beneficial to make the process more efficient keep users from the mistakes. Strategies offered in case of streamlining data generation and submission equips environmental monitoring information to environmental management and educates citizens to participate in environmental management. (2) Quality Control: The Wiggines from the University of Syracuse in 2011 stated appropriate data application and propose indicators of data quality as well as verification of validity, consistency, precision, and accuracy (Wiggines et al.,2011). Data quality control in mobile-based citizen science is to ensure validity, consistency, precision and accuracy. Having quality control is paramount to avoid misleading in data with the application. There are various ways to ensure data quality in different cases varied with observation subjects, volunteer number and project scale, therefore, approaches of data quality control evaluation are to check if the cases own systematically quality control strategies that customized for each project such as outlier removal or data model standardization during sampling. (3) Data Sharing: The evaluation item of data sharing in mobile-based citizen science consists of the platforms for user communication, public submitted data accessibility, data sharing authorization and user privacy. If the selected cases provide the platform to users for information exchange, for

instance, a chat room is going to be evaluated as well. In addition, user-customized profile establishes the personal connection among people with the similar interests. User permission of data sharing and organized-regional activities also enhance user participation in environmental management. User submitted data and information are accessible to the public or not is another element in the case evaluation. Privacy is crucial to protect the user's personal information and allow the user to maintain the data copyright. According to COPPA (Children's Online Privacy Online Protection Act), when personal information is collected, the homepage and each page of the website must link to privacy notices with data policies that explaining how to use the data, contact information of a person responsible for the data and parental rights of minors. Meanwhile, COPPA has the age limit to protect children's online privacy" Volunteers notify that "if you are under the age of 13, you must have your parent, a guardian or a teacher register for you." (Bowser, et al.,2014). Therefore, whether having the link and warning box of privacy information for minors and those of-age, is examined to summarize the status of the privacy policy of mobile-base citizen science cases.

4.3 User Participation

User participation is the degree of citizen involvement in mobile-based citizen science, and it can represent the popularity of the project. Haklay (2012) articulated the hallmark of citizen science as the role that the public plays being passive and active contributors. On the one hand, active users collect environmental data or perform data analysis deliberately and actively send data electronically via the mobile device. On the other hand, passive volunteer act as an observation and generate data without active engagement in the program. When applied mobile-based citizen science to environmental

management, various stakeholder information input is inevitable. Having a large amount of participation bring countless benefits for the decision-making process. Active volunteers exhibit passion of environmental activities through citizen science and unremittingly submit information. User participation can be evaluated and indicate that mobile-based citizen science can influence large population to express interest in participating the environmental management. However, user participation level is hardly estimable. Tang and Liu (2012) collected users number and total posts in a certain period from Internet-based public participation GIS (PPGIS) and volunteered geographic information (VGI) analysis cases in order to calculate post per user to represent the level of user engagement. This research adopts the methods of Tang and Liu and in order to obtain descriptive data such as total user and observation submission in the certain period from websites of each case. Then total information posts by per registered users are calculated by dividing total submission with user number. Post data roughly shows the amount of active users and the level of user participation and interaction. Research here will contract statistical data among cases and summary level of user participation status of each of them.

4.4 Partnership

Partnership accelerate the development of mobile-based citizen science. Cooperation with the government, environmental agencies, and non-governmental organization are conducive to expanding the influence of these cases to the public. Despite the benefit that citizen science brings to citizen participation in environmental management, there are some obstacles that hinder the development such as insufficient grand, technical support and the absence of reputation. Therefore, mobile-based citizen

science needs investment to maintain operation expand the social network and local influence. For instance, organization or primary investigator administer support and facilitate regional activities to advertise the citizen science program or entice local interest to environmental management (McKinley et al.,2016). Research here inspects if selected cases have collaborated partners to assist development.

Data management is an internal factor. Citizen participation and partnership are external factors that that bias the effectiveness of citizen science application in environmental management. Therefore, Strength and Weakness in SWOT analysis epitomize the data management conditions of cases. Likewise, user participation level and partnership status are classified into Opportunity and Weakness.

CHAPTER 5 RESULT

After the case analysis with three variables and SWOT analysis, the status of each case revel. Evaluation results in the advantages and shortcomings of current mobile based citizen science, and the result of data management, user participation, and partnership of mobile-base citizen science display below and SWOT analysis exhibit internal and external factors that impact cases application in citizen engagement in environmental management.

5.1 Data Management

5.1.1 Data Collection

All cases except What's Invasive! design strategies to guide users correctly operate data generation via the mobile device. (1) eBird: As the worldwide citizen science project, it established various means to simplify data collection to sustain data quality. eBird streamlines data submission and collection to diminish data errors. For instance, the

survey with three basic sampling scheme (time, distance, location) assists the user to create information report in eBird. Moreover, “Quick Start Guide” is displayed in “Help” page with the explanation of data submission in detail, and step-by-step instruction in official website are design to make the data collection intelligible especially for new users. (2): iNaturalist: iNaturalist owns a lot of users and data submission every year. Detailed info-graphics as well as the online tutorial shows the interface of information posting via the mobile device through Android or iPhone system to instruct the data posting. Approaches via website and flicker are displayed on the official website as well. Concerning the fact that errors exist in the data collected by non-professional citizen,, iNaturalist present introduction information page in “Help” section of observation, identification, and wildlife species taxonomy to users fully understand ecological knowledge. (3) Project Noah: Project Noah is mobile base citizen science project that educates citizen by encouraging users to generate surrounding wildlife photos through tagging and classification system as long as documenting the ecology biodiversity with crowdsourcing. “Mobile” page in official website exhibits info-graph of photo taking and images uploading to guide the mobile device novice. Project Noah make the public apprehend the functions and the operations they can perform with the citizen science application in the mobile device. Then “ FAQ” pages display the general questions from users about documenting wildlife, identifying wildlife, program missions, copyrighted and inappropriate content that can also address issues from first-time registers. (4) Galaxy Zoo: Galaxy Zoo encourages users to observe the sky at night and classify galaxies from the Sloan Digital Sky Survey. The homepage of Galaxy Zoo introduces galaxy knowledge including how it formed, its history and images. The users can sort galaxy

morphologically by selecting galaxy example pictures to define the classification of real-time observation and submit them. Galaxy classification helper in the main website ensures users have maximum help to perform galaxy images classification while obtaining knowledge. (5)What's Invasive: What's Invasive! is the invasive species geographical distribution monitoring by the citizen. Posts documented to the website are species taxonomy and location submitted electronically in public parks of the United States. There is missing guidelines or protocol to inform users on how to avoid misidentification. In conclusion, four out of the five cases have proper schemes to navigate users correctly, observe and record information and transfer that information via the mobile device.

5.1.2 Data Validation

(1) eBird: eBird creates two data verification strategies. The automation allows raw information from observers compared with daily average counts with the same region and same time that standardized as the reference. If the raw data is distinctive with the standard number, then it is marked and considered irregular information. Users receive the pending confirmation after submitting abnormal data. The information is reported to the regional editor for further verification after users ratify the accuracy of data. Therefore, data quality control of eBird efficiently maintain the creditability of data and is responsible for data application. (2) iNaturalist: Global Biodiversity Information Facility shares user observations with iNaturalist. To prevent amiss data, data quality assessment behind the screen rates the grade of every individual observations. They attached with completed background information including dated, georeferenced and photo or sound are in the research grade. Otherwise, data is rated as the casual class to

forestall imprecise application in research. (3) Project Noah: Project Noah documents every post after the user's complete submission survey including species identification, location, photo and categories without the quality check. In spite of learning biology taxonomy, there might be existing bias or errors occurs when users to identify species. (4) Galaxy Zoo: Galaxy Zoo doesn't have approaches to ensure the quality of user galaxies classification. (5) What's Invasive: What's Invasive collect all user data observation and display in the official website, yet there aren't data quality filters to remove the invalid information. Only eBird and iNaturalist have systematical quality control for user submitted data. Therefore, data quality control is inadequate in selected cases.

5.1.3 Data Sharing

(1) eBird: E-Bird is the platform of a database in eBird with numerous data formats and provides various data search options such as point count, transects and area varied with interest of users. Register users need to agree on the program policy before they download the data products and provide personal information including Country of the resident, project title and type, abstract and affiliation. Meanwhile, registered birders do not only have accessibility to bird species distribution database but also authorized to build the database to manage individual postings and share with other users. Each user has the chance to customize personal profile and discretionary action to publicize it. eBird grants users to the platform to reach out other birders with the same interest or live in the same region. However, eBird doesn't send the link to data policy page or warning box to first-time registers and attempt to ensure underage minors have guardians or parententals supervision. (2) iNaturalist: All submission from all over the world are displayed on the iNaturalist website and are available for download. Registered users can

manage observations and communicate with others through online messaging or following activities. iNaturalist complies COPPA (Children Online Privacy Protection Act) to protect privacy by sending the link to data policy information before the user filling out the registration form. However, it doesn't guarantee to avoid minors under 13 to reveal personal information online by automatically sending warning box to confirm the age of registers. (3) Project Noah: Homepage of Project Noah exhibit observation posts from participants in the continent classification. Also, each registered users can store and govern their observations, and they can follow the activities or posts of other users for friendship building. Modifying online profile and adding personal information such as name and email address chance users to know others and have further contact. Copyrighted of wild species pictures and location are authorized to each user, but personal information especially people under 13 is unprotected because there isn't any safety link to inform users the privacy policy of projects when they register and submit data. (4) Galaxy Zoo: User-generated data are free to obtain from "Data" page in Galaxy Zoo official website. Each user in the program has the manageable account to document the entire collection they submit. However, classifications of others are unavailable as well as profile and contact information of others. Communication platform doesn't exist in Galaxy Zoo. Likewise, data and personal information privacy link doesn't automatically appears before people register and submit classifications. (5) What's Invasive!: Each register users have the personal account that notes the submissions, but they can neither see observations from others nor reach out further communication due to absence of personal profile. What's Invasive! doesn't comply COPPA because it doesn't

send the program privacy to inform users before they register and upload invasive species information.

5.2 User Participation

The official website and citizen science certified workers of selected cases provide the total users, total submission and start date (shown in Table 2). Total users are the entire citizen who registered on the site and contribute to observing through the mobile device. Some submissions and active users are critical variables to estimate the popularity of selected cases roughly, and it affected by period, coverage area and the awareness of citizen. Table 3 below presents statistical data of each case.

According to Table 3, deviation of average submission per users is significant among five selected cases. The geographical scale of projects determines the number of people due to the reduction of geographic restriction. Compared with other four cases, What's Invasive! has the least users (261) and total submission (11,058) due to the nation-wide coverage but it has the second highest average submission per users (42.37). Therefore, research can roughly assume that large user numbers, online posts and the longest period might lead to the less submission per users. Moreover, iNaturalist have 1000 times users (42.37) more than users (261) in What's invasive! but the average submission per users (8.823) is five times less than What's invasive (42.37). However, the numbers of eBird don't behave this rule accordingly. The data post per use (68,210) as the highest among the other five cases owns the second largest register users (330,000), total submission (252,240) and the longest data collection period (since 2002). Moreover, Project Noah has the third lowest of average posts per users (2.415) in spite of the second heights of total submitted observations (785,000) and more than 300,000

registers. Galaxy zoo has comparative less total users and posts also results in the second lowest average post per users Therefore, the result shows can roughly show that there isn't relationship among total registers, total submission and average post per user. Meanwhile, diversified factors also have the potential influence on average data per users. Total users and coverage area have the positive relationship with total submission, and there is the logical explanation that the more users result in more submission. For instance, even though What's Invasive! (2006) Was found two years earlier than iNaturalist (2008), there are more than 1000 times users registered in iNaturalist than What's Invasive! on account of the iNaturalist is the worldwide program. An average number of information submission per user is the indicator of the user participation level in the research here.

5.3 Partnership

All of the study cases have at least one partners to offer support and collaborate with, and they (1) eBird: eBird has total 40 partners including sponsors and affiliates worldwide, and they form various kinds of collaboration with eBird. For example, financial support from National Science Foundation provided grant No. ESI-0087760 for data submission website creation in eBird. eBird, Birdlife and International and Bird Studies Canada collaborate organized synergic activities for bird watchers and habitat conservationists to promote citizen environmental awareness. Moreover, eBird as data provider has been the helpful online tool for research facilities, research institute and organization such as Alaska and California Audubon birders. (2) iNaturalist: iNaturalist gains support from 11 nation-wide and domestic organizations. Encyclopedia of Life (EOL) assist iNaturalist in initiating projects and developing guides. iNaturalist is the

research-grade data feeder to Global Biodiversity Informatics Facility (GBIF) and Encyclopedia of Life (EOL). (3) Project Noah: National Geographic as the main supporter of Project Noah invests the program technically and develops collaborative nature explorer to conserve wildlife. (4) Galaxy Zoo: Sloan Digital Sky Survey equips the origin of a million galaxies imaged in Galaxy Zoo, and the website of Galaxy Zoo relaunched and combined new images from Sloan. (5) What's Invasive!: What's invasive was online citizen program and supported by UCLA's Center for Embedded Networked Sensing (CENS), the National Park Service, Center for Invasive Species and Ecosystem Health at the University of Georgia. EDD Maps is the primary receiver of invasive species site from What's Invasive!.

5.4 SWOT Analysis Results

Information presented in Table 4 outlines the result of cases evaluation in strength, weakness, opportunity, and threats of the SWOT analysis. The text section below also explains the bulletin points in Table 4 in detail.

Table 3. Statistical Information of Case Analysis

Citizen Science	Total Users	Total Submission	Average Submission Per Users	Time Range
iNaturalist	374,000	3,300,096	8.823	Mar-2008 to Nov 2016
Project Noah	325,000	785,000	2.415	Early 2010 to Nov 2016
E-Bird	330,000	22,509,379	68,210	2002 to Nov 2016
Galaxy Zoo	41,552	52,073	1.253	Jul-2007 to Nov 2016
What's Invasive	261	11058	42.368	2006 to Nov 2016

5.4.1 Strength

One of the hallmarks of mobile-based citizen science is simplicity when compared with traditional citizen science. Simplicity is connected growth of mobile technology,

because it conveys instructive guidelines of information collect and submitted either from mobile device or web portal. Mobile device broadens the time and location possibilities of data generation as well as diversify users class from scientist to non-expert citizen. Mobile-based citizen science makes scientific information attainable without sophisticated sample collection procedures and science degree requirements. It fosters public engagement in environmental research and management. In addition, citizen science websites and mobile devices are user-friendly as they accommodate with the citizen science program neophytes by simplifying the site operation to click, zoom, search or delete to perform scientific data management. Moreover, data in citizen science has potential application in scientific research and environmental management with the real-time community-based environmental monitoring.

Table 4. SWOT Analysis Result

Strength
• Simplicity • Data Accessibility and Sharing • Active User Interaction
Weakness
• Data Quality Control • Privacy Protection
Opportunity
• Partnership
Threats
• Large Users and Data Submission don’t lead to Active Participation

Information acquired by the public in mobile-based citizen science are priceless, and people apply data in selected mobile based citizen science in various scientific discipline and environmental management. Citizen efforts in the programs are visible to the public after quick identification check. Open data source makes citizen science more compatible in helping citizen science engagement in environmental management because

it expands the horizon of decision maker chance them aware citizen environmental discoveries and opinions. Meanwhile, when public efforts are seeable and tractable, it is more likely that environmental managers apprehend environmental information from the public which allows them to be subjective and recognition to perform duties.

Mobile-based citizen science can serve as the online communication tool is the channel for to communicate with others with joint interests and friendship builder. Active users can advocate and organize local environmental activities depends on the social network users involve through citizen science. Mobile device citizen science abridges the gap between citizen groups and scientists and foster cooperation. User authorization of data sharing and optional personal information revealing stimulate the collaboration among citizens and engagement in environmental management.

5.4.2 Weakness

Data quality control vanishes in Project Noah, Galaxy Zoo and What's invasive! But both eBird and iNaturalist. Data quality is consequential and is worth discussing issues in mobile-based citizen science. The approaches in different cases are dissimilar because they vary with project scale and data application. However, bias or wrong-judgment occur when users perform data generation caused by the incorrect operation and influenced by scientific knowledge of users. For example, species identification determined the information correctness in iNaturalist or Project Noah and influenced by perceptivities and the observer's apprehension of biological taxonomy. Data inaccuracy is inevitable, so it is essential to verify data accuracy before sharing overtly to scientific research and environmental management where environmental information matters significantly. Users of selected cases have been applied data in various disciplines. A

mobile-based citizen with the abundant data submitted from users is more likely to increase the data imprecision due to the erroneous possibilities that observers make mistakes during data collection. Inadequate qualified data in mobile-based citizen science not only vitiates the value and credibility of data applications but also reduce the chances to engage citizen participants to environmental management.

It is unlikely that users have the awareness to protect data and personal information privacy when involving with digital communication. All selected citizen projects don't auto-send privacy policy warning link before user register or upload information and ensure the minor parental information authorization. Personal privacy in citizen science includes personal information including name, address, phone number and data sharing authorization. Citizen ignorance of personal privacy and potential risk of personal information expose when uploading data can cause users or stakeholder confliction in citizen science or environmental management. The different interest of citizen is inevitable that has potentially trended to algorithmic discrimination, and diminish citizen safety (Bowser et al.,2011). Violating personal privacy hinders openly public expression and motivation to participate in environmental management. Thus systematic privacy guard in citizen science is essential when applied in environmental management.

5.4.3 Opportunity

All elected cases have numerous partners or supporters to cooperate with or obtain investments. For example, eBird and iNaturalist have more than 20 collaborative organizations, affiliates and supports worldwide and they partially credit for the development and popularity of cases. Partnership plays various roles in mobile base

citizen science. Data analysis and visualization in mobile devices are significant, and technology supports highly impacts it. Bond with different agencies like the scientific institution that invest in technology in the programs is the crucial factor to developing based citizen science. Organize environmental activities to advocate public input in environmental management is more efficient when citizen science have the financial or physical devotion from local environmental agencies or organization. Cooperative relationships with influential organizations increase citizen participant motivation and passion by initiating regional or worldwide activities and outreach programs.

5.4.4 Threats

Average citizen submission per user determines the citizen participation. A large amount of registered users in citizen science don't lead to the active contributor, it varies with program scale, and the time during citizen motivation. There is not currently existing positive correlation of average information posts per citizen and total registered users or total submission. Thus citizen participation level is undefinable, and large projects with worldwide coverage and considerable citizen input can't claim they own significant contributors. Therefore, the absence of citizen self-motivation and participation level are the main threats to current mobile based citizen science engagement in environmental management. The long-term active contributors have enthusiasms to devote in public environment management as well as environmental activities, and they are the incentives for citizen science improvement. Therefore, strategy for maintaining users and increase new users is necessary to have in mobile-based citizen science otherwise it loses the influences on citizen and environmental management.

CHAPTER 6 DISCUSSION

SWOT analysis identifies strengths, weakness, opportunity, and threats of mobile base citizen science cases. As stated in the previous cases analysis, mobile-based citizen science features with that simplicity, data source accessible, user power of data sharing, communication chance with other users and multiple partners. However, most of the selected cases don't provide data quality control and the user privacy protection. Statistical data of each case extrapolate the fact that high user number and total submission don't lead to the high user participation. SWOT analysis disclosed the internal and external factors that impact the capability of citizen application on increasing public engagement in environmental management. The section below offers possible suggestions or strategies to optimize mobile-based citizen science and maximize citizen participation in environmental management.

6.1 Maintain Strengths

6.1.1 Simplicity

Retaining the simple operation in mobile-based citizen science is the approach to boost citizen participants in environmental management rather than the convoluted interface of the mobile device. Hence, additional simplification methods are beneficial to attract users and share the insights about the concerning environment. The user-friendly design of mobile interface can emphasize to the integration of online tutorial with data collection page to guide information generation. Clicking minimization, automate checklist for data collection, and species identification helper are productive strategies to facilitate data collection. For instance, one of the characteristics of eBird is manifold of users in attributes to other mobile applications such as BirdsEye and Bird-Watcher's Dairy. They were designed to automate repeated information including time, location and

GPS data to streamline information input process in eBird, and it is one of the strategies aiming to simplify data collection process (Ferster et al.,2012). Moreover, the variety of data formats fit the needs to different data application.

6.1.2 Open Data Source

Scientific research needs data over large spatial and temporal extent. Multiple data search filter classified by geography, period and taxonomy species fulfill the different data inquiry from users. Data display in mobile-based citizen science impart scientific knowledge to the citizen. For example, Devictor mentioned (2010) the citizen science programmes as the helpful tool in scientific research that promotes the citizen connection with the natural resource in biogeography conservation in 2010. Therefore it is arduous to have education propose without having open data source to the public (Devictor et al.,2010). There are more strategies to make data information more accessible such as displaying user-submitted data applications aboveboard and grant credits to the contributors. Technology investment to the cases also diversity data formats, and awareness of environmental knowledge can stimulate citizen participation motivation to environmental management.

6.1.3. User Interaction

Another aspect of mobile-based citizen science is the social media application with the scientific, educational propose. They provide the communication platform to users by allowing them optional to build the personal profile and connect the other interest people. User interaction ranging from the single communication via chat room to groups local activities is critical elements in social media in the mobile device as well as citizen engagement in environmental management. Thus, maintaining the active user interaction

by promoting online or offline group theme activities to bond the users. Also, the design of mobile device or web-interface can provide emphasis on providing service to users of automatically suggesting friends that have the similar interests, occupying the same professionals or living in the close region to promote the social network. There will be communication and negotiation involved during consensus building in environmental management, so the regular channels for users to have proper communication, exchange information and expand the social network elevates the participation in environmental management.

6.2 Diminish Weakness

6.2.1 Data Quality Control

Data quality control ensures the correctness of data as community-based environmental monitoring. There are numerous data quality controls are developed and adopt in citizen science currently. For example, Dunlap (2015) proposed Science Caching project has data validation system that it automatically compares new input data with the old information. When detecting errors, the system guides people to check data, re-observe and resubmit data while still on the site with the instruction displayed on the mobile device (Dunlap et al.,2015). Additional data quality controls designed for disparate data formats are necessary because there are multiple types of data. Therefore, the environmental specialist can help to create data standard based on the average data in the particular region or period. Systematical outlier removes and standardized user submitted data are capable of improving the data accuracy. The more data input makes it easier to build up completed data based on the different standard. Moreover, a designed data collection checklist to pre-eliminate the potential incorrect data can filter out the

“not-allowable” user submission in the location of data collection. No matter what approaches the program choose to verify the data, scientific specialists need to attempt to examine the observations and build up the effective data processing. Therefore, investment and cooperation with other organizations help improve the data quality methods.

6.2.2 Privacy

Privacy requires attention either in environmental management and citizen science. There should be data exchange and personal information sharing policy of the program to auto display before users reveal any personal information online and submit their data. Moreover, confirmation should be sent to inform users under age 13 be supervised by adults when they display personal information online. After all, enhancement of user privacy protection needs the help of technical support.

6.3 Seize Opportunity

The partnership is viewed as the consequential in mobile-based citizen science project development by solving environmental issues and engaging citizens with environmental management. Supporters and partners can create more chances for cases to technically improve the mobile device application or web-interface. Research Institute is one of the most promising case studies because it is the source of technical force to push the development of mobile-based citizen science. Partners such as the local environmental agencies or non-government organizations also co-organized with citizen science local online or offline activities for gathering more participants by influence them with regional reputation. Partners form incentives of increasing the public input to environmental management or participate the citizen science program. They strengthen

the public connection with the citizen science and bolster the program development. More collaboration with influential organizations agencies or the government is the potential way to achieve public engagement in environmental management.

6.4 Respond Threats

Enthusiasms of citizens participating in citizen science is an external factor that can determine the program public acceptance. achieve a lot of participation, and have active contributors. When current mobile based citizen science owns large registered user numbers, yet it doesn't indicate the essential long-term contributors. A few active contributors imply the less influence on citizen and directly diminish public involvement in environmental management. Citizen motivation increment is the way to appeal the larger amount of users in mobile-based citizen science. Strategies of keeping users involved and the committee in the program is key to attracting users and maintaining contributors. User-friendly mobile device operation of citizen science project or environmental outreach program are necessary to promote citizen motivation. Program awards also activate the users to perform environmental observation and data collection.

CHAPTER 7 CONCLUSION

As mobile-based citizen science continues to rapidly develop, more citizens will become in scientific research and environmental management. Therefore, it thrived to accelerate engagement public environmental management and connect citizen with environmental scientists. This study establishes the conceptual framework that concludes the evaluation variables data management, user participation level and partnership. Based on the assessment results of five selected mobile-based citizen science, SWOT analysis conclude the strengths, weakness, opportunity, and threats of selected cases were

analyzed. Strengths and opportunities of the cases including simplicity, open data source, user interaction platform and partnership are the incentives for citizen participation in environmental management in this study. The major weaknesses and threats of mobile-based citizen science are the lack of user privacy protection and lack of positive correlation between user number and user participation. Weakness and threats create gap among citizen engagement in environmental management. Simplifying the data collection, publicizing the data submitted by the users, and activating user communication platforms could help the mobile-based citizen science and involve citizen in environmental management thrive. Additionally, suggestive information to cope with disadvantages could be used as strategies to attract, retain users and increase active participation. Moreover, an increase in citizen motivation to get users involved in environmental research and management could be beneficial in further analysis regarding this topic. The results of this study proves that mobile-based citizen science has potential to engage citizens in environmental management, but they need the improvement of sustaining strengths and opportunity and removing weakness and threats.

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