THE INFLUENCE OF TRAINING ON POSITION AND ATTRIBUTE ACCURACY IN VOLUNTEERED GEOGRAPHIC INFORMATION

by

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A Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at George Mason University

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DEDICATION

This is dedicated to my family and friends who stood by supportively and patiently while I carried on this work. To my father who always believed in me, and to all those still living who listened to me while I worked things out. Without their continued encouragement and even silence, this would have likely not finished.

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ABSTRACT

THE INFLUENCE OF TRAINING ON POSITION AND ATTRIBUTE ACCURACY IN VOLUNTEERED GEOGRAPHIC INFORMATION

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Geo-crowdsourcing is an important emerging technique for geospatial data collection, where contributors identify the position and attributes of features to be included in geographic information systems. The geo-crowdsourcing movement shares many similarities to other well-known citizen science projects, including the use of training to improve the accuracy of the information being collected. This thesis describes an ongoing research project where participants are being trained to contribute data to a crowdsourcing system used to identify accessibility problems associated with transient obstacles and navigation hazards. The training includes information about determining and establishing location of obstacles and defining attributes for obstacles. In order to assess the effectiveness of this training program, student participants were divided into two treatment groups, with one group receiving the standard training program and the other receiving no training other than a short introduction to the project. The students in the trained treatment group were shown images of obstacles along with a characterization of each obstacle, followed by a series of sample images of obstacles that they could practice assessing and characterizing. Student participants in both treatment groups were then led one-by-one on a pre-determined path around campus and asked to report at least 4 obstacles encountered, using a crowdsourcing web-map. Concurrently, several trained project moderators independently characterized all obstacles along the path to provide ground truth for this study, and compiled a master list of obstacles. The moderators then evaluated the reports submitted by study participants and provided a comprehensive quality assessment of each report. Analysis of this quality assessment data using t-tests and Mann-Whitney tests finds that with the small sample size used in this study (n=23) there was no significant difference between the trained participants and the untrained participants. Both groups achieved quality scores in the 60-65% range, with the trained group having a higher (but insignificantly higher) average total quality score, obstacle type quality score, and moderator-assessed final quality score. The untrained group had a slightly higher (but insignificantly higher) average score for accuracy of report location. These findings and their implications are discussed in this thesis, along with future suggested research directions.

CHAPTER ONE: INTRODUCTION

"Your true pilot cares nothing about anything on earth but the river, and his pride in his occupation surpasses the pride of kings."

"Fully to realize the marvelous precision required in laying the great steamer in her marks in that murky waste of water,"

'No! You only learn the shape of the river, and you learn it with such absolute certainty that you can always steer by the shape that's in your head, and never mind the one that's before your eyes.'

~ Mark Twain, from Life on the Mississippi

1.1 Application of Geo-crowdsourcing

Changes in technology since Mark Twain's 1883 accounts of navigating the Mississippi River have been vast and rapid. Although methods of piloting described in *Life on the Mississippi*, are not in practice today, some of the problems faced in an effort to manage and control one's surroundings are similar. Continuous changes in today's physical environment make use of modern applications in geo-crowdsourcing to meet such challenges. Citizen science coupled with training or familiarity in the use of a specifically designed website can contribute much toward the control and better understanding of one's surroundings. Web 2.0 has been able to provide a storage and exchange platform for new types of geoscience information (Ruitton-Allinieu 2011). These key ingredients (citizens and the web) have emerged as citizen science, where tagging of photos, maps, and other images help to identify the interrelatedness of citizens with their environment. This interactive activity may be referred to as geo-crowdsourcing or VGI depending on purpose, format and organization of the work (M. F. Goodchild 2007, Howe 2008, Ruitton-Allinieu 2011). Such collaborative community efforts in collection of data can benefit both environmental and scientific. Motivations for participation are as varied as the topics and those coming together to contribute. The desire to be part of the community, to share one's knowledge of an area and to use open-source platforms brings together a powerful force in the collection of ever-changing information (Ruitton-Allinieu 2011). Citizen science training may also be considered beneficial for numerous applications. Sample applications could include identifying invasive species in a park, tracing the spread of White Nose Bat syndrome, or detecting a significant change in geologic stability of a park trail. Accuracy in the collection of data points in such applications may be improved by training in cases where the attributes are more stationary (Fowler et al. 2013).

This study considers the effectiveness of training volunteer participants in geo-crowdsourcing in the identification and positioning of path obstructions on a web map interface. Participants worked in areas of their own expertise, based on familiarity within campus neighborhoods. Training participants in general methods for the study was expected to improve both attribute identification and positional accuracy. Analysis of volunteered datasets was done to determine the influence on accuracy using two different training levels: some training, or none at all.

The problem of keeping certain types of information updated in real time, particularly in areas of public use, has been one of importance for safety, for improved accessibility and for better utilization of public spaces. This can be critical during times of crisis in geospatial criteria that can change citizen interaction with the environment almost overnight, such as during an emergency or natural disaster (Boulos et al. 2011). Implementation of some personal geo-crowdsourcing devices, such as cell phone applications, or open source software such as OpenStreetMap, saves both time and funding. Local governments, community groups and neighborhoods benefit from better citizen science largely because participants feel more connected and purposeful in their environment when permitted to contribute meaningfully in some way (Roth and Lee 2004). This is especially so if work done is seen as valuable by agencies that receive end-user input. Training can be tailored to participants, either online where the applications are being used, in person, or in a group setting in which volunteers are deployed to targeted areas for geospatial data collection.

An inherent problem with geo-crowdsourcing (CGD) data sets, regardless of who collects the data, or what is being collected and how it is presented, is the trustworthiness of the data (Brown 2012b) Fowler et al. 2013). Since volunteers are not contracted by government or other authoritative agencies, their decisions in the field in regard to precision and validity of data are generally untrusted without the type of quality assessment typically performed by government agencies and businesses (Brown 2012b).

Definitions of terms used in this study are listed in the next section followed by an overview of background literature in Chapter 2; general studies of citizen science and those that included some type of training. Chapter 3 discusses the general methods and procedures, development of the testbed environment, sampling methods and description of the methodologies and moderation processes. Chapter 4 is a discussion of the results, problems encountered, data analysis and statistical tests. Finally Chapter 5 includes the conclusions and ideas for future work.

1.2 Definitions of Terms

Definitions of some terms that will be found in this study, often referenced by initial letters, include the following:

CGD is an emerging geospatial crowdsourced or crowdsourcing phenomenon that includes a shift in how geographic information is created and shared (Zook et al. 2010). CGD is any geospatial data set collected by end-users and placed on a site or in a report, and such end-users are not necessarily compensated, obligated nor contracted by an authority in this collection process. Crowdsourcing, as a term, can be traced to Jeff Howe's 2006 neologism, which describes the phenomena of end-user participation in many activities (Howe, 2006).

VGI is volunteered geographic information, any geographic information that is provided voluntarily and collected on the basis of its geographical interest such as anecdotal description of earthquake aftermath for a community (these could be posted on social networks, even text messages or tweets; or via more formal and organized, purposeful web application to report such data).

VGI falls into the National Spatial Data Infrastructure (NSDI) model as authorized by President Clinton in 1994. As such, a collection of individuals acting independently in varying localities can create patchwork coverage of events on the ground based on a response to the needs of local communities (M. F. Goodchild 2007).

PPGIS is public participation geographic information science, a term conceived at the 1996 meeting of the National Center for Geographic Information and Analysis (NCGIA) to indicate the use of GIS technology by public participation in a variety of applications with the goal of inclusion and empowerment of marginalized populations in decision-making (Brown 2012a).

Web Apps refers to any Internet-based application, some of which are used by the citizen participants in geospatial data collection. For example, a Wikimapia adaptation, Google map mash-up, OpenStreetMap, Waze, SeeClickFix, Place, I Care! or other online software allow end-user interaction in providing VGI.

Citizen Science is an activity in which people of the community, without specific qualification, contribute datasets to a scientific study. Such an activity may be open on the web, but is generated, moderated and overseen by experts with a benefit toward some scientific end, such as a seasonal bird count. Citizen science spans quantitative natural science datasets as well as social sciences and qualitative collections.

Training involves targeted instruction for methodology of a citizen science, VGI or CGD activity in which participants are given an overview plus any idiosyncrasies regarding end-user tools in order to contribute to the activity. It may be done online, self-paced, as needed, in person, in group presentations or workshops.

Accuracy is defined as the amount of deviation from a true value. In this thesis, accuracy refers to the deviation of the X Y coordinates of the obstacle being reported from their true values, as determined by moderators.

Moderation is an expert review process resulting in rejection or acceptance of datasets, and assigning QA scores based on key criteria for various measurements and agreement of reported data to verified, or ground truth data.

A **testbed** is a platform for software and environment requirements used to scientifically test replicable methods for a project, including use of tools and outline of test procedure.

GIS stands for Geographic Information Science (or system), and is the interaction of computer software designed to capture, store, manipulate, analyze, manage and present sometimes many types of geographical data based on purpose, application or need, within the jurisdiction of a city or other government body, agency or other group.

CHAPTER TWO: BACKGROUND LITERATURE

2.1 The Emergence of Citizen Science

Today, private citizens with little training in geographic methods, fundamentals or theory, are able to place volunteered geographic information on the web. This emerging process can be traced back to the naming of America in 1507, but has been defined as VGI by Goodchild in 2007. User-generated content is found in Wikimapia, OpenStreetMap, Google Maps, and various map mashups made with a variety of web-based mapping applications. In general, this user-friendly approach has allowed selection of data points, tagging or marking significant locations on a map by the public; actions that were previously reserved only for authoritative and official agencies. An end-user's ability to supply content to websites became more prominent after 2000 with the advent of Expedia, eBay, and Craigslist. Later, wikis and blogs allowed users to edit contents of such pages. Goodchild said: "We are all experts in our own local communities," (M. F. Goodchild 2007).

Citizen science can contribute to any number of activities, saving costs and time for government or official administrative bodies in the general area and the immediate community. On the other hand, such crowdsourcing can be exploitative. Participants become involved in an acitivty that they may believe contributes to the greater good where in fact the benefit is exclusively aimed towards an enterprise that profits from it. Labor and time of participants is used without compensation or obligation. Contrary to this is the large scale community activities that make use of open source platforms in the development of software or sharing of information, as found in Wikipedia or OpenStreetMap (OSM) (M. Haklay 2010).

Citizens who are experts in their own backyards are also quite interested in improvements for optimum use of areas surrounding where they live and interact. For those with mobility or visual impairments, the interaction changes in direct and dramatic proportion with physical changes in that environment. On George Mason University campus in Fairfax, Va. for example, there is continued construction and disruption of pathway accessibility, requiring practical and real-time updates of path changes. In this interest, a project was undertaken by Rice et al. 2012) to examine best use of crowdsourcing and VGI to improve path accessibility and finally leading to the question being asked for this thesis (Rice, Aburizaiza, et al. 2012). The question of whether or not training can improve VGI datasets as far as accuracy related to path accessibility was key in this research, and will be addressed in the results and conclusions sections in later chapters.

One of the longest records of spatially informed biological data is represented in the Christmas Bird Count (CBC), conducted by the National

Audubon Society. It has been carried out every year since 1900. Efforts have been made to oversee the counts, to cover areas consistently, to include all species of birds, and yet there has so far been no documentation to provide quality assessment (QA) for consistency (E. H. Dunn et al. 2005).

Challenges inherent to this extensive dataset are due to its lack of digitization by tradition, and the idea that entering, editing and keeping the data accessible for scientific use is daunting. In order to address these and other challenges, a panel addressing the National Audubon Society (NAS) determined that any change in the count methodology toward a more rigorous population-monitoring program would cause detrimental effects, including a drop in participation. Instead, small, less dramatic changes were suggested to help increase the usability and scientific value of the data in the future. It was found that data entered on the Internet since 1997 allowed for more widespread use. Providing forms with clear data-entry fields to enter into a permanent database was believed to be a key step toward increased value of the data and publicized results (E. H. Dunn et al. 2005). The successes of the CBC can provide important lessons for other applications in citizen science. Perhaps the standards, training and procedures that have preserved CBC attendance, growth and value to professionals such as NAS, could point to answers that enhance data collection in other fields.

Like the movement of birds in their migratory patterns, and changes in population and construction on campus, GIS-based data is in constant flux. Geo-crowdsourcing offers a way for such dynamic information to be managed within such change, and to meet the demands for use within the environment. There are many relevant cases in which not only the use of VGI is a best fit, but the need for specialized training in order to improve the quality of participant input is also considered in many of these studies.

Today, VGI continues to evolve from this growing interaction of citizens and the web. Waters (2014) notes that some websites gauge the importance of networks based on influence and reach while others, such as Kred and Klout, stress the connections of the network as a whole and its nodes, or individuals. Social network studies and network science have splintered into many categories besides geospatial, topological, economic, marketing, computer science, network mining and cyberpsychology. Each specialty has its own journal or annual workshop featuring new ideas of interest. Yet geography and distance will likely continue to play a role in regional science that includes social network analysis (Waters 2014).

Because VGI can bring together large quantities and types of data that have never been available to the mapping community beforer web 2.0, it has great advantageous application in today's fast-paced world of continued change. Collection of data in this manner can be inadequate for scientific purposes due to its variable and undocumented quality, the failure to follow principles of sampling design and incomplete coverage. Instead, vast amounts of citizen science data can contribute to early exploratory and hypothesis-generating stages of science, and could be of great benefit if its quality could be assured (M. F. Goodchild and Li 2012).

Recently applications for a large number of interests in science have developed that allow for crowdsourcing at a level of detail much greater than could be done a decade ago. Citizen science can provide millions of data entry points to a specialized dataset in a matter of months that would have taken a team of professional scientists years to accomplish without the volunteer component. Scientific American hosts a site supported by FeedBurner™ that allows input for citizen science of more than 50 different ongoing projects, depending on one's interests (Greenemeier, Larry 2011). Some of the projects were selected, listed and summarized in the table that follows (Table 1). Selected projects relate to geospatial types of crowdsourcing with some degree of similarity to this study. Some projects offer online training or other methods of screening before participants can sign up.

Table 1: Citizen Science selected projects (http://www.scientificamerican.com/citizen-science)

Project Name	Category type	Principal Scientist	Description	Location/ Site
Frog Watch USA	More Science	Paul Boyle	Volunteers learn to identify local frog and toad species by their calls and report their findings to gain increased experience and control over asking and answering scientific questions which, in turn, augments science literacy, facilitates conservation action and stewardship	FrogWatch USA
Old Weathe r	More Science	Philip Brohan	means of better understanding historical weather patterns worldwide.	UK National Weather Service

Wisconsin Bat Monitoring Program	More Science	Jeannette Kelly	Volunteers assist Wisconsin Dept. of Natural Resources with the program, using AnaBat detection systems, the "Bat Monitoring Kit," for up to three nights to conduct bat surveys of local parks, neighborhoods, lakes and trails. The AnaBat is attached to a GPS-enabled personal digital assistant, and picks up the echolocation calls emitted by bats	Wisconsin Dept. of Natural Resources
Cornell Lab of Ornithlogy eBird	More Science	Janis Dickinson	An on-line checklist project where you can enter and store your bird observations in a central database, track your personal records, and share your observations with other birders and scientists. Cornell also provides graphing, mapping and analysis tools to better understand patterns of bird occurrence and the environmental and human factors that influence them.	Cornell University
Project Budburst	More Science	Sandra Henderson	BudBurst participants observe on a regular basis and record in a field journal (pdf) they download from the BudBurst Web site. Observers are asked to describe the site they are monitoring in terms of proximity to buildings, presence of asphalt surfaces, slope, sunlight and irrigation (Voluntary training offered online is available as informative)	ProjectBudburst
Invaders of Texas	More Science	Damon Waitt	Identification and management of non-native invasive species in Texas in which citizens can join the team must attend either a workshop or complete online training in the use of GPS as well as identification of species	Texasinvasives.org
Did You Feel It?	More Science	David Wald	Geological Survey (USGS) to tap the abundant information available about earthquakes from the people who actually experience them. By taking advantage of the vast numbers of Internet users, USGS seeks to get a more complete description of what people experienced, the effects of the earthquake and the extent of damage.	USGS
Marine Debris Tracker	More Science	Jenna Jambeck	to spread awareness of marine debris, as well as serve as an easy-to-use and simple tool for marine debris data collection. debris tracking might take place in remote areas or even on the water, where there is likely no WiFi or even a cell signal, citizen scientists can log and track as many items as they want and store this info in their smartphones until they return to a place where they can wirelessly submit their findings.	NOAA Marine Debris Division

Roadkill Survey for Road Bikers	More Science	Gregg Treinish	citizen scientists help researchers understand where wildlife live and the threats they face from (mostly) human activities - if you can't identify an animal to the species level right away. A picture will help researchers	
Safecast	Technology	Sean Bonner	measuring radiation levels and making the data available to the public through maps, a Web site and data feeds to citizens, scientists and the public. Safecast is releasing data openly and pushing the Japanese government as well as universities and researchers to share their medical, sensor and other data	Keio University, Japan
The Quake Catcher Center	Technology	Elizabeth Cochran	a collaborative initiative for developing the world's largest, low-cost strong-motion seismic network by utilizing sensors in Internet-connected computers. Volunteers can help provide better understanding of earthquakes, give early warning to schools, emergency response systems and others.	University of California
Zooniverse Cyclone Center	Technology	Chris Hennon	Volunteers will be shown one of nearly 300,000 satellite images and answer questions about that image as part of a simplified technique for estimating the maximum surface wind speed of tropical cyclones. This collaboration will result in a new global tropical cyclone dataset that provides 3-hourly tropical cyclone intensity estimates, confidence intervals	CycloneCenter.org
Nature Mapping	Energy & Sustainability	Karen Dvornich	NatureMapping's mission is to protect biodiversity through data collection and dissemination. It is designed to engage citizens of all ages in hands-on, technology-enabled exploration of our natural environment	13 states: NatureMappingFoundation.org
Ventus Project	Energy & Sustainability	Kevin Gurney	Information regarding where the world's power plants are located and how much each one is emitting is not well-known outside of the U.S. Citizen scientists can provide the exact coordinates of a single power plant, correct the location of one already identified, or provide information of not only location, but power generation, fuel type and CO2 emissions	http://ventus.project.asu.edu/#
Redwood Watch	Energy & Sustainability	Ruskin Hartley	Redwood tree observations can be made anywhere redwood trees are found and recorded using the Redwood Watch iPhone application. By submitting observations citizen scientists will help their professional colleagues track the migration of redwood forests over time and learn what climate redwood trees can survive.	

How Radioactive is our Ocean?	Health	Ken Buesseler	There currently is no U.S. or international agency monitoring the arrival of radioactive water from Fukushima along the West Coast. Citizen scientists can provide support directly to work being done at one of the locations listed on their Web site.	Woods Hole Oceanographic Institute: ourradioactiveocean@whoi.edu
Meteor Counter	Space	Bill Cooke	With each keytap, the Meteor Counter app records critical data such as the time, the meteor's magnitude and location. Users can also turn on an optional voice recorder to capture your own description of events.	NASA Meteoroid Environment Office
Loss of Night	Space	Franz Holker	Light pollution has intensified, impacting humans and the environment. While investigations have narrowly focused within astronomy, this project helps scientists measure and understand the effects of light pollution when citizen scientists identify visible stars in the sky and contribute to a database for research on health, environment and society.	

2.2 Training for Participants

Some projects found in the *Scientific American* website (http://www.scientificamerican.com/citizen-science/) and listed in Table 1, offered training to familiarize participants with either the use of an application (website or downloaded app) or with specific attributes that they would identify, such as type of frog or road kill animal, or a description of damage from an earthquake. The training was voluntary on the websites found, not required for participation. Because of the difficulty in having untrained or lightly trained end-users participate in data collection activities that require knowledge of geo-referencing or object attribute definitions, some projects have developed their own training systems (Foody et al. 2013, Galloway et al. 2006). Some training may be similar to existing citizen-science training systems, while others are more specifically oriented to geographic data collection and the use of technical equipment (park service GPS units, for example).

One study that involved training was done with groups of school age children trained to identify Oregon White oak trees (Galloway et al. 2006). The training was for one hour, for students in grades 2-5, and 6-10. Using images, students were trained to identify tree types, trunk size and canopy shapes and report this data on field forms. Reports from student groups were compared to a selection of professionals who also identified the trees within some of the same transects as the student groups. Although benefits to participants in such a program are evident, benefits to resource management is dependent on data reliability. Interestingly, this study found that when students documented certain tree types, they might have exaggerated results in some instances. For example, students counted more pines (n=11) than did the professionals (n=4) on the same 22 transects that were checked. The sample size in this case was too small to allow for testing. Despite otherwise consistent tree counts between students and pros, the “disparity in pine counts is important” and that “because of the uniqueness and larger size of pines in the study area, students may have altered the survey transects to include pines. Students may feel it is important to document a unique or rare item without understanding how this kind of selective sampling can bias a data set.” (Galloway et al. 2006, p. 1427) Training given to students in this type of work required a focus on the importance of surveying and sampling methodology in order to minimize errors.

In another study, Fowler et al. (2013) found citizen data tends to be fairly accurate if one is able to verify by revisiting points of acquisition. Such verification tends to be more challenging when the data is short-lived, or fleeting, as in the case of condensation trails in the atmosphere. Here, the authors indicate that training can contribute to improved accuracy in both identification and location of attributes that are more stationary such as invasive plants. In assessing the quality of climate data observations made in this study, verification of VGI against existing scientific knowledge and datasets is used, as suggested by Goodchild (2007). Due to the complex nature of the atmosphere, a methodology in Fowler's study consisting of spatial, temporal, and altitudinal components was included for analysis of results. Verification studies of the volunteered data sets were then completed (Fowler et al. 2013). In this thesis study, the subjective nature involved in obstacle identification faced a similar challenge requiring the need for several cirteria to complete the moderation and verification for final quality assessment of reported data.

Powell et al. (2013), in a study involving the GeoExposures web site (http://www.bgs.ac.uk/citizenScience/geoexposures.html) launched in 2011 in the UK, showed that using volunteer participants could enhance the knowledge base of a geological community. While the British Geological Society is the main repository for UK's geoscience data, it has limited statutory rights within the government. The Society can be greatly assisted by interested participants who, after making observations, place images and data on the GeoExposures web site, which is supported by Creative Commons license. Temporary exposure of rock, soil or other interesting phenomenon otherwise lost to science, can be captured by an image or recording (Powell et al. 2013). In this example amateur citizens with an interest in the topic of geology could contribute to a dataset even without training. Those with an interest and perhaps some background knowledge or previous training in geology, can provide recognition of rock or soil outcrops and lend sufficient expertise to the base information being sought.

One advantage of crowdsourced geographic data is the repeatable nature of observations used for cross-validation, such as video recordings made of the Wenchuan earthquake in May 2008 (Yang and Wu 2012). Such recordings are considered less biased in their viewpoint compared to most media broadcasts. The drawback of such datasets is their lack of reliable geo-referencing. With proper guidance to include location and time of input data, citizen recordings of this type are helpful in disaster management and scientific investigation of macro-seismology, as noted by Yang & Wu (2012). This supports the idea that a component of education or training of participants in geo-crowdsourcing improves datasets.

Many examples of the use of VGI and web 2.0 to increase the collection of scientific and geospatial datasets point the way to continued and emerging changes within communities. Citizens who are involved in reporting data feel more connected and invested in their surroundings. Areas in which a person works, resides or frequents are naturally areas of familiarity and so citizens render a level of expertise. Those familiar with their environment tend to deliver higher quality results with fewer errors in data acquisition and fewer problems with ambiguities (Heipke 2010). Their contributions can likewise result in a sense of satisfaction. Adding a simple but effective training program for citizen volunteers would likely increase not only citizen benefits but also the reliability and trustworthiness of the data being submitted. With limitations in funding and time for government agencies to provide needed geospatial data, an increase of reliance on VGI for some emergency or every day management seems practical (Coleman et al. 2009).

2.3 Participant Issues

Citizens motivated to participate in a study will sometimes bring their own set of problems to the work, either due to lack of skills, or possibly malicious intent to fool the study. Participant problems can be simple to fix and may be temporary. Regardless of the underlying reasons, the problems brought into crowdsourcing are likely as varied as the personalities of those involved. In addition, there can be difficulties with software being used, a lack of consistency with Internet connections to enable reliable participation, or even some oversights in requirements to set up a project, such as permissions, waivers, or field forms required to get the work done (E. H. Dunn et al. 2005). Although Wikipedia is an excellent model for crowdsourcing and the world's largest encyclopedia, early episodes of malicious content caused a drop in their reputation. The more mature, current version of this online source has found a good balance between open editing privilege and the ability to rapidly detect false or erroneous content that could be harmful. Wikimapia has similarly developed methods of detecting and preventing vandalism on their site (Nkhwanana 2009, Ruitton-Allinieu 2011, Rice et al. 2013).

Martin's (2013) funded program for debris removal from Georgia shoreline vicinities in order to improve sea turtle habitat illustrates an example of training to improve CGD, but also discusses some problems encountered. With a grant from the National Oceanic and Atmospheric Administration (NOAA) Marine Debris Division and the Southeast Atlantic Marine Debris Initiative (SEA-MDI) the Marine Debris Tracker application was developed to log debris removed by volunteers. The 2012 portion of this project was designed to educate children and public about the harmful effects of marine debris and to involve volunteers in the collection of data about debris. Citizens were able to use the app in order to list type, quantity and GPS location for each piece of debris collected. The educational component of this study had two targets: to improve the process of using the app in their work, and to aid in the prevention of further pollution. Once recorded, focus was on the tabulation of collected debris by type, and number of volunteer hours. Volunteer participation extended outside the state of Georgia due to interest, to include four other states, enlisting 15 established volunteers and 216 episodic volunteers in total. Of the thousands of pieces of debris listed as removed, some pieces were not logged due to a variety of difficulties. Some volunteers used different usernames than the one assigned, or failed to log all data collected. Some volunteers were unsure of how to use the app. By using the same people to train volunteers in use of the app, some inconsistencies were removed. Starting in the second year of the study, Martin's team expanded efforts toward further education of the public (Martin 2013).

A study by McClendon and Robinson (2013) that considered social media sources of input for geospatial information did not address the element of training. This study was considered relevant in its potential use of CGD for disaster information, as well as aspects of accuracy and management of incoming datasets. The researchers considered how information was collected, processed and geo-located with Tweak the Tweet (TtT) and Ushahidi during 2010 Fourmile Canyon fire, 2011 Joplin tornado, 2010 Haiti earthquake, and 2010 Gulf oil spill. Ushahidi is a non-profit software company (http://www.ushahidi.com) that began in 2008, developing free open-source software for collection of information, visualization and interactive mapping (Wikipedia 2014b). Ushahidi has gained use since its entry during a Kenyan election in 2008. It had first been used for election results, reports of abuse, and disaster updates. The platform provides interactive mapping services combined with the ability to capture real-time data streams from Twitter as an example. Ushahidi also provides SwiftRiverPlatform, http://www.ushahidi.com/product/swiftriver that allows filtering and verification from multiple data streams, and the Crowdmap, http://www.ushahidi.com/product/crowdmap a cloud-hosted mapping solution designed to support rapid launches of both of these platforms (McClendon and Robinson 2013). Such a study suggests that the direction of VGI is related to how the technology is made available, particularly when open to all end-users capable of access and use via the Internet.

The difference between PPGIS and VGI, according to Brown (2012b), is in its purpose or motivation, since PPGIS projects are developed to inform policy and planning in an area while VGI may have no other purpose than individual enjoyment, even though both are voluntarily carried out. Despite the potential advantages, government adoption of PPGIS has been reluctant due to mistrust of such data. Stakeholders and others vested in planning outcomes have traditionally controlled regional and environmental planning decisions in developed countries. Because the planning processes can be very technical (town, regional, public lands and environmental levels), these regional and environmental bodies rely on technical assessments of land capacity and probabilistic forecasts. So the question that arises is what can an individual possessing lay knowledge and understanding of a place substantially contribute to the process? Brown argues that PPGIS can provide understanding of place from the lived experience, providing unique knowledge that is “earned rather than learned" and supplies a built-in check and balance to expert and vested interest assumptions on planning outcomes (Brown 2012a, p. 7-8).

Studies that benchmark accuracy in PPGIS data have not been done, and the mere perception of inaccuracy undermines its acceptance. Brown (2012b) completed a 3-million hectare study in New Zealand's Department of Conservation (DOC), utilizing public GIS techniques. Data collection by the participants included two components: attribute mapping using a custom Google Maps application, and survey questions that addressed familiarity with areas in the region and some socio-demographic points. Participants were instructed to drag and drop markers into the map to represent attribute locations of 30 different landscape values. Among the list of values was native vegetation. Placement of this attribute was the target for statistical analysis. PPGIS results were compared to expert-driven Land Cover Database (LCDB) of New Zealand. In general, an error rate of about 6% or less was found in identifying native plants, compared to an expected error, by random chance, of 22%. A key factor in explaining the results was participant familiarity with the region (Brown 2012b).

A similar finding in an earlier study of PPGIS done by Brown and Reed (2009) indicated as well that those familiar with the region identify more attributes than less familiar participants (Brown 2012b). PPGIS taps into a deeper indigenous knowledge of place, with an understanding of culture and value rather than technical knowledge or scientific knowledge. It may not fit neatly with the demands of GIS, but it is a fuzzy, emotional, yet holistic and consequently useful spatial knowledge base (C. Dunn 2007).

One issue that has been surveyed is in regard to completeness of coverage. In Haklay's (2010) study, since OSM coverage relies on participant choice of area to cover, deprivation will be found to influence data collection. It also means that errors will not be randomly distributed within a dataset (M. Haklay 2010). Of course, this can enter into any VGI dataset, since the primary incentive for most participants is based on the voluntary aspect, which entitles one to choose the area, the time and the extent that is given to the activity.

Foody's (2013) study recognized the need for land cover details as a component to geographic information, and found validation of such information crucial to the usefulness of maps generated. Land cover is critical in its influence over both environmental and human systems, and so contributions of crowdsourcing to map validation is very constructive and cost-effective for the community in which VGI is made active. Despite the benefits of VGI, its acceptance into the field of science is sometimes hesitant due to its unreliability. VGI can be inconsistent in its accuracy. Participants themselves differ in their expertise and ability, but sometimes deliberate inaccuracy and malicious intent can be entered into a study. Foody's study explores accuracy of VGI by using a Geo-Wiki application and a series of satellite images, asking that volunteers identify land covers. Professionals collaborated to complete ground reference data for verification. Out of the

65 volunteers, 229 data points consisting of 10 different land covers, volunteer data that were most thorough were selected along with unbiased data points to develop a matrix for statistical analysis. Completed analysis using latent class models provided a way to estimate the accuracy of volunteer data sources without reference data. This provided useful information on the quality of VGI, and also characterized performance of each volunteer based on specific and overall accuracy. Sources of variation in accuracy among volunteers were attributed directly to differences in background education, skills and experience (Foody et al. 2013). The identification of such accuracy levels in volunteers can point out those volunteers who would benefit most from training as well as those most suitable to use in future studies.

Validity of PPGIS data generally depends on participation rates and the quality of the data. Spatial data quality depends in turn on precision and accuracy of attributes being placed on a map. Precision is the exactness of such placement and is therefore dependent on marker size, map scale, participant's physical dexterity and acuity. Accuracy is how well the marker represents the true spatial dimensions of an attribute and is influenced by the quality of the mapping environment including clarity of map features, scale, and participant familiarity with the landscape of the study area (Brown 2012b).

One praactical drawback of PPGIS is that regulations, as those in the US, can thwart participation and even give disincentives for agencies to engage in PPGIS. Following a formal request from the US Forest Service for assistance to use PPGIS in national forest planning, for example, has been delayed over three years as the request is being denied by the Office of Management and Budget, (based on communication with P. Reed) (Brown 2012a).

Citizen science assessment and monitoring of large-scale data with temporal and spatial assets can be helpful for use in decision-making, management and predictive models on many levels. Weaknesses in crowdsourcing projects can result from lack of training, or non-standardized methods of data collection. A study of Queensland Coral Watch proposes the use of social network analysis tools to infer reliability of data based on reputation of a contributor (Alabri and Hunter 2010).

Although researchers have used this approach of a reputation model in the context of web based data, it has not been applied to citizen science data. In order to develop a reputation model for a study, several objectives needed to be considered: citizen registration, profiles, backgrounds, training, frequency of contributions, length of time of involvement, ranking from other members in the study, etc. A process to identify and optimize a reputation model in order to filter unreliable data is described in this project. It is possible to significantly improve the trustworthiness of citizen science by the use of a range of technologies in data quality. Social trust and online reputation fields can help maximize the quality of citizen science. In their study, the researchers developed a table of sixteen quality-related factors such as timeliness, ease of manipulation, objectivity, and other metrics. Such methodology for evaluation of data using a reputation model can facilitate the detection and correction of simple errors (Alabri and Hunter 2010). Reputation data models were not in fact used in the path accessibility study for the GMU campus environment, yet other quality-related factors were used to enable researchers to complete needed assessments of reported data. If the project were to expand a great deal, use of reputation models might be an interesting endeavor to increase the quality of datasets.

2.4 Progress and Improvements

Efforts to move citizen science in a positive and useable direction are continuous, and will therefore result in solutions, over time, as an emergent process. Many of the innovative ideas that are practiced by smaller communities, progressive government bodies, or citizens facing an emergency in their own town, will shape the future of this science as it evolves and continues to be adapted to the needs and demands that arise. GIS is no longer for the specialists that have been trained, but has entered the realm of crowdsourcing, where large groups of users can perform functions that are either too expensive or too difficult to automate (M. Goodchild 2009, M. F. Goodchild and Li 2012). Of course the nature of this work is *voluntary*, so includes no contract or obligation and likewise, no quality assurance. Many participants are not versed in data collection standards, verification or use. Naturally, questions arise regarding quality of the volunteered information (C. Dunn 2007).

A study by Haklay (2010) compares the accuracy of VGI found in OpenStreetMap that began in London in 2004, to the Ordnance Survey (OS). The comparison of geospatial datasets between OSM and OS takes into account not only positional and attribute accuracy, but also completeness and lineage. OSM is licensed under Creative Commons (CC) in a copyright scheme that allows participants who are registered with the site to view and edit in a lightweight approach that works within a browser. CC continues to change through various updates of its licensing such that a combination of tools and users provides a vast and growing content that can be edited, distributed and built upon within copyright law boundaries. The OSM project has been able to produce a high-quality product from a small core group of highly skilled contributors coupled with a large user community that may often lack formal training in geospatial technologies (M. Haklay 2010). "The OSM products, produced in a crowdsourced framework, are similar in quality to many commercial products and because of their licensing framework, provide a good source of base map data for many other open-source projects" (Rice et al. 2012, p. 105).

Participants with OSM organize local workshops (known as mapping parties) giving hands-on experience to newcomers while providing general project coherence. In order to maintain *its* internal standards, Ordnance Survey considers a certain percentage of digital map units in terms of completeness and temporal qualities, while positional accuracy is evaluated in a separate process. Haklay's (2010) study shows that VGI can achieve good spatial quality, can be done automatically by untrained persons with little investment, and can be done in little time. Within a short period of time a team of 150 volunteers and minor help from 1000 others collected data for about one-third of England (M. Haklay 2010).

Perfect measurement is not possible, and even GPS offers citizens a 'worst case' pseudorange accuracy of 7.8 meters with a 95% confidence level (http://www.gps.gov/systems/gps/performance/accuracy/). Increased accuracy can be achieved, depending on conditions. In order to be useful, maps must be transitory to keep up with changes in landscape. How people think about space is not in terms of latitude and longitude or other metric distances as much as it is of vaguely defined places, with names and vernacular. The gazetteer is an exhaustive and authoritative collection of place names that are geoparsed to their locations. The most common way to represent a location in this type of database (gazetteer) is by a single location using coordinates. A building would be named (Johnson Center) and the coordinates of its center would become its location in terms of coordinate position on a map, even though the building is represented by a larger polygon of space on the map. The gazetteer is a somewhat hybrid tool used in crowdsourcing because it offers a link between the recognized name of a place, including vernacular (such as 'JC'), and the precise spatial location. (Rice et al. 2012, Rice et al. 2013)

OpenRouteService (ORS) (http://www.openrouteservice.org) is much more than a routing service. Although it uses OSM based data, ORS can be used for other applications, such as emergency routes, and in many different scenarios. It includes an accessibility analysis, which can calculate the time it takes to reach an area within a polygon specified on a map, for example. ORS was created from OSM data initially and developed by Pascal Neis in 2008 (Wikipedia 2014a). This technology could be most useful in supplementing the application of crowdsourcing by offering a variety of ways to view and analyze datasets. Amelunxen (2010) carried out a study of ORS positional accuracy compared to that of Google in positioning of houses based on an exact house number match. Using ORS, the study was able to achieve a positional error of 11 m (n=13,283) compared to Google's 32 m error in the same area. No other geocoding service could provide accuracy even close to the extraordinary value according to this study (Amelunxen 2010). As the activities of VGI have moved more into the realm of web 2.0, potential for change in application, availability, adaptation will continue to expand and develop new applications.

VGI and crowdsourcing studies, including PPGIS, all agree on at least a few things. Foremost among the agreed-upon principles is that VGI can benefit one's community. Although it might be difficult to measure in terms of accuracy or monetary benefit to the community, it is evident that the trend made possible by web 2.0 is moving forward. Anyone can publish or broadcast on the web in this information rich society, but no one user or group can digest it all. Large numbers of sensors can help to filter out the 'noise' of misinformation, bias, and trust issues, leaving behind the relevant correlations of data with which decisions can be made (Boulos et al. 2011). Determination of the influence of training for CGD applications or VGI, as this study considers, is a necessary part of the process in furthering geospatial studies. Because VGI, PPGIS and CGD often, and now more than before, move geospatial rendering of datasets into the hands of unknown, different, sometimes unreliable participants, some concerns and questions will arise. The questions address how to ensure the empirical, rational and sound science behind the activities of the crowd. If specific carefully focused training results in better quality VGI datasets, increased trustworthiness and reliability, then this body of science advances. If such training is found unnecessary and does not have an influence on such datasets, then our focus and efforts can be best utilized on other questions that lead to continued progress in related areas in the field of VGI.

CHAPTER THREE: METHODS AND PROCEDURE

3.1 Study Site Establishment

Since 2010, a team led by Dr. Matthew Rice, has developed a testbed environment for crowdsourcing to enable the collection and evaluation of geospatial data on the GMU campus (Rice et al. 2013). Work began with the development of conceptual models, the development of tools within an interactive website, and training to facilitate both the modifications and usability of the tools, the website, and the general testbed environment. End-users included students, faculty and community members, who are also members of the disabled community. George Mason is the largest university in the state based on students enrolled, and in 2013 this included 1000 members registered as disabled by the Office of Disability Services. (These might be temporary or permanent disabilities.) All members of the campus would benefit from knowing in advance about pathway obstructions. In the case of the disabled, pathway obstructions pose more than an inconvenience. Some key concerns of end-users to provide geospatial data to the campus network are outlined in Table 2.

Table 2. Key concerns of the community of end-users to provide path access data

√	the campus accessibility map (Fig. 13) is updated once per year and is otherwise static.
√	some campus infrastructure, e.g., sidewalks, entryways, exits, and door openers, have problems that impact accessibility
√	temporary equipment or structures such as tents and electrical equipment or conduits across walkways, can introduce hazards to the disabled or others on campus
√	construction detours may require longer routes or unsafe detours into streets
√	poorly-designed curbs, corners, or other structures that need to be remodeled or changed
√	general poor surface conditions, such as large gaps or cracks in walkways, steep but poorly graded surfaces
√	weather-related issues such as mud, ice, or standing water

Based on user needs assessments and the outlined requirements in Table 2, a system was designed to facilitate reporting of various transient obstacles related to sidewalk obstructions, detours, crowds or temporary structures, bad surface conditions, and entrance or exit issues. Reports by end-users depended on availability of mobile computing devices, and ability to accommodate desktop or mobile screen sizes. Images and documentation of the most common issues were gathered for use in training and informing project contributors. Recruitment of initial end-user participants was done within the campus community (staff, students, friends and family from within the closer network of the Department of Geography and Geoinformation Sciences) in order to test the tools, software and general environment (Rice et al. 2013). The interactive web map was designed to fill a gap in assistive geotechnology. The Personal Guidance System or GPS apps for the disabled, are not only more closed from interaction with the community, but also are more static. The focus for Rice et al. in this VGI project is one of analogous applications with altruistic benefits.

Throughout the project's development, images, descriptions and data about each obstacle were stored, categorized, and reviewed extensively by Rice and his team of researchers. The web application and its accompanying code serve as both a collection tool and viewing and management tool for moderators. The website created for this project, http://geo.gmu.edu/vgi, was the main technological tool used. The expanded role of quality assurance methods has become more robust and thoroughly documented with the continued progress of this overarching project. Rice and his team designed the map interface with functionality influences from Waze, OpenStreetMap and SeeClickFix. Use of open source software was a key component to permit frequent updates of temporary obstacles in the public rights-of-way.

The system developed by Rice et al. focused on integration of VGI with assistive geotechnology using a detailed gazetteer. In fact, the two most important functions of this system were indicated as: (1) the ability to identify the use of place names within VGI; and (2) the assignment of metric georeferencing to volunteered content through the use of a detailed local gazetteer (Rice, Aburizaiza, et al. 2012).

Most people rely on place names for geographic orientation, and few have sufficient understanding of metric georeferencing systems. Use of VGI, geoparsing and georegistration algorithms has been central to the text-based descriptions of obstacles that make up most of the reports in the datasets for this project. Assignment of metric georeferencing to volunteered content was possible with this gazetteer. It has evolved to include over 1200 separate geographical entities in a 2 square-mile area within the George Mason University campus. Former, abbreviated, vernacular and official names for buildings, streets, sidewalks, squares, parks, landmarks, neighborhoods, and other miscellaneous features are cross-referenced in the local gazetteer, in order to include all variations and languages in names for places (Rice, Aburizaiza, et al. 2012).

Dr. Rice, Fabiana Paez, Han Qin, Rebecca Rice, Christopher Seitz and others developed the testbed environment on the campus previous to this study. Their work established not only the gazetteer, but the main tool as an interactive web map and a training powerpoint for use in recruitment of participants (Rice et al. 2014), moderation tools as part of the web map, a database of verified obstacles and a system in place of how to carry out continued research of this VGI application.

3.2 Sampling Methods

With focused training for participants, it was hypothesized in this study that data entry by trained volunteers would be significantly more accurate both in position and attribute identification than similar data by untrained volunteers. Data entry by trained individuals was not expected to be statistically different from those of professionals, or as compared to verified data points by well-trained researchers.

Because sample population selection is of critical importance in scientific research in terms of testing sample results, some flaws are worth mentioning. First, the understanding that the 'sample' was selected from students enrolled at GMU for the semester who were available to complete a consent form connected with the study. Individual forms were filled out and signed by students interested in participating. This was a sample of convenience, or accidental sampling, and therefore introduced volunteerism, given that some could decide not to participate. While the hope was to have a group of about 15 students for each of the two treatment groups, the sample selection did not meet this expectation. In order to extend the invitation for this study to the entire campus or even beyond the campus, a much greater time commitment and level of management logistics would have been required to broaden the reach for participants. Such demands in researchers' time could not practically be met. This brings up the second concern with the sampling method.

Based on a 2010 article written by Joseph Henrich called "Most people are not WEIRD," it was pointed out that Western, educated, industrialized, rich and democratic (WEIRD) societies are in fact psychologically unusual. Generally, research on humans assumes findings from one population apply across the board, and that everyone shares the same conginitve processes. In fact, a 2008 survey found that 96% of subjects used in multiple types of studies were from countries where only 12% of the world's population resides. Variations that would play a role in this research fall into domains such as visual perception and analytical reasoning. While it was found that most Western cultures rely on analytical reasoning strategies which separate objects from context, Asian populations take on a much more holistic approach. One suggestion from this article was to evaluate how findings can apply to other populations (Heinrich et al. 2010).

A closing thought on the sampling method comes from Brown, as he relates to PPGIS: "The biased composition of PPGIS participants is a persistent critique that is difficult to rebut. And yet, PPGIS results are still likely to differ from outcomes advocated by interest groups and government agencies working without the benefit of PPGIS because the data are more socially inclusive, even if proportionately unrepresentative." (Brown 2012a, p. 13)

3.3 Methodologies

The current study to assess the influence of training on accuracy of object location and description continues the development of end-user interfaces and VGI tools developed in previous work by Rice and his team of researchers. An initial application for this project was submitted to the Institutional Review Board (IRB) along with IRB training of researchers in early February. Revisions of the application followed, and GMU Office of Research Integrity and Assurance (ORIA) granted expedited review with approval for the project on March 13, 2014.

Selection of participants was based on enrollment in a GIS class whose professor was willing to assist in making his students available for this study. Of those selected, half were randomly signed up to receive training, while the second half of the group was not trained. Training consisted of two activities within the classroom setting: a presentation with instructions about the web-based campus map created for the test bed environment (Rice et al. 2014), including all steps to record data for an obstacle, sample images of several obstacles that could be found on walkways, and a written exercise for practice in using obstacle categories like those found on the map interface.

During the presentation and recruitment, participants signed up for a 30-minute block of time to complete the activity in the field. All work took place on campus over a time period of about one hour in total for participants, including training and time spent for recruitment. Participants walked along a defined path on the campus, where at least 11 or 12 features, or obstacles could be found. Participants only needed to choose 3 or 4 obstacles within the path to report. This was done on an individual basis, so that corroboration or discussion among participants did not occur.

Two researchers met each participant at the time for which the student signed up. An iPad was provided, with the map interface pre-loaded, and cleaned of any previous objects, reports or pictures. One researcher accompanied the participant on the route for obstacle reporting, in the event of any questions or need for technical support.

There were five main types of obstacles (see Figures 1-9 for some examples), including a category for 'other,' which allowed participants to identify something outside the five types. Participants found an obstacle on campus, completed a report about the obstacle's potential hazard, duration, and descriptive text in regard to its characteristics. An icon (L) on the web application was dropped on the map location of the obstacle, and images were taken and submitted along with the digital report. While participants were encouraged to use the camera app on the iPad to upload images to supplement their reports, some did not attempt this. See figures 10 and 11 for images of the interactive map (http://geo.gmu.edu/vgi). A participant could access this web site on an iPad, or with a personal mobile device, such as an iPhone. Due to greater ease of use, and for consistency, only the iPad was used for this study.

Once finished, students completed a feedback survey of 6 questions regarding ease and usability of the interface.

"Geo-crowdsourcing to Support Navigation for the Disabled" was the power point presentation developed by Dr. Matt Rice, Fabiana Paez, Rebecca Rice and Patricia Pease in Spring 2014, based on research done within the past year. The presentation illustrated four kinds of attributes to be found within the campus area and located on the web page for this research. Obstacle attributes include its position as determined by X Y coordinates on the map, the obstacle type (5 types), duration (short, medium, long), and priority or urgency of the obstacle (low, medium, high). Examples of obstacle types are illustrated in the figures that follow. Obstacle types, duration and priority are reported based on choices shown in Table 3 (Rice, Matt; Paez, Fabiana; Rice, Rebecca; Pease, Patricia 2014).

Table 3. Choices embedded in web tool to report obstacle identification

Obstacle type	**Duration**	**Priority**
sidewalk obstruction construction detour entrance/exit problem poor surface condition crowd/event other	Short < 1 day	Low: small inconvenience
	Medium 1-7 days	Medium: high inconvenience, small hazard
	Long > 7 days	High: threat to safety

Figure 1. Taken from the training power point, this example illustrates choices to correctly identify an obstacle type, its duration and priority

Figure 2. Example of a poor surface condition

Figure 3. Example of an event or obstacle of short duration, < 1 day

Figure 4. Sidewalk obstruction on campus of short duration

Figure 5. Path obstruction of short duration.

Figure 6. Sidewalk detour or construction obstacle

Figure 7. Mobility impaired issue at entranceway

Figure 8. Possibly inoperable entrance button

Figure 9. An event or crowd that changes path accessibility

Selections made for each choice appear in the web site shown in the next images, where some flagged objects are shown, and space to enter object descriptors is provided (Figures 10 and 11).

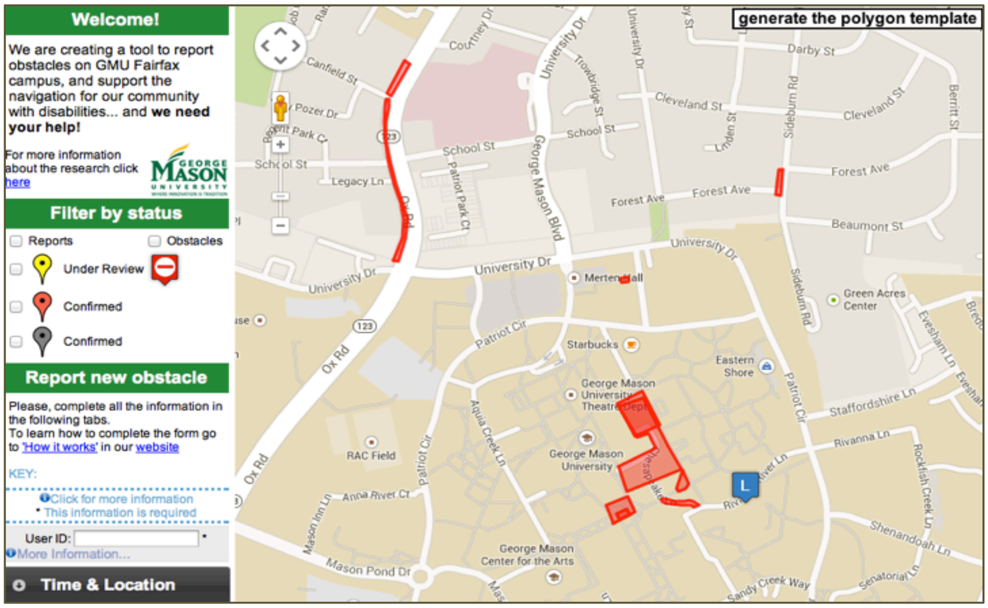


Figure 10. Interface of web map (http//:geo.gmu.edu/vgi) where an end-user would begin to enter obstacle report data. Blue 'L' icon is moved to location of obstacle

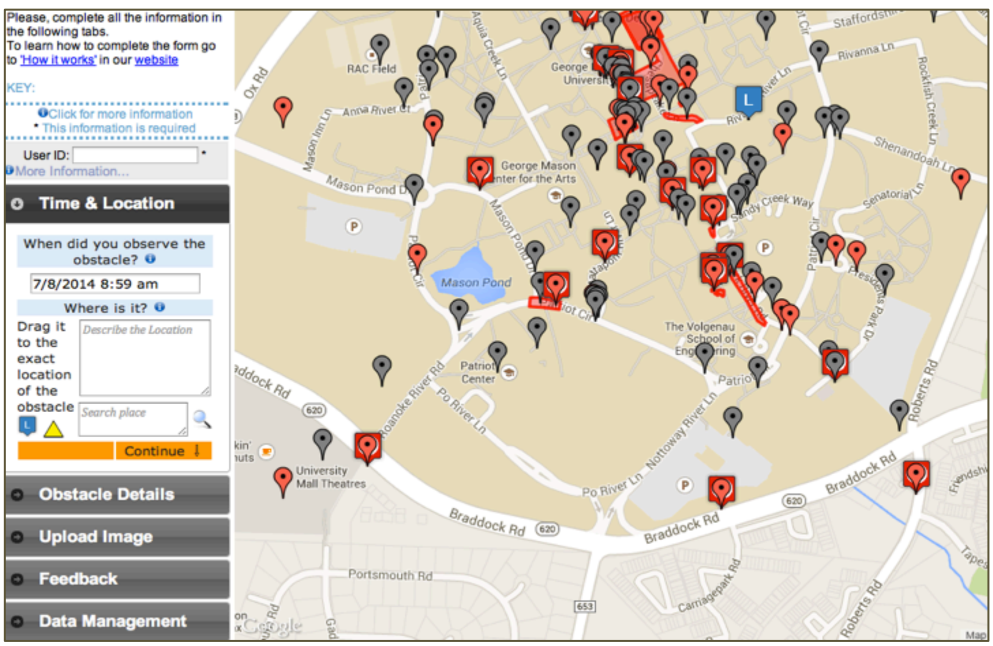
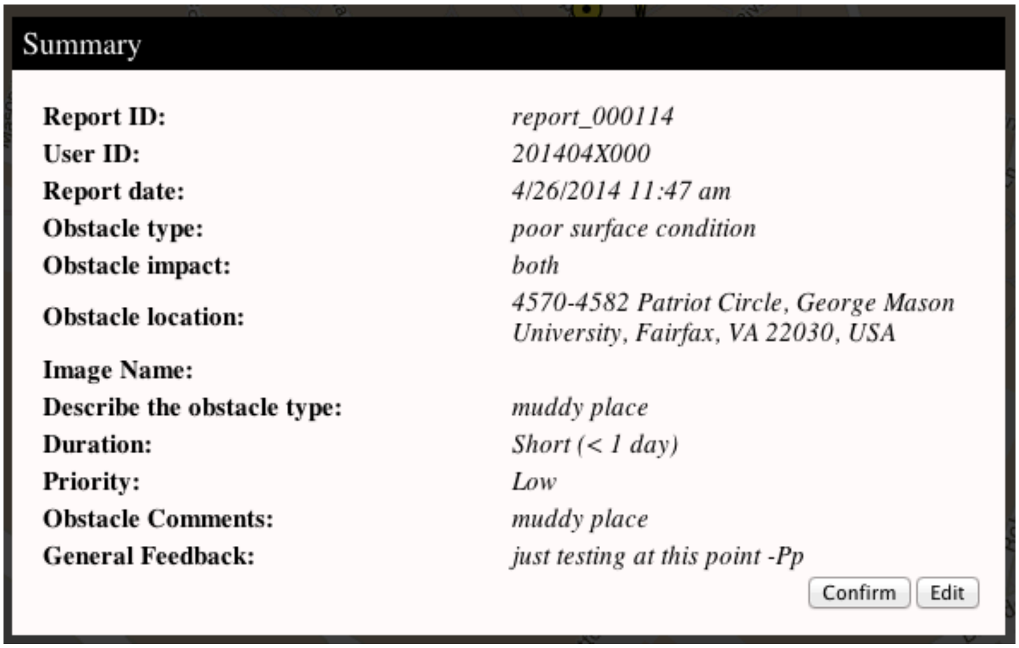


Figure 11. Another view of web map, showing several reports (confirmed) as well as known obstacles. Report details are entered in tabs shown along left column.

When report data was entered, a chance to edit before submitting was provided to end-users. Figure 12 illustrates the choice to 'confirm' or 'edit.' The confirm button uploads the report data to the management end of the system, where researchers conducted extensive moderation, confirmation and verification of data. Before an obstacle was confirmed and placed on the map as a known obstacle, the process required careful field checks, and comparison to known values of existing data.


Summary

Report ID:	*report_000114*
User ID:	*201404X000*
Report date:	*4/26/2014 11:47 am*
Obstacle type:	*poor surface condition*
Obstacle impact:	*both*
Obstacle location:	*4570-4582 Patriot Circle, George Mason University, Fairfax, VA 22030, USA*
Image Name:	
Describe the obstacle type:	*muddy place*
Duration:	*Short (< 1 day)*
Priority:	*Low*
Obstacle Comments:	*muddy place*
General Feedback:	*just testing at this point -Pp*

Confirm Edit

Figure 12. End-user sees this summary of a report to confirm or edit before submitting

Although the University's webpage includes a path accessibility map, the ADA information contained in this map (Fig. 13) is updated once a year, but the construction updates on campus are much more frequent. Continued construction as well as incidental changes, such as mechanical faults in doorways, presented both safety and practical issues to many on the campus in regard to path accessibility. Neither the ADA compliance map nor the campus map showing construction notifications were updated frequently enough and with enough detail. Dr. Rice and his team of students developed and continue to maintan a VGI mapping tool to address this problem. This map tool can be used by anyone on campus with internet access and it is updated as changes are reported and verified.

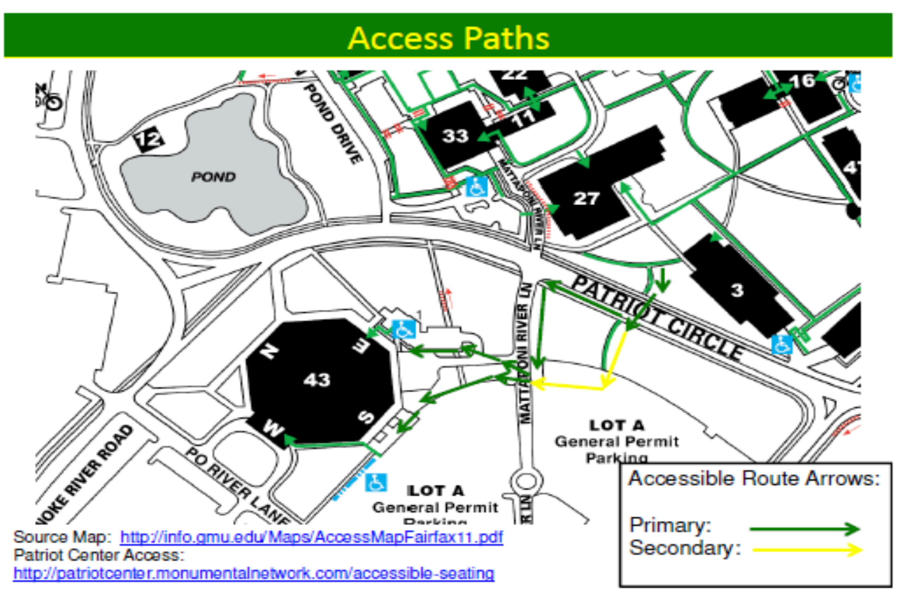


Figure 13. GMU accessibility of path map

3.4 Moderation Process

Dr. Rice and graduate student Han Qin worked to prepare a moderator tool with which to complete quality assessment for all reports. The moderator report is tied to the user-ID number, date and time of submission, as well as a report-ID issued by the software. When a participant places or moves the icon on the map, a latitude and longitude value is generated and stored for the report as X Y coordinates for obstacle location. Later, this latitude and longitude value is used in the analysis of positional accuracy.

Positional accuracy is described as deviation of a feature position within a measureable unit of meters, from the true location of the feature in horizontal and vertical domains, as determined by highly trained project moderators. Although standards were developed for printed and fixed-scale maps in the 1940's in the US by National Map Accuracy Standards (NMAS), these have been replaced by the National Standard for Spatial Data Accuracy (NSSDA) to adjust to the multiple and changing scales of geospatial data. NSSDA uses a statistical method to estimate positional accuracy that was designed for geospatial databases and interactive maps such as GPS and smartphones. CGD positional accuracy is related to the end-users method of positioning features, such as the place markers of Google Maps (Rice, Paez, et al. 2012).

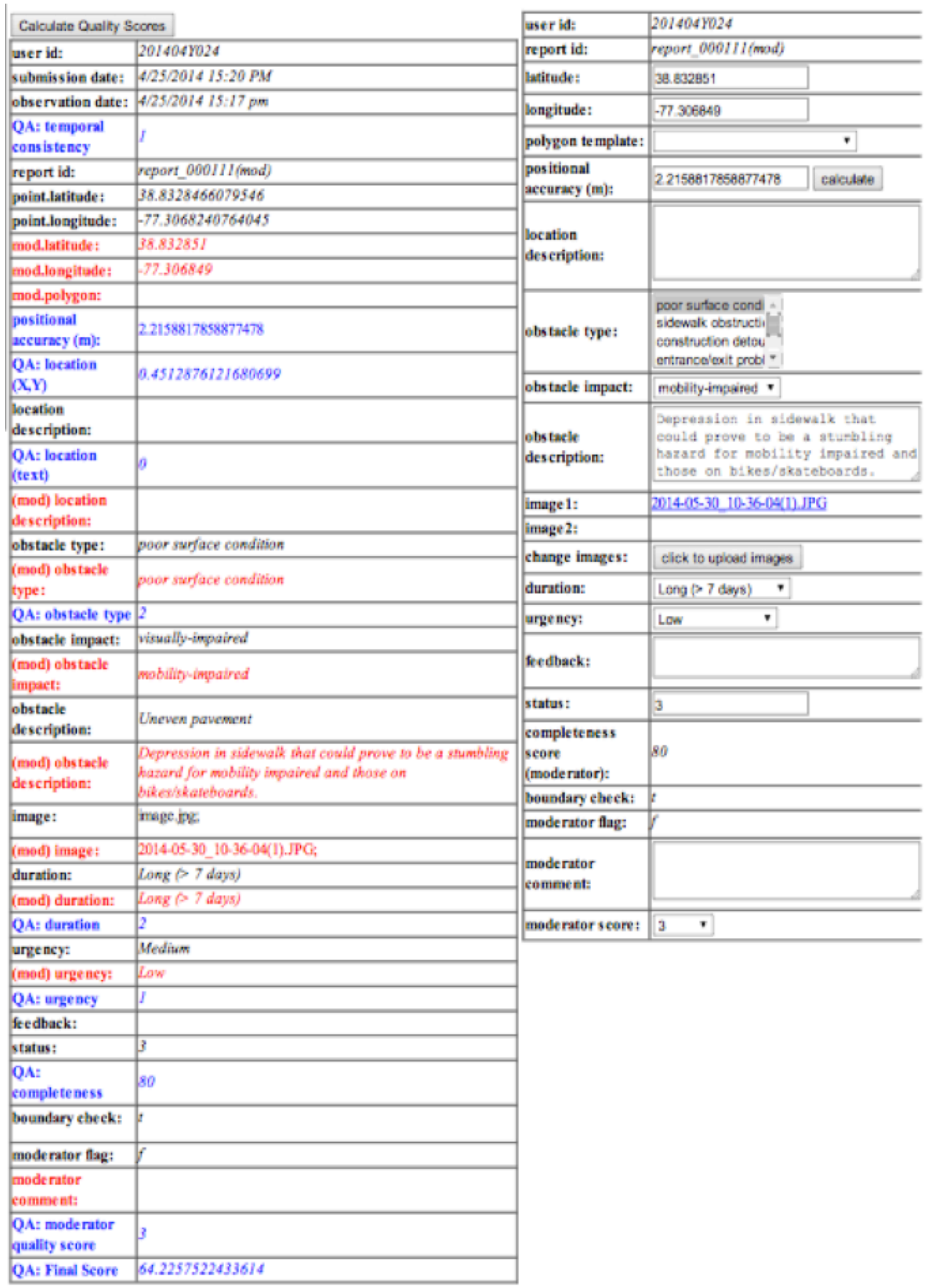
Once an obstacle report was submitted, it became available to researchers for moderation, confirmation and verification processes, as noted previously. Extensive quality assurance measurements were done during the moderation process of the study. Ongoing adjustments had to be done within the moderation tool and web site. Due to continued changes in the test environment, requirements for updates of the map and moderator tools interface were very demanding.

There were five status codes in the moderation report: 1- submitted, 2- confirmed, 3- sub-obstacle (if clustered with others, for example), 4- test purpose, vandalism, or low quality, and 5- closed. A moderator 'flag' code was triggered by any profanity, out-of-bounds, low completeness score, temporal inconsistency or status codes 1 or 4. The moderator checked for report completeness and for location in general. The program for the moderator tool automatically completed the boundary check. If the reported obstacle was outside the boundary, the boundary check indicated *f* for *false,* and the moderator flag turned to *t* for *true,* which meant the report needed to be checked. The boundary limits were set according to the upper left and lower right extents of latitude and longitude as follows:

UL: 38° 51.409', -77° 19.938’

LR: 38° 48.852', -77° 17.250’

Obstacle description made up an important part of a report. Reports were required to include type of obstacle (a category in text format such as *detour*), impact (also a category as specified on map tool, this might be *visually impaired, mobility impaired, both, or do not know*), and location description (text, such as *sidewalk in front of Starbucks*). Reports were scored based on these and other criteria, including image quality and moderator established position, using a point with X Y coordinates. Including an image with a report assisted in verification and report moderation, and provided completeness. Polygons were generated for moderator use to provide more realistic measurements of positional accuracy in a report. Reports were all point-based features, while the moderator’s version of report location was either a point or a polygon, depending on the nature of the object. An overall ‘final’ score was rounded to the nearest percent, with 100% representing a complete report. A report consisted of 37 lines of possible data that were evaluated, while the moderator report had 22 lines (Fig. 14).



Calculate Quality Scores

user id:	201404Y024
submission date:	4/25/2014 15:20 PM
observation date:	4/25/2014 15:17 pm
QA: temporal consistency	1
report id:	report_000111(mod)
point.latitude:	38.8328466079546
point.longitude:	-77.3068240764045
mod.latitude:	38.832851
mod.longitude:	-77.306849
mod.polygon:	
positional accuracy (m):	2.2158817858877478
QA: location (X,Y)	0.4512876121680699
location description:	
QA: location (text)	0
(mod) location description:	
obstacle type:	poor surface condition
(mod) obstacle type:	poor surface condition
QA: obstacle type	2
obstacle impact:	visually-impaired
(mod) obstacle impact:	mobility-impaired
obstacle description:	Uneven pavement
(mod) obstacle description:	Depression in sidewalk that could prove to be a stumbling hazard for mobility impaired and those on bikes/skateboards.
image:	image.jpg;
(mod) image:	2014-05-30_10-36-04(1).JPG;
duration:	Long (> 7 days)
(mod) duration:	Long (> 7 days)
QA: duration	2
urgency:	Medium
(mod) urgency:	Low
QA: urgency	1
feedback:	
status:	3
QA: completeness	80
boundary check:	t
moderator flag:	f
moderator comment:	
QA: moderator quality score	3
QA: Final Score	64.2257522433614

user id:	201404Y024
report id:	report_000111(mod)
latitude:	38.832851
longitude:	-77.306849
polygon template:	
positional accuracy (m):	2.2158817858877478 calculate
location description:	
obstacle type:	poor surface cond / sidewalk obstructi / construction detou / entrance/exit probl
obstacle impact:	mobility-impaired
obstacle description:	Depression in sidewalk that could prove to be a stumbling hazard for mobility impaired and those on bikes/skateboards.
image1:	2014-05-30_10-36-04(1).JPG
image2:	
change images:	click to upload images
duration:	Long (> 7 days)
urgency:	Low
feedback:	
status:	3
completeness score (moderator):	80
boundary check:	t
moderator flag:	f
moderator comment:	
moderator score:	3

Figure 14. The moderation tool with sample report data listed in the right column, and the detailed moderation tasks in the left column, which includes the ability to edit, analyze, calculate and assign final QA scores for reported data.

A final score was assigned collectively by three moderators based on the average of all reports submitted by an end-user. This moderator quality score, ranging from 1 (far below average) to 5 (far above average), took into account all quality indicators. Scores of 1 were reserved only for reports that lacked any location or description. All scores of 2, 3, 4 and 5 were included for analysis.

Of course, the moderator's Final Score was the broadest and most objective measurement of quality, computed as a linear combination of all categories: (1) Temporal Consistency (2) Positional Accuracy (3) QA (location) [perfect location = 1, extremely poor location is close to zero] (4) Location text (5) Obstacle type match (6) Duration (7) Urgency and (8) Completeness (see Table 4). These scores ranged from a low of 48 to 81 as the highest overall score given.

Table 4. This is the descriptive listing of moderator process with each report submitted.

Moderator task	Description
Temporal Consistency	Measures difference between submission and observation time
Positional Accuracy	Measures the difference between moderator report position and contributor report position, in meters
Location (X,Y)	This is based on the Positional Accuracy measure, and represents the quality of the positioning of the report.
Location (text)	Assesses whether Location text exists
Obstacle type	Assesses whether the contributor's obstacle category selection(s) matches the moderator's obstacle category selection(s)
Duration	Measures ordinal category agreement between contributor and moderator
Urgency	Measures ordinal category agreement between contributor and moderator
Completeness	Measures the proportion of fields with content
Moderator Quality Score	Subjective Moderator Quality Score (takes all elements of report into account)
QA: Final Score	Computed as a linear combination of all QA fields

During the project fieldwork, moderator instruction recommended checks to be done twice per day. Filters were implemented that sorted through reports based on time, status, boundary checks and moderator flags. These filters enabled moderation of incoming reports to be more manageable as they were grouped into various queues.

Once data was submitted and verified followed by moderation and quality assurance measurements, statistical analysis was done to compare the results of participants who were trained to those who were not trained. Items analyzed in this study included how accurately a participant placed an observed object on a map, how well they were able to describe the attributes of the object including urgency and duration, and how well these characteristics matched those of the same object, as determined by highly trained project moderators.

3.5 Participant Feedback Analysis

After a participant contributed reports to the map interface, each was asked to fill out a feedback survey. Survey questions addressed the general ease with which the map interface could be used to report obstacles on the path, with a scale of 1, being very easy to use, to 5, being mostly difficult. One graph for each of the questions illustrates the results of the 23 participants. Whether the participant was trained or not is not indicated in these graphs.

Figures 15 – 20 illustrate responses to the six survey questions in the feedback survey. Graph titles indicate the category of a question only, whereas the questions from the survey as they appeared in written form, are shown in each caption. A reply of 1 meant very easy, 2 was mostly easy, 3 not as easy, 4 was sometimes difficult, while a 5 meant mostly difficult.

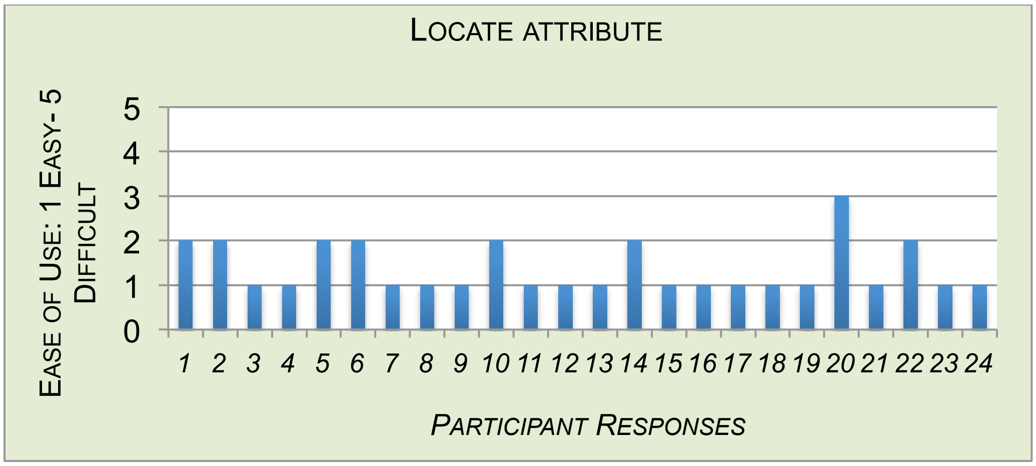


Figure 15. Locating attributes in the field: Did you find it easy to locate at least a few types of obstacles in the field within the allowed time? Average response: 1.375

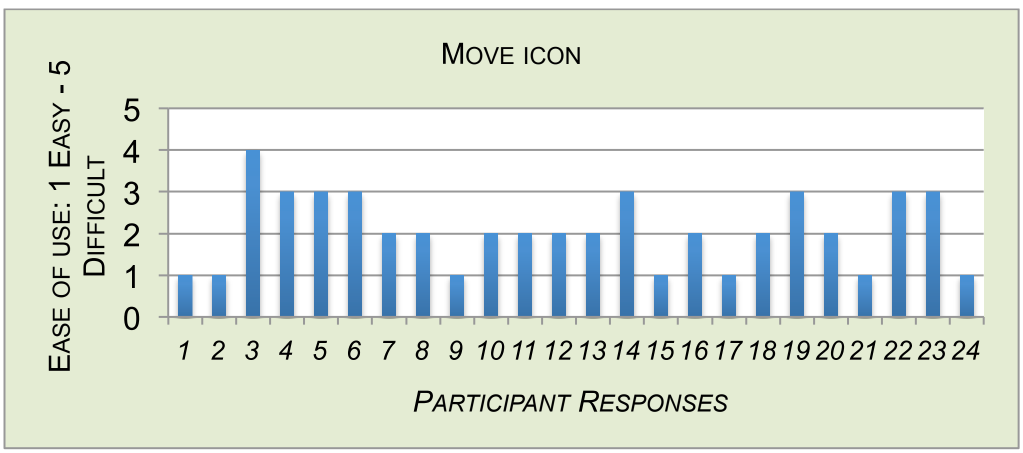


Figure 16. Moving icon onto map location: How was the process of moving the location icon onto the map? Average response: 2.083

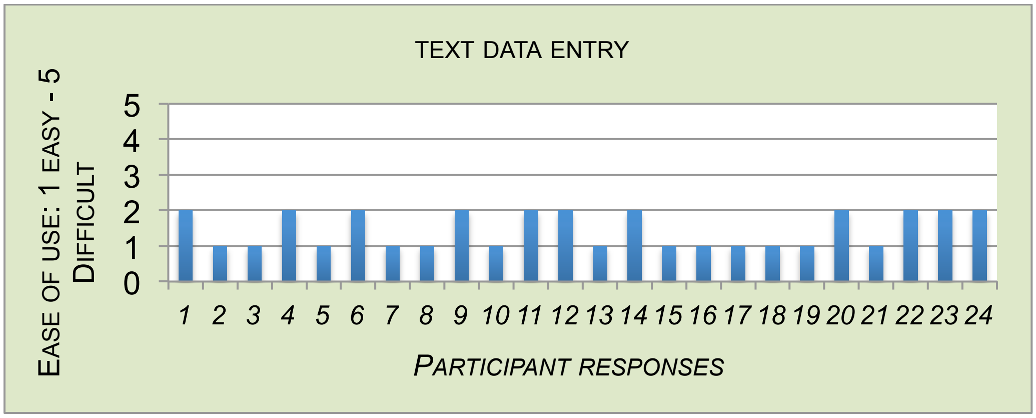


Figure 17. General data entry about an obstacle: Working with the map interface, how was the process of recording data about an attribute? Average response: 1.458

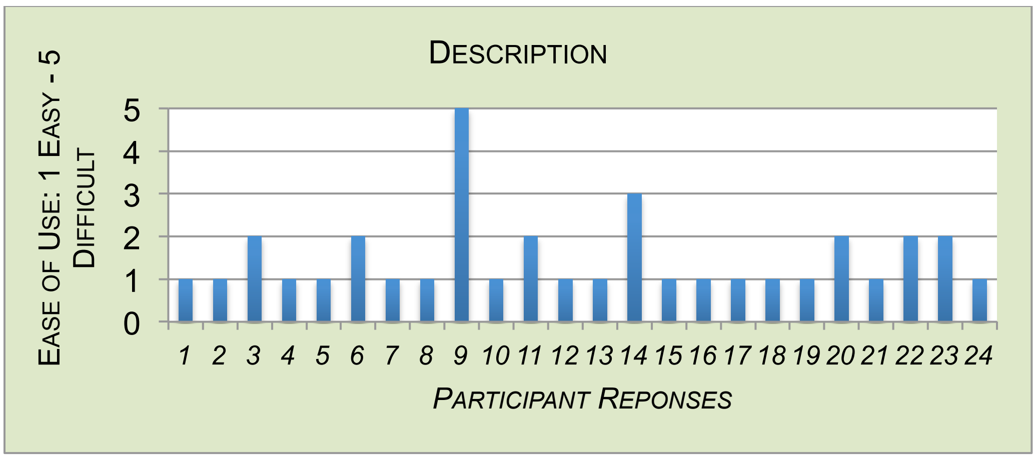


Figure 18.Description of an obstacle or object: When you entered data regarding duration, type, and urgency, how did this go? Average response: 1.500

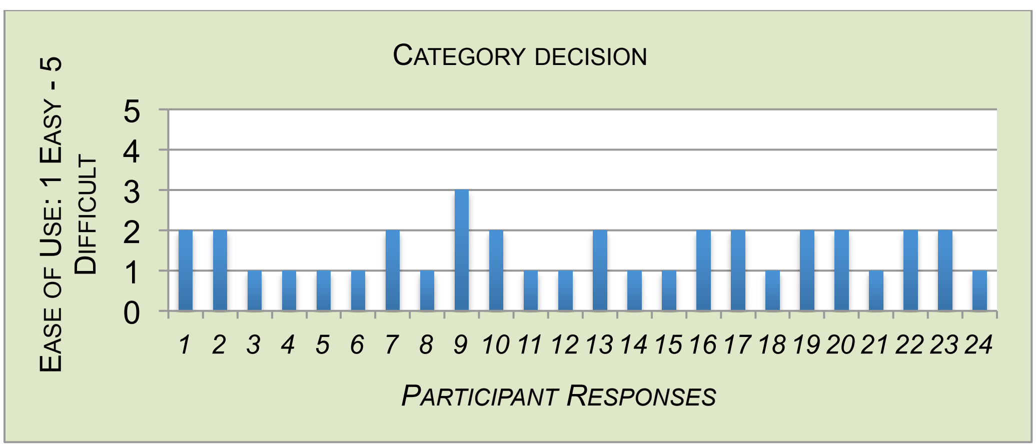


Figure 19. Category decision for an object: Did you spend much time in deciding the category for an obstacle? Average response: 1.542

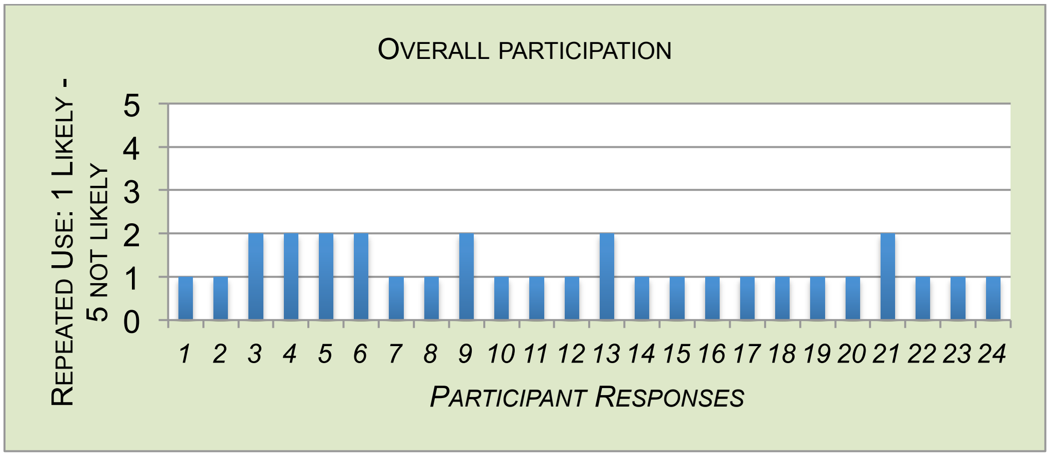


Figure 20. Overall participation: Would you participate in a data collection activity such as this again? Do you think others would be likely to do so? Average response: 1.292

Within the survey questions, most responses were affirmative answers, indicating that the use of the interactive web map was mostly easy (average responses were between 1.292 and 2.083). Locating an attribute by moving the icon (L) was the question with the lowest value average response of 2.083. A closer look at this question shows that 35% gave an answer of 3 or 4 (not as easy, sometimes difficult), while 30% answered with 1 (very easy) and 35% answered 2 (mostly easy). Otherwise, the overall participation question gave the highest value responses, averaging 1.292, which indicated that participants would likely do this activity again or think that others would be likely to participate. This and some written feedback were overall affirmative for the project. The many adjustments made to the interface were positively received, making the web site user-friendlier, even for the untrained, and unfamiliar (with similar GIS applications, or Google maps, for example).

Excerpts from the survey feedback spreadsheet are provided in the table below for an illustration of the types of comments that were received.

Table 5. Excerpts from feedback survey comments

Comments about difficulty	Feedback ideas	Additional feedback
it was hard to move it exactly where you wanted. If GPS could be used to locate the device used to make the report it would be easier	a more detailed location when zoomed in would be helpful	overall good application, internet access was the only finicky part
sometimes hard finding current location on map	it may be better to record information on a laptop wifi kept disappearing while recording obstacles	I think people would be more willing if they could access this on a smartphone
did not always pick up location of obstacle	if you can must make it so you can click & L pops up instead of dragging it	an extremely necessary rsch project - many obstacles on campus that would affect people disabled in any way
did not want to overreport if I thought obstacle were together, some trouble choosing urgency	maybe have a live dot showing your location if you have wifi or mobile signal	overall easy, but the only issue was losing the internet connection causing data collection to be postponed until back in range
uploading images was slow - had to skip uploading a photo for one of obstacles	interface software is contingent on wifi network: if you're not connected, you can't upload images accordingly	this is a fun way to help others using technology we use everyday

CHAPTER FOUR: ANALYSIS OF RESULTS AND DISCUSSION

4.1 Problems Encountered

The testbed environment for the geo-crowdsourcing project on the GMU campus is a work in progress in many ways. Minor inadequacies were encountered, while behind the scenes work by Dr. Rice, Han Qin and others corrected and provided ongoing improvements. For example, to clear or hide all previous reports each time a new participant opened the map to make a new report helped to avoid any confusions. In some instances a student did not know, especially if untrained, that they needed to drag and drop the 'L' icon to the obstacle's location on the map. Once the script was changed such that movement of the icon was required in order to proceed, the chance of missing this step was no longer an issue. The map interface was a smooth part of the project overall. Of the field participants, 29% had very positive things to say about the application, its usefulness, and that this was an easy and good project to do, which helped others and let the Mason student's voice be heard. The most frequent complaint encountered with all students was in relation to Wi-Fi availability; whether it dropped connection during their work with the map, or was very slow to upload images that a student had taken. Based on feedback surveys, 38% had issues with Wi-Fi, and 17% complained otherwise of slowness or minor problems in the software (these were not specific, and could have been internet related).

Commitment to participation was an area of some problems. By selecting students from classes on the campus, many had motive only to gain extra credit in their classes as was offered. Participants could not be coerced into submitting more or better reports, to add images to their reports or descriptions for an obstacle. During the moderation process, many reports were found incomplete or of such low quality as to be unusable. There was some difficulty in scheduling students to arrive at appointment times due to time conflicts that arose. Ultimately, the study was completed with a sample size of 23 participants, 12 untrained and 11 trained. This has provided us with some data to analyze but is not a balanced number in the two test groups.

Another problem occurred when pictures uploaded on the same day were replaced by the next set of pictures, in which case the newly uploaded pictures did not necessarily match the obstacle that was being reported. This was not an error of the participants, as much as it was in the logistics of how reports overlapped as they came in, and were being numbered sequentially by the system of moderation. Looking at figure 14, any report submitted has several ways in which it can be identified. A queue had to be developed ultimately in order to properly organize all incoming reports by various filters. The research team, including Dr. Rice and Han Qin, made all necessary corrections to avoid such problems within the data collection process.

Much of the work done for this project was behind the scenes in order to organize, compile, and moderate the incoming reports. That work, done by Dr. Rice, Han Qin, Christopher Weitz, Rebecca Rice and Eric Ong, has permitted final statistical analysis to be done in order to answer the questions asked in this research.

4.2 Data Analysis

All reports submitted went through moderation and verification processes until data from the participants was tabulated, scored and assigned QA scores for assessment. Some reports had to be eliminated due to poor quality. Each of the 23 participants submitted between 2 and 8 reports. Of those, 123 reports were scored and verified with the moderation criteria and subsequently included in final analyses. Moderation criteria included temporal consistency, positional accuracy, location (both X and Y, and text description), obstacle type, duration, urgency, and completeness. An overall moderator quality score was assigned by 3 moderators based on all elements of a report, between 1 (very poor) and 5 (very good). The QA Final Score was computed as a linear combination of all moderator fields. The numbers fell between 48 and 81, out of a possible 100. A histogram illustrates this range for QA Final Score, (see Fig. 21, and also Table 4).

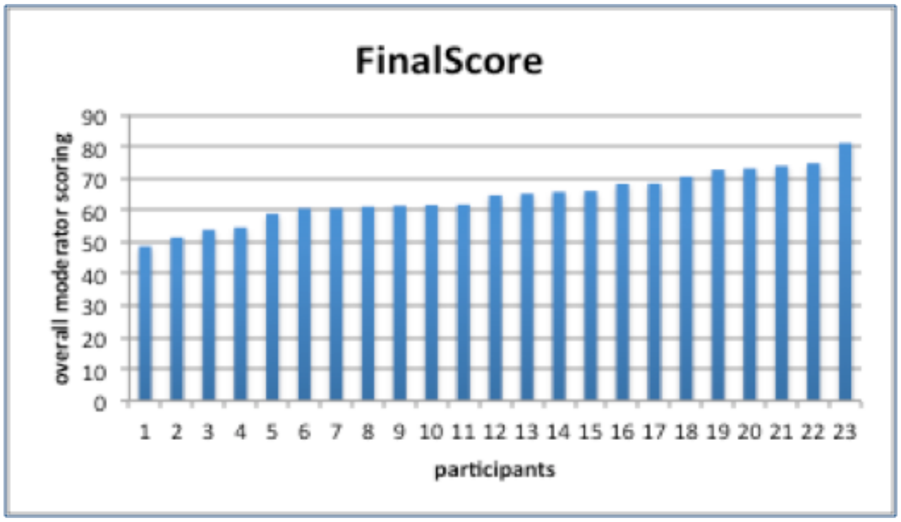


Figure 21. Moderator final scores, shown in ascending order

An example of QA calculation of a report is shown below, with the resulting score of 99.6, which is a high final score.

QA: Temporal Consistency	0,1	6	none	5	1	1	5	5
QA: Positional Accuracy	0-unknown	not used	not used	Used in QA: Location	0			
QA: Location (X,Y)	Max = 1, Min	2	none	20	1	1	20	20
QA: Location (text)	0,1	7	none	5	1	1	5	5
QA: Obstacle type	0,1,2	4	divide by 2	12	2	1	12	12
QA: Duration	0,1,2	5	divide by 2	10	2	1	10	10
QA: Urgency	0,1,2	3	divide by 2	14	2	1	14	14
QA: Completeness	0-100	8	divide by 10(	4	90	0,9	4	3,6
QA: Moderator Quality Score	1-5	1	divide by 5	30	5	1	30	30
							QA Score:	99,6

Figure 22. This shows factors in computing a moderation QA final score for a report

Once all data was available, inferential statistical tests were done on the results, which included two-sample t-tests and Mann-Whitney U tests. One t-test considered the X Y location QA as an interval scale dependent variable with trained and untrained as a categorical independent variable. Another two-sample t-test was done with QA final score as interval-scale dependent variable and trained/untrained as categorical independent variable. The Mann-Whitney test was of QA moderator score as the ordinal scale dependent variable against the trained/untrained categorical independent variable.

4.3 Results

Expected results (H_a), were that trained participants would provide higher scores in positional accuracy, Final QA scores, general moderator scores and object type agreement; while the null hypothesis (H_0) was that there would be no significant difference in the scores as tested. While the same t-tests for the samples assume normally distributed populations and both groups (trained and untrained) are independently selected from the same population, an F-test was done to determine if the sample variances are identical in both test groups. A critical value was established by F-test, and a probability of 0.34677 was found, which leads us not to reject the null hypothesis in this case. We therefore cannot conclude that the variances are not equal. In fact, when the two-sample t-test is applied assuming equal variances, the p- value is 0.48397, even higher. The trained and untrained groups of participants are therefore not significantly different with respect to positional accuracy.

Given the positional accuracy means and variances that were observed in this study with the t-test statistic of 0.04066769, and with 21 degrees of freedom, even with the largest sample size possible and infinity degrees of freedom, the t-test result is 1.64485 for $\alpha = 0.05$. There is no sample size where the statistics found could be deemed as significant, given the means and variances that we observed (Ostle and Malone 1988) .

The test suggests that training of subjects does not particularly influence their ability to position objects on a map. Below are two histograms that illustrate results in positional accuracy of all participants (fig. 23), in descending order of error (in meters). As might be expected, the second histogram correlates directly (since smaller error is a better accuracy) by each participant to the moderator QA Final Score shown in the first histogram (fig. 21). While positional accuracy ranged from 0.5 to almost 52 meters in error, the average error for all 123 reports was 18.50 meters, with trained participants averaging 18.67 meters and untrained participants averaging 18.44 meters.

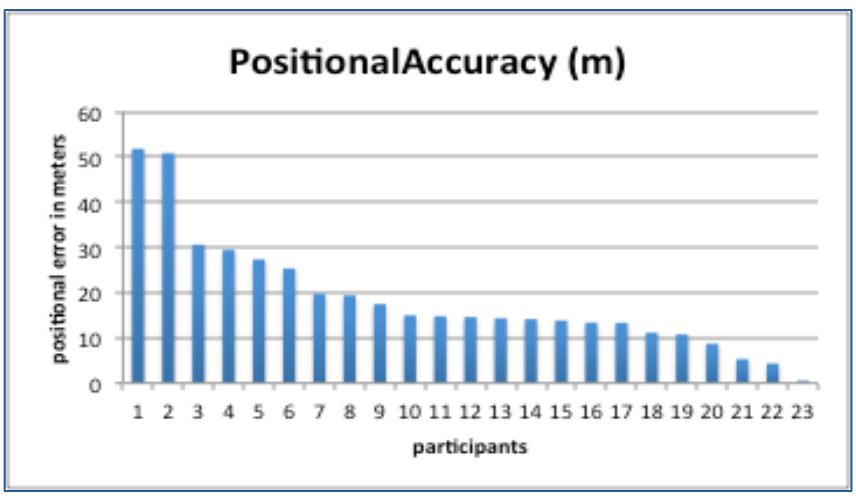


Figure 23. Positional accuracy of all participants, in descending order of error

Measurements of average positional accuracy variances for the trained participants and untrained were 12.0215 meters and 14.0304 meters (in error), respectively. The final moderator scores for the two groups were 65.7762 (trained) and 62.9805 (untrained). These small differences are insignificant. Even though overall moderator QA final scoring for the trained participants is higher (65.7 compared to 62.9) than the untrained, the difference is not significant. The p-values are not less than alpha, (0.05) and therefore the null hypothesis (H_0), that the mean is the same for both samples, is not rejected. In this case, regarding QA Final Score, we would have to adjust alpha level from $\alpha = 0.05$ to $\alpha > 0.22$ and increase the sample size to 1000 in order to detect a significant difference in this statistic (Ostle and Malone 1988).

Final Score		
t-Test: Two-Sample Assuming Equal Variances		
	Variable 1	*Variable 2*
Mean	65.77626215	62.9805802
Variance	65.60192548	65.11522278
Observations	11	12
Pooled Variance	65.34698597	
Hypothesized Me	0	
df	21	
t Stat	**0.828510526**	
P(T<=t) one-tail	**0.208349467**	
t Critical one-tail	1.720742903	
P(T<=t) two-tail	0.416698933	
t Critical two-tail	2.079613845	

Figure 24. Section of spreadsheet showing final score moderator data with statistical values found.

Positional accuracy		
144.5175887	12.02154685	variance of trained
196.8530971	14.03043467	variance of untrained
18.66776335		mean of the trained
18.44517413		mean of the untrained
Final score		
mean of trained:		65.77626215
mean of untrrained:		62.9805802
Moderator score		
mean of trained:		3.16991342
mean of untrrained:		2.996825397
Obstacle_Agreement		
mean of trained:		1.636363636
mean of untrrained:		1.483928571

Figure 25. Final calculations of positional accuracy, moderator, final scores and obstacle agreement scores

Mann-Whitney tests were used to test the overall Moderator scores as well as for Obstacle agreement scores. The moderator scores, discussed earlier, are ordinal measurements from 1 (very poor) to 5 (very good), and even the average score is not truly interval or ratio in nature, but closer to ordinal. This test compares two samples and determines whether the criteria selected, in this case the overall moderator ranking scores, are different for the two samples. The null hypothesis (H_0) states that the ranks for both groups are the same, suggesting that underlying populations are the same with no difference between trained and untrained. The Mann-Whitney U statistic of 58.5 is not small enough to reject the null hypothesis at a 0.05 level. The trained and untrained are not significantly different with regard to this overall moderator score. The Mann-Whitney was also used for the Obstacle agreement category, and a U statistic of 50.5 was found as the lowest of both U-values in this case. This category had ranking values of 0 (no agreement), 1 (some agreement), and 2 (complete agreement), which are ordinal values as well. Below are diagrams of the average rankings for these tests, which merely illustrate the similarity of our sample groups. The trained participants are plotted on the left of each graph while those untrained are to the right in each plot.

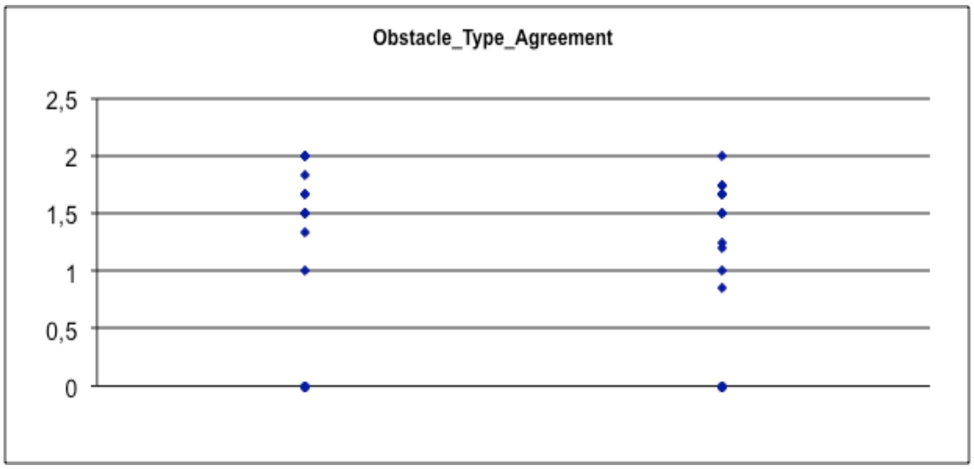


Figure 26. Mann-Whitney diagram of results for Obstacle type agreement with moderators (trained plotted on left, untrained on right)

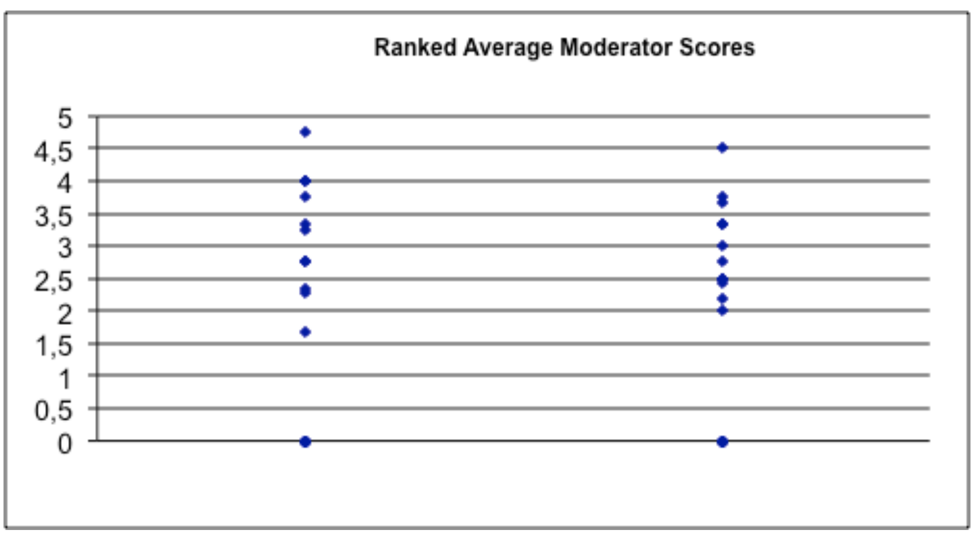


Figure 27. Mann-Whitney diagram of overall Moderator scores, ranked averages for trained on left, untrained to the right.

In consideration of obstacle type, it should be pointed out that during the development of the testbed environment, Dr. Rice's research team was guided largely by the needs of community end-users for the system being tested (Rice, Curtin, et al. 2013).The categories for obstacle types are based on this earlier research, and remain true to the criteria and requirements of those findings.

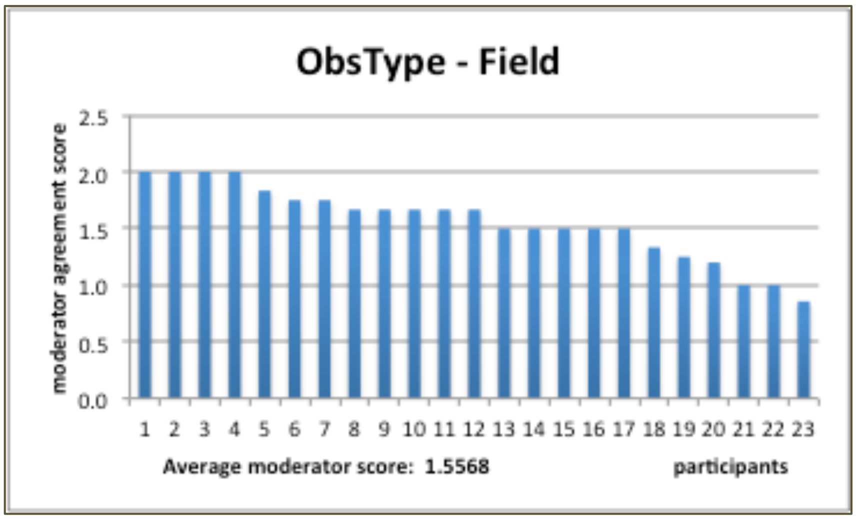


Figure 28. Agreement for obstacle type with correct (moderator) score.

Moderators used a simplified system to measure whether or not moderators agreed with the user about the selection of obstacle type. Of the six types, moderators first chose the 'correct' type or types, and then assigned a 0, 1, or 2 depending on agreement. (0, no agreement, 1, partial agreement, 2, perfect agreement.) Partial agreement could only occur in those obstacles that had two or more correct categories. The results in terms of agreement in naming obstacle type, as shown in the graph (fig. 28) has an average agreement score of 1.5568, compared to a perfect score of

2.00. Compared to obstacle type agreement from the training, the average score was 1.6187, using the same system as described above. This slightly higher score is obtained from participants who have just viewed sample images from the powerpoint training, and is not significantly different from the fieldwork average for the same moderator score.

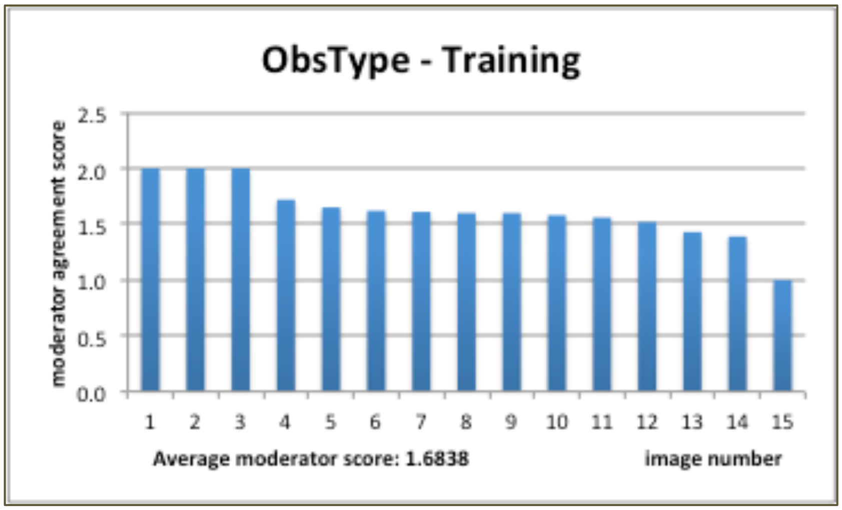


Figure 29. Agreement for obstacle type with moderator score from training data.

Table 6. Excerpt from spreadsheet to indicate agreement with moderator score on Obstacle Type identification both in field and in training.

Image/Participant	ObsType ID (Field)	ObsType ID (Training)
1	1.200	1.650
2	1.000	2.000
3	0.857	1.390
4	1.667	1.560
5	2.000	1.520
6	1.333	2.000
7	1.667	1.600
14	1.667	1.720
15	1.250	
18	1.667	
19	1.750	
20	2.000	
21	1.500	
Average	**1.5568**	**1.6187**

CHAPTER FIVE: CONCLUSIONS AND FUTURE WORK

5.1 Conclusions and Discussion

Excellent training material such as that developed and provided in this research by Paez help to fill in the gaps for citizen science and VGI data. The power point presentation gives a clear and easy to follow view of the interactive, visually appealing and somewhat intuitive system for reporting obstacles on campus walkways. In her conclusion, Paez offers the idea of considering the behavioral, educational, and socio-economic backgrounds of participants in their understanding of the obstacle reporting system developed. This would allow researchers to consider necessary adaptations in order to export this system to other locations and communities (Paez, Fabiana 2014).

This project was limited to some degree by time and logistical constraints which precluded an ideal rendering of some components such as sample sizes, the extent of work put into further trials, adjustments for error, and possible refinements. When it was found, for example, that participants who signed up but did not arrive to complete the fieldwork, or those who arrived but did not complete all steps of the exercise, such as descriptions of obstacles, or uploaded images in the field, measures could have been taken to increase the total number of reports and results which consisted of adequate quality.

Refinements were made of the website as soon as the need was apparent, and this was ongoing as required. Keeping the website interface as clean, simple and user-friendly as possible is important to the overall appeal of the map, and this was accomplished. Possibly finding a better timing for gathering participants would add much to improved future work. For example, building a mid-term campus social event around the opportunity to learn on one's own and contribute to a geo-crowdsourcing project as a culminating activity would possibly invite students with a higher motivation level.

Statistical tests of the influence of training on participants in this project led to a conclusion of no significant difference between those trained or untrained. Even though larger and more random sampling sizes are sought for statistical purposes, the results may not have been very different in this study. As mentioned in the previous section, there are in fact no reasonable sample sizes in which the statistics found in this study could have been deemed as significant for the positional accuracy means and variances that were observed.

Much of the technology used in this study and the nature of the tasks involved were not very different from those with which participants are already familiar. In fact, feedback surveys indicated that the tools were easy to use and posed little difficulty. Many participants were, or had been enrolled in GIS classes, and many had used an iPad or an iPhone, Smartphone or similar device before. Much of the interaction with the interactive map was, in other words, intuitive. The map interface is simple, logical in design, and is appealing. Training may not be necessary based on the levels of accuracy we can expect and in the environmental setting that we have. Training would not improve the statistical accuracy of data input in this case, but it might encourage more frequent use, as that use might become even easier, and therefore take less of a person's free time. In addition, improved quality would be anticipated from frequent use of the tools and returning participants who gain in precision and accuracy with practice.

Considering the frequency and consistency of participation, one goal should be to increase participation. VGI is about participation, and the more the better. More contributors can compensate for any errors in classifications made by volunteers based on Linus' Law, as an average consensus emerges. The idea of Linus' Law for open source development projects is that when many programmers are involved and are able to examine the code, try it in different scenarios, and improve what it can do, the software becomes better without formal QA procedures (M. (Muki) Haklay et al. 2010). If the map interface tool for this path accessibility were more broadly known and used such that it was an integrated part of the social setting of the campus community, it would bring many eyes to the project. Improvements could be expected.

Goodchild notes that altruistic or social interaction organized around an open access activity of crowdsourcing such as this would lead to improvements in such a project for a campus setting (Rice, Matt; Paez, Fabiana; Rice, Rebecca; Qin, Han; Seitz, Christopher 2014). In regard to VGI, Goodchild (2012) suggests that the best question to ask about VGI application in science is what limitations are imposed by the nature of VGI. Sampling will never be entirely random or representative of the larger more global populations, plus quality of data will always be variable. Instead VGI will represent volunteers, and by identifying the demographics of such volunteers, they can be correctly weighted (2012_VGIworkshop_Goodchild.pdf 2014).

In addition to the idea implied by Linus' Law as this impacts VGI, Haklay (2014) offered a list of the essential ingredients for quality assurance. This includes crowdsourcing as the number of people that edited the information, the social component are the gatekeepers or moderators, the broader geographic knowledge, the more specific domain knowledge, the technical and technological calibration as instrumental observation, and following a procedure as a process oriented tendency (INSPIRE_conference_-_Haklay_-_2014.pdf) . The suggestion in this list is that these are the components that will address quality in VGI as the process continues to emerge, adjust and find its way into scientific communities. Systems such as that of Dr. Rice and his team of researchers have built in quality assurance in the form of geographic knowledge (of the campus and of the area by the community), the use of the internet and iPad is a type of calibration, and of course the use of moderators as gatekeepers to datasets before these are submitted to the web map as a true report.

5.2 Ideas for Future Work

As VGI applications continue to develop, evolve and emerge, there will always be opportunities to learn and improve for better application. Those applications with altruistic purpose are in a good position to attract the interest of the general community who seek betterment. VGI continues to face challenges of trustworthiness, reliability, and the commitment of the few who contribute to VGI datasets. Quality assurance in a study requires constant oversight and monitoring of incoming datasets, yet this is a practical solution to verify and filter data that is fit for use. The QA process can be very costly, unless it is supported by grants, other funding or student-led work that provides opportunities for practical application. Student work would also require its own level of supervision, however, and would vary in its consistency as students moved ahead in their plans for graduation and employment.

An idea expressed by Dr. Goodchild, included in a team report and presentation (Rice, Matt; Paez, Fabiana; Rice, Rebecca; Qin, Han; Seitz, Christopher 2014) , is to move the data models into Universal Modeling Language (UML) in order to allow for more extensive analysis, but also to include intersections, walkways, buildings and an address linkage between GMU facilities and local government to provide a shared interoperability in the community. This opens the project from the confines of campus into the community. Paez expressed a similar idea of extrapolating the techniques developed in this CGD project of obstacle reporting on the campus, to extend it into the other locations and communities (Paez, Fabiana 2014).

All projects of citizen science involving geo-spatial criteria include multiple overlapping interests. The benefits for one study would undoubtedly benefit another with similar needs. To enable sharing of results and developments, both gains and setbacks, within a network of similar interests would enable such collaboration. These ideas work well with the open source platforms being used in this study and the continuous development of tools via web 2.0.

Community benefit and interest as indicated in the initial work done in this project is to continue the study, recognizing that a good model for training has been developed, and an excellent web interface with robust moderation and quality assurance processing has also been developed and well established. Whether this is done as part of a class curriculum, with the fieldwork requiring students to each recruit a few volunteers in a well-monitored setting, or as a social campus-based event that approaches the altruistic element of the work, it has moved well into the current century in its evolution and so would be wise to continue moving ahead.

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BIOGRAPHY

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