A DESIGN FRAMEWORK FOR TECHNOLOGY-MEDIATED PUBLIC PARTICIPATORY SYSTEM FOR THE ENVIRONMENT

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Abstract

The rapid decline in biodiversity associated with environmental degradation has encouraged governments worldwide to take urgent action aimed at monitoring and documenting its current state. In response, governmental and non-governmental institutions have supported the rise of technology-mediated public participatory systems, also known as citizen science initiatives, designed to encourage citizen participation in gathering relevant environmental data using their mobile devices. However, despite the ubiquitousness of mobile phones, there is a disturbing paucity of these systems in developing nations as compared to the developed nations. A review of the literature dealing with the extant participatory systems offers interesting insights regarding this uneven distribution. This paper explicates the design of extant participatory systems and the constraints in translating it to the context of developing nations often characterized by low levels of literacy and ICT skills, lack of appropriate devices, sparse internet connectivity and high data costs. Following design science principles the paper identifies the problem and delineates a solution. Taking inspiration from social science theories on enabling access to and motivating participation in environmental systems, the meta-requirements for design are identified and associated design principles are extracted. Future directions for researching operational aspects are discussed along with a description of the potential design architecture of the participatory system.

Keywords: citizen science, design science research, universal access, motivational frameworks

1 INTRODUCTION

Developing nations, currently tackling primary level problems such as infant mortality, malnutrition and population growth, are further challenged by rapid environmental degradation (Reuveny 2007). The increasing burden on these nations calls for treating environmental degradation as an urgent problem (Melville 2010; Lopez-Carr & Zvoleff 2012). The dire need also motivates designing of Green IS capable of assessing and analysing data gathered through monitoring of various environmental attributes to formulate appropriate policies (Malhotra et al. 2013).

Recognizing the fact that solutions to public good problems require participation by a motivated citizenry (Reed 2008), developed nations have leveraged the ubiquitous web and mobile technologies for their mobilization. These online efforts are known as crowdsourcing initiatives (Howe 2006) or Technology-Mediated Social Participatory (TMSP) systems (Nov et al. 2011) and broadly defined as IT-enabled processes that rely on volunteers to contribute their time, skills and energy for the creation of a public good (Amichai-Hamburger 2008). These participatory systems, comprising of a computing system capable of supporting distributed resources and an incentive framework to ensure users participate and contribute (Nov et al. 2014), also occur in domains as diverse as language translations, knowledge markets and innovation. This research focuses broadly on TMSP systems in the domain of science, also called Citizen Science (CS) projects (Irwin 1995) and in particular on those that address environment related issues.

The proliferation of CS systems for the environment in developed nations (Ohab 2012; Theobald et al. 2015) has not found an echo in developing nations. Even in situations where benefits to the public are direct and personal, governments of developing nations have been forced to provide incentives to increase participation, for example, in remedial measures dealing with malnourishment and early childhood education (Afridi 2011) or poverty alleviation (Badodiya et al. 2011). In light of this, it is difficult to encourage participation in systems for common good where benefits are neither immediate nor personal. Considering the critical nature of the problems associated with environmental degradation, the challenge is for the governments of developing nations to act decisively and create structures that enable and motivate collaborative action (Liverman 2004).

This lack of inclusive participatory systems to act on common good issues in developing countries has motivated our interest in the topic. Consequently, in this research-in-progress paper, we first introduce the literature survey to summarize the drawbacks in translating the design of extant participatory systems to the developing world context and delineate the research gap by identifying the research questions that are to be investigated. In the subsequent section, we draw upon the knowledge base of existing theories that stipulate ideal conditions under which public participation is enabled and contributory behaviours are enhanced in the domain of environment, to present a potential design for a participatory system in the developing world context. Next, we follow the procedural rules for the design science research methodology as laid out by Peffers et al. (2007) and delineate the components of an information systems design theory as proposed by Jones and Gregor (2007) to elucidate how the design principles for the construction of an IS artifact are extracted and captured in the form of theory. Finally, we discuss the expected outcomes and next steps.

2 RELATED WORK

Ever since technology-mediated participatory systems were implemented in the early 2000s, the prevailing paradigm in their design architecture has centred on contribution, with an emphasis placed on motivating contributions by the participants. As a consequence of theories in social sciences linking motivational need satisfaction as an antecedent to contribution (for example, Ryan & Deci 2000), a plethora of research on TMSP systems is structured around designing for motivational affordances, that is, the properties of these system designs to fulfil ‘participant motivational needs’ (Zhang 2008) thus leading to contributions. In general, the system’s motivational affordances are derived either from the peculiarities of design (user interface, ease of use) or from the peculiarities of hardware used to access and participate in the system (GPS enabled smart phone, computer or a text-to-voice enabled feature phones). Thus TMSP system design has consolidated into two research

streams. One major stream approaches system design from a 'social science theory-driven design lens' while a minor and (relatively) recent stream approaches TMSP system design from a purely functional 'problem-solving lens'.

2.1 'Social Science Theory-Driven Design Lens' Research Literature

Literature on social science theory-driven design deals with the study of systems whose design is based on mining the social sciences to build successful technology-mediated participatory communities, also known as evidence-based design (Kraut & Resnick 2011). In the context of developed nations with high levels of literacy and access to appropriate technology, research (Kaufmann et al. 2011; Ren et al. 2012; Arazy & Gellatly 2012; Nov et al. 2014) has identified motivational factors influencing public participation: extrinsic motivation - money, skills and reputation enhancement (Mason & Watts 2010), intrinsic motivation - achievement, accomplishment and entertainment from participation, altruistic need fulfilment (helping others), identification and bond formation with the group (Ling et al. 2005; Ren et al. 2012). System design has been guided by social theories that suggest how to invoke intrinsic motives (Nov et al. 2011; Venkatesh 1999; Arazy et al. 2010), fulfil altruistic needs (Loock et al. 2013; Marett et al. 2013), identify with the group (Ling et al. 2005), recruit and retain participants (Bell et al. 2008), have fun (Good & Su 2011), express collective behaviour (Okolloh 2009) and invoke egoistic behaviour (Nov et al. 2011). Studies on the effect of interface design on user behaviour (Ling et al. 2005; Kraut et al. 2010; Kraut et al. 2012), of task design to activate intrinsic motivations in users (Zheng et al. 2011), of efficiency and cultural biases in usage pattern (Reinecke & Bernstein 2013) have further bolstered the importance of evidence-based design.

2.2 'Problem-Solving Lens' Research Literature

Participatory systems whose technical design is viewed through the 'problem-solving lens' utilise the characteristics of the device to provide motivational affordances thus ensuring participation in and contribution to the system. For example, the wide use of mobile phones in developing nations has given rise to a steady stream of research into their use as enablers of participatory systems (Kaplan 2006; Hellstorm 2008). Acknowledging the constraints within local contexts, many of these systems typically use the device characteristics to enable motivational affordances, thus enhancing participation. For example, 'localizability' (ability to provide information based on user's location), a characteristic of mobile phone devices, is used in systems that require public participation in areas with specific boundaries (Jun & Hui 2010; Hellström & Karefelt 2012) thus addressing design needs related to autonomy and the self (Zhang 2008), competence and achievement (Schneider & von Briel 2013). Further, the characteristic 'ubiquitousness'(accessible from any location) is used in systems that require public participation across a broad region thus addressing needs connected to relatedness and autonomy; another characteristic of the device, 'convenience' (elimination of time, cost and space constraints via the use of sms and mms), has enabled the public to participate in situations of critical importance (Hellström & Karefelt 2012) and in situations of apathy and indifference (Schroeter 2012), thus enabling realization of relatedness, autonomy and the self (Zhang 2008). Yet other characteristics such as personalization and social connectivity have facilitated in enabling competence and achievement need fulfilment (Asthana & Singh 2013).

2.3 Translating Extant System Design to Local Contexts: Some Issues

In extant participatory systems (for example, http://www.projectnoah.org) participation requires that participants possess the appropriate devices (internet connected computer and/or a smart phone), be literate and sufficiently skilled in navigating ICTs in order to meaningfully engage with and contribute to system. Effectively, this design blocks participatory access for a vast majority of the population in developing countries with their lower literacy levels (International Literacy Data 2014), sparser internet connectivity and minority ownership of smart phones (International Mobile Data 2014). Given that for a participatory system to succeed, it is crucial that members of the community

participate (Nov et al. 2014), extant design has not provided recourse to this critical constraint on participation.

Prior research on motivations for participating in these systems (Raddick et al. 2010; Preece & Shneiderman 2009; Nov et al. 2011; Arazy et al. 2012), all of which are volunteer based systems, is predicated on the idea that participation is dependent on participant motivations and independent of their socio-economic status. This is bolstered by survey data that informs us that 'helping', 'doing my part' and 'have leisure time, so want to help' are some of the main reasons given for participation. Interestingly, research on participatory systems in developed nations suggests that the provision of extrinsic motivations such as financial incentives may lower their intrinsic interest (Mason & Watts 2010). These learnings have influenced the evolution of system design in developed nations. However, research also reveals significant under-representation of participants from socio-economically deprived areas but is inconclusive on whether this is due to lack of 'leisure time', impact of design or other unknown factors such as cost (Hobbs & White 2012). In the context of developing nations, the uptake of e-governance services is low (Heeks 2003) and not just amongst the marginalized communities (Kumar 2002; Ascher 1995). This is variously attributed to literacy issues (Akman et al. 2005) and lack of awareness and interest (Pal 2009) among other factors. Existing research has not addressed whether the antecedents that motivate participation in systems for common good is similar in both developed and developing nations. So, can the existing participatory system design with its motivational mechanisms be translated to a different socio-economic context and still be as effective?

Design principles of extant citizen science systems regard technological affordances of devices as universal and providing for motivational needs (Zhang 2008); and that, in general, volunteers participate out of an intrinsic desire to help mankind (Raddick et al. 2010; Bell et al. 2008; Good & Su 2011; Hobbs & White 2012; Arazy et al. 2010; Nov et al. 2014; Rotman et al. 2014). While mechanisms providing intrinsic motivations mechanisms work well for enhancing contributions, they typically are designed to specifications based on commonly used communication devices in the developed world or, focus on a narrow set of features of the existing implementation. So, the question arises as to whether design principles evolved in the context of devices with higher motivational affordance capabilities can be successfully translated to the context of devices with minimal motivational affordance capabilities.

It has been established by Herrmann et al. (2008) that across cultures and socio-economically distinct groups, both in developed and developing nations, human beings generally like to reciprocate to ensure the common good. So in theory, participatory systems for common good ought to exist in disadvantaged socio-economic communities. Yet, there are very few examples of such systems. It is important to note that extant citizen science systems are either managed/ supported by institutions of higher learning or, are allied with governmental and non-governmental agencies (Pocock et al. 2014). Moreover, the outcomes from these participatory systems inform policy decisions taken by these agencies (European Commission Environment Science Report 2013). This collaboration between government policy makers, institutions of higher learning and participatory systems is absent in developing nations. Could the absence of such collaboration explain the lack of these systems in developing nations? Additionally, can a participatory system design that has evolved organically in the context of this inter-organizational collaborative framework be transplanted effectively to the context of a developing nation where this framework is absent?

This research addresses the aforementioned research gaps and motivated by the desire to develop a body of systematized knowledge (design theory) of what works and why so that it can be transferred to other domains such as health and education (Gregor et al. 2014) seeks to answer the following: Can an effective technology-mediated participatory system design be developed for a developing country context? What are the main principles underlying such design? What, if any, are the motivational frameworks that might underpin such a design and encourage participants to contribute to a system for common good?

3 Developing a Method for a Technology-Mediated Participatory System

Our main goal is to define and develop a method for environmental monitoring and decision making that supports universal participation and since a universally accessible participatory system is a novel approach, its design can be seen as a search process (Hevner et al. 2004) involving a cycle of evaluation and refinement. We started our journey with the problem identification and motivation for a solution (Sections 1 and 2). In this section, we extract the objectives of a solution that enables universal access; infer the meta-requirements for the design and the design principles inspired by them.

3.1 Meta-Requirements

In spite of the push towards universal usability of technology (Shneiderman 2000), prior studies suggest that barriers to participation exist either due to shortcomings in technology, device or personal abilities. So, a solution for a system design fit for the local context will potentially satisfy certain objectives. From these objectives, we infer the meta-requirements of a system design that will enable improved participation.

3.1.1 Objectives informing the solution of a participatory system design for the environment

The objectives of a potential solution for problems encountered with extant system design are listed in the table below (see Table 1) along with a short description:

Objective	Description
Allow for optimal participation in a technology-mediated participatory system	enable any user to both initiate and engage in an interaction in a technology-mediated system designed for the common good
Support diversity of accessing devices	remove barriers to access due to device variation to ensure participation by owners of various devices
Facilitate engagement with system in spite of literacy and ICT skills barrier	facilitate participant's engagement with system in spite of hurdles such as lack of reading, writing and ICT skills
Cost-neutral participation and contribution	ensure participation and contribution is free
Adaptability in implementing motivational frameworks	ability to invoke and act upon different motivational needs

Table 1 Summary of the objectives of a solution for designing an improved technology-mediated public participatory system

In order to develop an improved design for technology-mediated participation in the environment domain, we intend to make use of the large body of research in social and socio-psychological theories that discuss the antecedents to positively influencing participation. Our first design goal is to ensure optimal conditions for universal access and participation in a participatory system for the environment with the corresponding construct of 'likelihood of participating in the system.' The second design goal is to associate participants with an incentive mechanism that provides the greatest motivation to contribute and the corresponding construct is 'likelihood of participant being motivated and thus contributing'.

3.1.2 Enabling optimal participation in the participatory system

Understanding the optimal conditions necessary for effective public participation in the domain of environment is a burgeoning field of study. Given the plethora of models and frameworks suggested for public participation (Rowe & Frewer 2005), it is essential we 'evaluate' and select the most 'effective' or 'optimal' participatory process for our proposed design. Rowe and Frewer (2000) define effectiveness of a public participatory process as either 'procedural effectiveness' or 'process effectiveness' and using these two as benchmarks for evaluation, argue that Renn et al. (1995) Normative Theory of Public Participation provides the most prescriptive framework for ensuring public participation. Renn et al. (1995) delineate the normative theory of public participation and

argue that 'fairness' and 'competence' are the necessary conditions under which public participation, at least in the domain of environmental decision making, is made possible. Webler and Tuler (2001) conclude that fairness in participation may be broadly operationalized as the ability to attend (take part/ be present), initiate a discourse (or interact with), and lastly, engage in the discussion while competence, conceptualized as two basic necessities - access to information and to its interpretations - may be operationalized as access to information, ability to engage in constructive interaction and ability to perform analysis using information made available. Thus, from the objective 'Enable optimal participation in the participatory system' the meta-requirements inferred are: a) ability to access system and be made aware of moderator and/or other participants, b) initiate discussion with moderator and/or other participants, c) respond to moderator and/or other participants, c) ability to access all information in the system and d) ability to engage in constructive interaction by performing analysis using information made available.

3.1.3 Support diversity of accessing devices

A design that supports universal access requires that participants can access the system irrespective of the characteristics of their device. Mobile device eco-system is highly fragmented with a multitude of operating systems (Basole & Karla 2011). So, development of any system that can work across devices and across operating systems must necessarily use the technological affordances and capabilities of the most common devices in order to ensure universality of access (Shneiderman 2000; Heeks 2008). The most common feature set for mobile devices consists of the following: ability to receive a short message as a text, ability to send a short message as a text, ability to receive an audio call, ability to make an audio call, ability to view an image and ability to send an image, all through a mobile provider. Thus, from the objective 'Support diversity of accessing devices' the meta-requirements inferred are: a) ability to access system either through short text messages or audio b) ability to interact with moderator or other participants in the system through audio or multimedia messages (visual)

3.1.4 Removal of barriers to participation

Ability to initiate and/or engage in a discussion with the moderator and other users requires that the solution cater to participant needs irrespective of literacy levels or digital skills. Shakeel and Best (2002) have shown through their Community Knowledge Sharing system that users with varying levels of literacy and digital skills prefer design with iconic interfaces and need audio and visual cues to work effectively. Research has also shown that textual messages are unintelligible to many mobile device users in developing countries such as India (Parikh & Ghosh 2006). However, visual and audio messages (in the vernacular) are universally understood. Issues such as non-uniformity in ICT skill level and the inability to access multi-media messaging format may form another barrier (Riggins & Dewan 2005). To overcome this, interaction maybe facilitated by the administrator via both audio and/or visual modes. Hence, system design needs to a) make use of audio and multi-media messaging features of devices and b) most importantly, make provision for a moderator to support user interaction with the system and increase participation. Thus, from the objective 'Removal of barriers to participation the meta- requirements inferred are: a) presence of a moderator to ensure interaction with other participants as well as with the information in the system, b) ability to access system via audio or short text messages.

3.1.5 Cost-neutral participation and contribution

Participation requires firstly, accessing system and then, interacting either with the moderator or with the other participants. Depending on the literacy level and ICT skills, this may happen via text, audio or images. Cost-neutrality may be enabled by setting up of a free voice, multi-media messaging and short text messaging number to which participants may call or send multimedia (MMS) and text (SMS) messages. So, system design needs to make use of audio and multi-media messaging features of devices to ensure engagement and pre-paid voice, SMS and MMS numbers for free access. So, from the objective 'Cost-neutral participation and contribution' the meta- requirement inferred is: ability to access system and interact with others via free voice, SMS and MMS numbers.

3.1.6 Adaptability in implementing diverse motivational frameworks

The objective 'Adaptability in implementing motivational frameworks' is equivalent to 'changeability of design' and the meta-requirements for its design are inferred from Systems Requirement literature. Adaptability is defined as "the ease with which a system or parts of the system architecture may be adapted to the changing requirements" (ECOOP 1996) and is considered an important Non-Functional Requirement (NFR) of system design (Chung et al. 2000). Depending on the type of motivations to be invoked the system needs to be adaptable for implementation of different motivational frameworks thus enhancing contributions by participants. One NFR approach to adaptability is the knowledge base approach whose advantages include a documentation of the history of design decisions, of development knowledge and past decisions (Subramanian & Chung 2001). This documentation may be used as reference guide while developing and testing motivational frameworks. The outcome of each observations and variations may also be recorded. So, the meta-requirements inferred from the objective 'Adaptability in implementing motivational frameworks' are a) ability to record participant interaction process for invoking alternative motivations b) ability to record the participatory outcome and c) ability to inquire preferences of participants.

Consequently, a public participatory system that claims to satisfy the meta-requirements outlined results in the following design features and a corresponding design implementation as shown in Table2.

3.2 Design Implementation

Objectives of solution	MetaRequirements/Design Goals	Design principles/Implementation
Enable optimal participation in the participatory system	a) ability to access system and be made aware of moderator and/or other participants, b) initiate discussion with and respond to moderator and/or other participants; a1) ability to access all information in the system, b1) engage in constructive interaction by analysing information made available.	Enable free access to system (consisting of moderator, the other participants (only to be contacted via moderator) and information) via voice, image and text through free to contact numbers
Support diversity of accessing devices	a) ability to access system either through short text messages or audio b) ability to interact with moderator or other participants in the system through audio or multimedia messages (visual)	Enable free access to system (consisting of moderator, the other participants (only to be contacted via moderator) and information) through voice, image and text via free to contact numbers
Facilitate engagement in spite of barriers such as lack of literacy and ICT skills	a) ability to access system via audio or short text messages, b) make provision for a moderator to support user interaction	Enable free access to system (consisting of moderator, the other participants (only to be contacted via moderator); free access to information through voice, image and text
Cost-neutral participation and contribution	a) ability to access system via free to call and/or text mobile numbers b) ability to interact with system' participants and/or moderator via a free to submit mms number	Enable free access to system (consisting of moderator, the other participants (only to be contacted via moderator) and information) through voice, image and text via free to contact numbers
Adaptability in implementing motivational frameworks	a) ability to record participant interaction process for invoking different motivations b) ability to record the participatory outcome and c) ability to inquire preferences of participants	Database to store user names, preferences and submitted information; database documenting design processes for each motivation invoked; database to store user names and user interactions; database to be able to group users with similar preferences

Table 2 Translation of meta-requirements to design principles to enable participation in and contributions to technology-mediated public participatory systems for the environment

4 EXPECTED OUTCOMES

To physically realize the concept of participatory method in a working IS, we intend to build a prototype, experiments on which will lead to a beta version of a technology-mediated participatory system. The prototype will simply make use of existing software such as MS Excel as a processing platform and a mobile phone as the participant-moderator interface. The prototype is to be experimentally tested in Guntur District, Andhra Pradesh, India. We expect the prototype model to confirm that our proposed design is operational. We will later use the system to test our hypotheses, demonstrate high levels of participation and contribution as compared to those in the extant system design, within the same demographic. Justificatory data from empirical studies proving this will be submitted for publication as a separate paper.

5 CONCLUSION AND FURTHER RESEARCH

In developed nations, the benefits of participatory systems to enable mass action on issues of common interest are evident. This 'research-in-progress' paper proposed an outline of the design of such a system in developing nations. The need for a new system design arose out of the deficiencies of embedding extant system design in the local context. The proposed design framework will overcome the deficiencies, enabling the creation of a accessible public participatory system. This research contributes to our knowledge of DSR by addressing a novel theme: the design of ICT resources for community participation, highlighting the innovation for its design based on local context and also to ICT4D research by shedding the light on the complexities of online interactions among participants from low socio-economic contexts. It is expected to further enrich our understanding of the impact of socio-economic context on participant motivations. Effective engagement of the public is a formidable problem faced by administrators in decision-making roles. There is much to be discovered about the design of participatory systems in the local context as well as a potential to provide practical guidelines to these officials on how to engage local communities in projects of common good. It is also hoped that knowledge of the process - motivating public participation in a specific domain, the environment - can be transferred to domains such as healthcare and education, thus ensuring better outcomes and less number of failed projects.

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