12-2016

MYTH OR REALITY? CROWDSOURCING AS A COMPLEX PROBLEMSOLVING MODEL: EVIDENCE FROM SOFTWARE DEVELOPED BY THE CROWD AND PROFESSIONALS

Abhishek Tripathi

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By

Abhishek Tripathi

A DISSERTATION

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Doctor of Philosophy

Major: Information Technology

Under the Supervision of Dr. Deepak Khazanchi & Dr. Lotfollah Najjar

Omaha, Nebraska

December, 2016

Supervisory Committee:

Dr. Deepak Khazanchi

Dr. Lotfollah Najjar

Dr. Harvey Siy

Dr. Matt Germonprez

Dr. Michael Cortese

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Abhishek Tripathi, Ph.D.

University of Nebraska, 2016

Advisor: Dr. Deepak Khazanchi

ABSTRACT

Crowdsourcing is a problem-solving model. Conventional theory suggests that solving complex problems is a province of professionals, people with sufficient knowledge about the domain. Prior literature indicated that the crowd is also a great source for solving complex problems. However, there is a lack of experimental research to support that crowdsourcing is a useful model for complex problem-solving (CPS), especially in the software development context. The broad goal of this dissertation is to address this research gap and improve understanding of crowdsourcing as a viable and effective CPS model. This research proposed and tested a research model of perceived quality of software designed using two development approaches (crowdsourcing method and professional method). Perceived quality is measured in terms of pragmatic quality (PQL), hedonic quality stimulation (HQSL), and hedonic quality identification (HQIL). Adopting a quasi-experimental research design, the researcher utilized a two-phase process to investigate the research question. The first phase involved the design of a software prototype for a complex task by the crowd and IT professionals. The crowd used Topcoder, a popular crowdsourcing environment, to design a software prototype. In the second phase, the researcher compared software designs by the crowd to those designed by IT professionals based on the three perceived quality dimensions. The major finding of this research is that the development approach (crowdsourcing versus IT professionals) has a significant effect on all three dependent variables: HQIL, HQSL, and PQL. However, univariate results suggested that there is no significant difference in terms of the hedonic quality, which refers to the general human needs aspect of a product. This dissertation contributes to research by building on relevant research in the areas of CPS, user experience, and crowdsourcing. Furthermore, it fills an important gap in the understanding of the perceived quality of crowdsourced software compared to software developed by IT professionals.

ACKNOWLEDGEMENTS

"The best teachers are those who show you where to look, but don't tell you what to see" Alexander K. Trenfor.

I would like to extend my gratitude to a number of people who assisted me with the completion of this dissertation. First, I would like to thank Dr. Deepak Khazanchi, my advisor, for all his valuable time, guidance, encouragement, and motivation during this process. His mentorship has helped me to visualize research problems from multiple perspectives. I am truly thankful for everything he has done for me. I would like to thank my co-advisor Dr. Lotfollah Najjar for his valuable guidance and support for completion of this dissertation. He has taught me a number of data analysis techniques.

I extend my sincere appreciation to my committee members, Dr. Matt Germonprez, Dr. Harvey Siy, and Dr. Michael Cortese, who gave constructive feedback that always aimed at moving me forward. I am also grateful to the students and peers from the University of Nebraska at Omaha for their participation in this research. I would like to thank the faculty, graduate students, and my fellow doctoral students of the College of Information Science and Technology for their support throughout this process.

I am fortunate to have a wonderful family and friends who are always providing me their unconditional support. A very special thanks and appreciation goes to my parents and brother for their advice, love, and support throughout the doctoral program (and my life).

Finally, a heartfelt thank you goes to my wife Suchitra. I would like to thank my children Vasu and Visu since they are my motivation and my world. I dedicate this dissertation to my children.

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CHAPTER 1: INTRODUCTION

Organizations increasingly tap the wisdom of crowds to solve *complex* problems (Bonabeau, 2009; Datta, 2008; Howe, 2008; Jack, 2009; Surowiecki, 2004). Howe (2006) coined the term *crowdsourcing* to describe this phenomenon. The accumulation of information in groups, crowds, can be processed for *collective wisdom* that is often better than professional wisdom. Surowiecki (2004) suggested that the collective wisdom of a group of less skilled individuals is more informative and creative than that of a few specialized people. The core of crowdsourcing ideas originated from the notion that the wisdom of crowds may be better than solutions created by professionals or small groups (Surowiecki, 2004). Crowdsourcing is “the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call” (Howe, 2008; Brandel, 2008; Huysman &Wulf, 2006; Whelan, 2007). Crowdsourcing is a problem-solving model (Baumoel, Gerogi, Ickler & Jung, 2009; Brabham, 2009; Doan, Ramakrishnan & Haley, 2011) to gain input from many unknown and unconnected contributors (Hayhornthwaite, 2009). It is a distributed production models that collects contributions via open calls from an undefined large network of people (Baumoel et al., 2009; Wiggins & Crowston, 2011). The common attribute of crowdsourcing in all definitions is that it is a collaborative effort enabled by people-centric technology. Crowdsourcing business models benefit organizations by providing cheap labor and tapping geographically disperse crowds (Brabham, 2010).

Since the inception of the crowdsourcing business model, it included different types of activities such as micro tasks, problem-solving, collaboration, and to contest-based crowdsourcing of customers, corporate organizations, governments, and academia (Kittur et al., 2013; Zhao & Zhu, 2012). Many organizations use crowdsourcing to tap collective wisdom, but most use crowdsourcing to solve simple problems. Crowdsourcing is essential to identifying ways to help organizations effectively solve complex problems such as software development. Conventional theory suggests that solving a complex problem is the province of professionals, people with sufficient knowledge about a particular domain. Prior literature indicated that the crowd (a diverse group of a large number of anonymous people) is also a great source for solving problems such as product innovation or idea generation because the crowd is familiar with their own purchases (Hippel, 2002; Howe, 2006; Ren, 2011). The crowd may provide input in terms of solutions and help to solve even a complex problem. However, it is not known whether a crowdsourcing business model can facilitate quality solutions for complex problems (Poetz & Schreier, 2012). This dissertation is an attempt to fill this gap by empirically addressing the following research question: *In the context of complex problems, does software developed by the crowdsourcing business model achieve the same or better quality compared to software developed by professionals?*

This chapter is organized as follows. Section 1.1 illustrates the importance of this topic. Section 1.2 explains the research question under investigation. Section 1.3 provides the organizational structure of the proposal.

1.1 Importance of the Topic

Suroweicki (2004) discussed the phrase *the wisdom of crowds* in the information systems (IS), and stated that under some situation, the collective wisdom of the group can be better than the smartest person in the group. Many organizations use crowdsourcing business models to tap collective wisdom for simple problem-solving (e.g., threadless.com, a web-based t-shirt company; istockphoto.com, which sells photos and video clips; and Kickstarter, which solicits crowdsourced seed money for innovative ideas). Critics of the wisdom of crowds suggested that collective wisdom may only be useful for simple problems, not complex problems such as software design and development (Lanier, 2010). As the practice of problem-solving with crowdsourcing becomes increasingly commonplace, it is essential to evaluate whether the wisdom of crowds can solve complex problems and whether it is better than using IT professionals.

There are two alternative streams of research on the legitimacy of crowdsourcing complex problems. One group of researchers suggested crowds consist of novices without sufficient domain expertise to participate in and solve complex problems such as product innovation and development (Bidault & Cummings, 1994; Lanier, 2010; Schrader & Gopfert, 1996). The others concluded that crowdsourcing *democratizes* information (Hippel, 2002). Crowds know the requirements of products and services, contribute to the development of a product, and can solve complex problems (Brabham, 2009; Hippel, 2002; Kittur, 2010). This dissertation focuses on evaluating these contradictory claims.

Research on complex problem-solving (CPS) revealed a wide variety of theories about the characteristics and operationalization of complex problems (Fischer, Geriff, & Funke, 2011). The research community debates which definition the scientific community should use, what *complex* means in CPS, and how to evaluate the complexity of problems (Quesada, Kintsch, & Gomez 2005). Organizations and groups use CPS to address challenges such as coordination of group tasks (Kittur, Smus, & Kraut, 2011), lack of domain expertise by community members, lack of motivation, and sustainability of the community (Quesada et al., 2005). Organizations fail to utilize CPS for crowdsourcing solutions to similar problems. Although the crowdsourcing business model supports creativity and problem-solving (Kittur, 2010), use of crowdsourcing for software design and development is different from general crowdsourcing (Wu, Tsai, & Li, 2013). Gaps in use of crowdsourcing suggest that research on CPS in crowdsourcing environments is valuable and may determine whether the wisdom of crowds produces quality solutions for complex problems such as software development.

1.2 Research Goals

To address these challenges, the researcher will design a software product using crowdsourcing and compare it to the quality of products developed by professionals.

1.3 Research Question

Lanier (2010) argued that collective wisdom is inadequate for creative or innovative problems; collective wisdom is useful when a problem is inadequately defined, a solution is simple, and the collective is aggregated by quality control that depends upon individuals to a high degree. Other researchers suggested that crowdsourcing is useful for solving complex problems (Brabham, 2010; Guinan, Boudreau, & Lakhani, 2013; Jeppesen & Lakhani, 2010). The overarching research question governing this dissertation addresses these two competing statements.

RQ: In the context of complex problems, does software developed by the crowdsourcing business model achieve the same or better quality compared to software developed by professionals?

The production of a tangible product (software) requires multiple processes such as requirements analysis, design, coding, and testing (Wu & Tsai, 2013). Therefore, software design and development is a complex and creative activity. The perceived quality of software products depends on the user experience (UX) perspective (Hassenzahl, 2003). Design and development challenges shifted from providing efficient, reliable, secured, usable functionalities with a competitive price toward providing users with pleasurable experiences (Olsson, 2012). UX should exceed expectations and fulfill human needs such as identification, past memory evocation, and stimulation through a product (Olsson, 2012). Consequently, good functionality and usability are axiomatic features; they are not enough when designing a successful product (Hassenzahl, 2003; Olsson, 2012; Oppelaar, 2008).

1.4 Expected Outcomes and Contributions

This research attempts to fill several gaps in the relevant literature. Critics of the *wisdom of crowds* suggest that collective wisdom may only be useful for simple problems, not complex problems such as software design and development. There are two alternative streams of research on the legitimacy of the crowd/customers' CPS abilities, and solving complex problems is the currently in the domain of professionals. As crowdsourcing practices become increasingly common, it is essential to identify whether the wisdom of the crowd can provide quality solutions for complex problems.

A major contribution of this study is its interdisciplinary nature. This study builds on relevant research in the area of CPS, UX, and crowdsourcing. The findings contribute to understanding CPS via crowdsourcing in a number of ways. First, the researcher evaluated the proposition that a crowdsourcing business model is useful for designing and developing software with greater perceived quality than software developed by professionals. Second, the dissertation includes a field study based quasi-experiment to compare software development approaches (i.e., crowdsourcing versus professional development) based on perceived quality of software solutions for a set of complex problems. The results have strong practical applications for firms interested in using crowdsourced software development.

1.5 Organization of the Proposal

This document has five chapters. This section completes the introduction and overview of the research. Chapter 2 contains a review of related research, key definitions, and the conceptual framework. Chapter 3 presents the research design, pilot study results, and lessons learned. Chapter 4 presents the analysis of the results. Finally, Chapter 5 provides implications, contributions, and conclusion.

CHAPTER 2: THEORETICAL FOUNDATIONS AND CONCEPTUAL MODEL

This chapter includes a review of prior research on complex problem-solving (CPS), CPS quality evaluation, crowdsourcing, and user experience (UX). This chapter also provides a brief exploration of the history and status of crowdsourcing research and research related to CPS by using crowdsourcing models. Chapter 3 also includes a description of the research model as the guiding framework for addressing the research question in this dissertation.

2.1 Crowdsourcing

Organizations increasingly tap the wisdom of crowds to solve problems (Bonabeau, 2009; Datta, 2008; Howe, 2008; Jack, 2009; Surowiecki, 2004). This phenomenon is *crowdsourcing*, a neologism (a compound contraction of *crowd and outsourcing*) (Howe, 2006). The term crowdsourcing, like any IS trend (Baskerville & Myers, 2002), gained attention from academics and practitioners. The annual tabulation of a Google Scholar search for the keyword *crowdsourcing* suggested that there is an increased interest in research on this phenomenon (see Figure 1). Gartner's hype cycle (2012)[1] predicted that crowdsourcing was on the rise (see Figure 2).

[1] https://www.gartner.com/doc/2100915

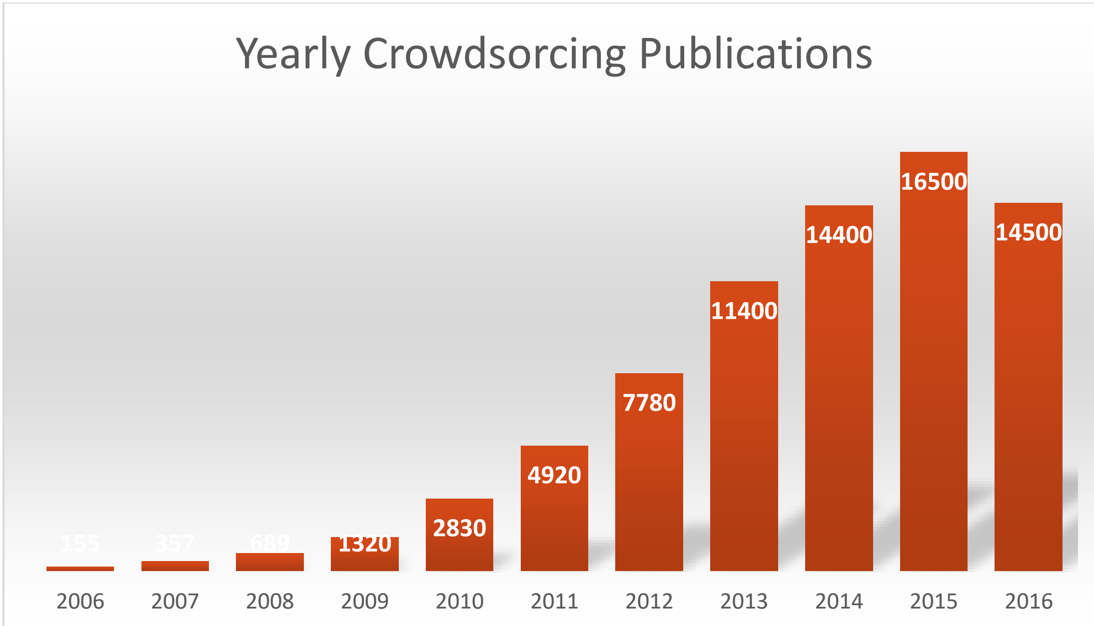

Figure 1: Crowdsourcing publications by year, January 2006 – November 2016.

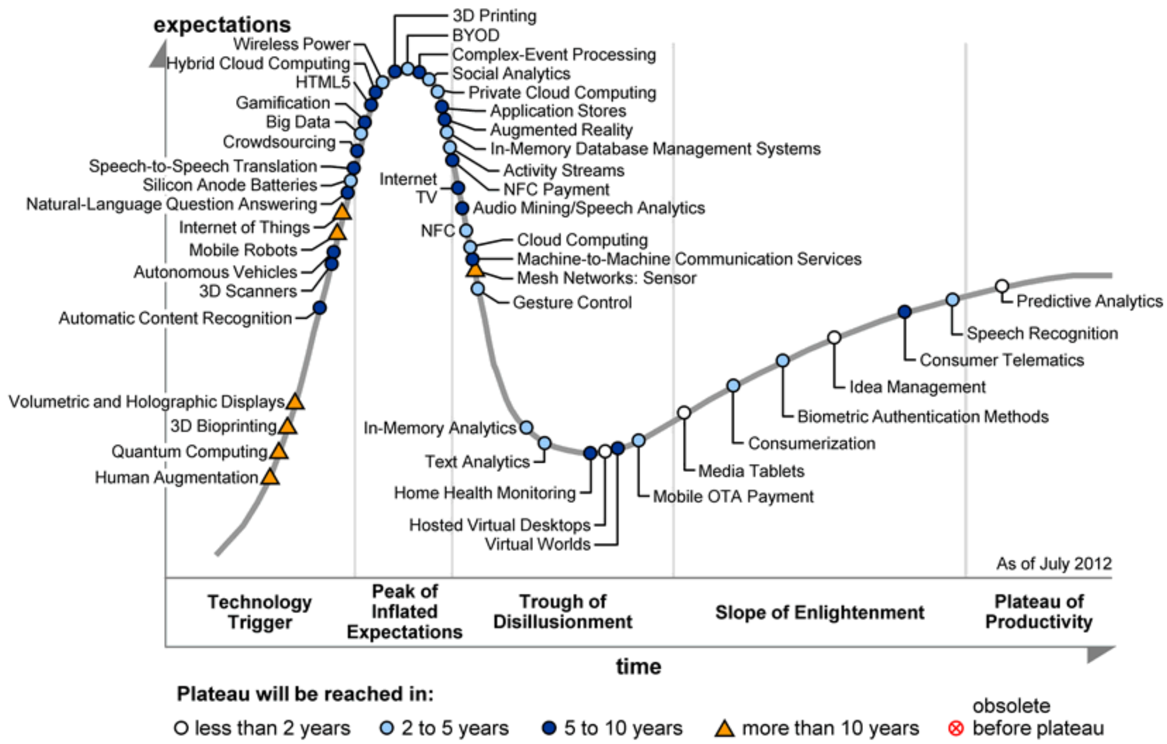

Figure 2: Gartner Hype Cycle for emerging technologies, 2012. Source: Gartner.

Crowdsourcing research spans various disciplines such as economics, psychology, organizational behavior, management, and IS (Pedersen et al., 2012; Zhao & Zhu, 2012). Howe's (2006) definition delineates crowdsourcing from other development perspectives, but is not acknowledged by all IS theorists. For the purposes of this dissertation, the researcher relied on a number of crowdsourcing definitions from existing literature that compare and contrast related concepts of crowdsourcing such as motivation to participate and the connection between crowdsourcing and CPS. Table 1 provides a chronological summary of various definitions of crowdsourcing in the literature along with their key attributes (Estelles-Arolas & Gonzalez-Ladron-de-Guevara, 2012).

Table 1: Definitions of crowdsourcing.

Definition	Attributes	Citation
A web-based business pattern, which makes the best use of the individuals on the Internet via open call and finally gets innovative solutions.	Web-based model, advertises problems via open call, and the outcome is innovative solutions.	Howe (2006)
The application of open source principles to fields outside software.	Open source type model but not limited to software	Howe (2006)
The act of institutions taking a function once performed by employees, and outsourcing it to an undefined (generally large) network of people in the form an open call. This can take the form of peer-production (when the job is performed collaboratively), but is also often undertaken by single individuals. The crucial prerequisite is the use of an open call format and a wide network of potential workers.	Outsourcing of a task to the crowd, peer-production, and via open call.	Howe (2006)
The act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call.	Outsourcing, crowd, open call.	Brandel (2008); Howe (2008)
An online, distributed problem-solving and production model already in use by for-profit organizations such as Threadless and iStock.	Distributed problem-solving model, profit organizations.	Brabham (2008)
A strategic model to attract an interested, motivated crowd of individuals capable of providing solutions that are superior in quality and quantity to those which traditional forms of business can provide.	Strategic model, superior quality when compared to the traditional form of business.	Brabham (2008)

New online, distributed problem-solving and production model in which networked people collaborate to complete a task.	Distributed problem-solving and production model.	Vukovic (2009)
An intentional mobilization, through Web 2.0 of creative and innovative ideas or stimuli to solve a problem. Voluntary users are included by a firm within the internal problem-solving process. They do not necessarily aim to increase profits or to create products or market innovations, but rather to solve a specific problem.	Web 2.0, problem-solving.	Mazzola & Distenfano (2010)
A general-purpose problem-solving model.	General-purpose.	Doan et al. (2011)
A way of using the Internet to employ large numbers of dispersed workers.	Facilitated by the Internet.	Grier (2011)
An industry that is attempting to use human beings and machines in large production systems.	Tap the crowd, large production systems.	Grier (2011)
An open call for contributions from members of the crowd to solve a problem or carry out human intelligence tasks, often in exchange for micro-payments, social recognition, or entertainment value.	Open call, problem-solving, reward.	Kazai (2011)
One particular manifestation of open innovation. It is the act of outsourcing a task to a large group of people outside an organization, often by making a public call for response. It is based on the open-source philosophy that used a large group of developers to build the Linux operating system.	One form of open innovation, outsourcing to the crowd based on open-source philosophy.	Sloane (2011)
Focal entity’s use of an enthusiastic crowd, or loosely-bound public to provide solutions to problems.	Problem-solving by motivated crowd, may be loosely bound.	Wexler (2011)
“Crowdsourcing is a type of participative online activity in	Participative online activity initiated by the problem	Aorlas & Guevara (2012, p. 10)

which an individual, institution, non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task. The undertaking of the task, of variable complexity and modularity, and in which the crowd should participate through bringing their work, money, knowledge and/or experience, always entails mutual benefit. The user will receive the satisfaction of a given type of need, whether economic, social recognition, self-esteem, or the development of individual skills, while the crowdsourcer will obtain and utilize to his/her advantage that what the user has brought to the venture, whose form will depend on the type of activity undertaken".	owner (individuals, institutions, and/or non-profit organization) to a diverse crowd via open call.	

A careful review of these definitions highlights common characteristics among descriptions. Estelles-Arolas and Gonzalez-Ladron-de-Guevara (2012) performed a literature review and analyzed 40 definitions of crowdsourcing. They identified eight common characteristics of crowdsourcing: a clearly-defined crowd, problem owner, crowdsourced task with a specified goal, online process, open call, Internet usage, a clear recompense for the crowd, and defined compensation for the problem owner (Estelles-Arolas & Gonzalez-Ladron-de-Guevara, 2012). Estelles-Arolas and Gonzalez-Ladron-de-Guevara (2012) combined these characteristics and presented a comprehensive, but complicated, definition (Brabham, 2012; Thuan, Antunes, & Johnstone, 2013).

This dissertation simplifies and adapts crowdsourcing in a software design and development context. Although the crowdsourcing business model supports creativity and problem-solving (Kittur, 2010), use of crowdsourcing for software development is different from general crowdsourcing (Wu et al., 2013). According to Wu et al. (2013), software crowdsourcing needs to support the rigorous engineering disciplines of software development; stimulate creativity in software development tasks through the wisdom of the crowd; address the psychological issues of crowdsourcing such as competition, open sharing, collaboration, and learning; address the financial aspects and recognition for various stakeholders; ensure the quality of the software product; and address liability issues in case of failure.

A key feature of software crowdsourcing is that it is a *contest-based* crowdsourcing model (Terwiesch & Xu, 2008). In a contest-based crowdsourcing model, a problem owner who faces an innovation-related problem posts this problem to a large independent crowd and provides a reward to the agent who produces the best solution (Terwiesch & Xu, 2008). Competitions promote creativity and support quality software development, but may decrease the number of participants in the contest (Wu et al., 2013). A contest-based crowdsourcing model promotes game play by different people with different roles, and focuses on a reward mechanism. The higher the reward, the higher the number of solutions (Zheng, Li, & Hou, 2011). In fact, reward is a significant determinant of a crowd's performance (Archak & Sundararajan, 2009; Zheng et al., 2011).

Crowdsourcing is a form of outsourcing: open source and open innovation (Schenk & Guittard, 2009). The wide array of definitions of crowdsourcing suggests that crowdsourcing contours are ill-defined. Schenk and Guittard (2009) suggested that there are similarities and differences between concepts of *crowdsourcing*, *open innovation*, *user innovation*, and *open source*. Open innovation focuses on innovation processes; interaction of these processes is between firms (Schenk & Guittard, 2009). Crowdsourcing is a general problem-solving model in which interactions take place between the problem owner and the crowd. User innovation addresses specific needs and is a community phenomenon (Schenk & Guittard, 2009). Crowdsourcing can be both a user-driven and firm-driven phenomenon (Schenk & Guittard, 2009). Any person can participate in a crowdsourcing process, whether he or she is a user of the product or not. Open source software operates on the *bazaar production* model (Raymond, 1999), and relies on the *copy left principle* so the entire world has free access to the source code to alter and share it. Crowdsourcing firms usually practice traditional methods of protecting intellectual property rights and patent their output (Schenk & Guittard, 2009).

The crowdsourcing model can solve various types of problems. Some prominent examples include design (threadless.com, 99design), research and development (InnoCentive), knowledge accumulation for business (Amazon), and funding for innovative ideas (IBM global entrepreneur). A crowdsourcing model benefits organizations by providing relatively cheap labor from geographically disperse crowds (Brabham, 2010).

2.1.1 Crowdsourced Software Development

Software development is a complex, challenging, and creative processes (Wu et al., 2013). Software development involves various stakeholders, requirements analysis, design, architecture, coding, and testing (Wu et al., 2013). The software development life cycle continues to shorten while software complexity increases and budgets are stagnant (Leicht, Durward, Blohm, & Leimeister, 2015). Software engineering includes many techniques and tools, and the field seeks new technologies to meet new challenges every year (Wu et al., 2013). IT industry leaders such as Fujitsu-Siemens (Fuller, Hutter, & Faullant, 2011), IBM, and SAP (Blohm et al., 2011) leveraged the crowdsourcing business model for innovation management (Leicht et al., 2015). Lakhani et al. (2013) reported on a crowdsourced programming contest in which approximately 75% of the crowd solutions to solve an immunogenomic problem outperformed the industry standard at a total cost of $6,000. (Leicht et al., 2015). Various commercial crowdsourcing platforms emerged to support crowdsourced software development. These platforms use different types of open call formats such as online competition; on-demand matching, in which the workers are chosen by registrants; and online bid, in which developers bid for tasks before starting to work (Mao, Capra, Harman, & Jia, 2015). The World Quality Report (2014), the premier authority for software testing practices, indicated that more than half of the surveyed organizations already employed crowdsourcing as a software testing process (Leicht et al., 2015). Leicht et al. (2015) performed a structured literature review of 27 articles in top IS and software engineering journals and conferences to review the current state of crowdsourced software development research. The results suggested that research in crowdsourced software development was still in a nascent phase. Almost 60% of research in crowdsourcing software development was from a systems perspective, about 40% of was on crowdsourcing applications in software development, and only one paper dealt with user perspectives (Leicht et al., 2015).

Platform	URL	Task Domain	Open Call Form
TopCoder	www.topcoder.com	Software Development	Online Competition
GetACoder	www.getacoder.com	Software Development	Online Bidding
AppStori	www.appstori.com	Mobile App Development	Crowd Funding, Online Recruiting
Bountify	www.bountify.co	Small Coding Tasks	Online Competition
uTest	www.utest.com	Software Testing	On-demand Matching, Online Competition
Passbrains	www.passbrains.com	Software Testing	On-demand Matching
99Tests	www.99tests.com	Software Testing	On-demand Matching
TestBirds	www.testbirds.com	Software Testing	On-demand Matching
Testbats	www.testbats.com	Software Testing	On-demand Matching
Pay4Bugs	www.pay4bugs.com	Software Testing	On-demand Matching
CrowdTesters	www.crowdtesters.com.au	Software Testing	On-demand Matching
TestFlight	www.testflightapp.com	Mobile App Testing	On-demand Matching
Mob4hire	www.mob4hire.com	Mobile App Testing	Online Bidding
Testin	www.itestin.com	Mobile App Testing	On-demand Matching
Ce.WooYun	ce.wooyun.org	Software Security Testing	On-demand Matching
Bugcrowd	www.bugcrowd.com	Software Security Testing	Online Competition

Figure 3: A list of commercial platforms for crowdsourced software engineering (Mao, Capra, Harman, & Jia, 2015).

Because of the great diversity in problems solved by crowdsourcing, various categorizations of crowdsourcing developed (Brabham, 2008; Geerts, 2009; Howe, 2006). The various attributes of the crowdsourcing model include problem owner, crowd, and technology.

2.1.2 Problem Owner

The problem owner is an entity that has a problem that needs solved. The problem owner may be a government organization, business, or an individual. The problem owner regulates most of the crowdsourcing process, including defining and communicating the problem to the crowd, process mechanisms to be put in place, and evaluation and selection of solutions (Pedersen et al., 2012).

2.1.3 Crowd

The crowd is an important constituent of crowdsourcing. The concept of crowd shifted from a social problem to a problem solver (Benkler, 2006; Wexler, 2011). The first wave of crowd theorists, such as Le Bon (1897) and Tarde (1901), considered the crowd as a herd mentality; the absence of a skilled leader can create mayhem in society. In this phase, the concept of *crowd* was more myth than reality (Wexler, 2011). The second wave of theorists, such as Couch (1968) and McPhail (1991), posited that crowds demonstrate rational collective behavior in contexts where *institutional norms and logic are tested* (Wexler, 2011). Turner and Killian (1957) suggested that the crowd is a social collective (whole, but underdeveloped) structure; its behavior is not an instance of collective madness but rather rationally motivated (Wexler, 2011). Couch (1968) posited that the crowd is a socially distinct system rather than a special case of collective or individual behavior. The third phase of crowd theory was the notion that crowds have a collective intelligence and can solve problems (Brabham, 2008; Wexler, 2011).

In the context of crowdsourcing, the crowd (aided by Web 2.0 technology or other Internet-related technologies) forms a collective intelligence to solve a problem in response to an open call from a problem owner. The crowd is a dynamically formed group of individuals who participate in a crowdsourcing problem (Pedersen et al., 2012). In crowdsourcing literature, researchers defined crowd as a large group of people (Howe, 2006), individuals (Chanal & Caron-Fasan, 2008; Pedersen et al., 2012), general Internet users (Pedersen et al., 2012), customers (Porta, House, Buckley, & Blitz, 2008), voluntary users (Mazzola & Distefano, 2010), and on-line communities (Whitla, 2009).

Crowd members can function independently, anonymously, and equally to arrive at a solution or they may collaborate to develop community-based contributions to the solution (Haythornthwaite, 2009). Prior crowdsourcing literature did not specify the minimum or maximum number of individuals that form a crowd. The crowd is an important factor in the crowdsourcing business model; the core of crowdsourcing ideas originates from the notion that wisdom of crowds may be better than solutions created by professionals or small groups. In the context of this research, *crowd* is a dynamically formed group of an undefined large number of Internet users who participate independently in a crowdsourcing problem.

2.1.4 IT Professionals

The human factor is one of the most important areas in software engineering (Palacios, Caro, & Crespo, 2012). According to Boehm (1981), the human factor is the second most important factor after product size to determine the effort required for the development of software (Palacios et al., 2012). An IS of complex and moderately complex tasks typically requires development by a professional IS team. IS professional teams play an important role in sustaining effective and efficient IS (Siau, Tan, & Sheng, 2007). Siau et al. (2007) identified 59 unique characteristics of software development team members that they classified according to eight dimensions: attitude/motivation, knowledge, interpersonal/communication skills and working/cognitive ability.

2.1.5 Technology

The advent of Web 2.0 technology was a key enabler of the rapid expansion of crowdsourcing (Howe, 2008). The technology increased speed, global reach, anonymity, asynchronous capabilities, interactivity, collaboration capabilities, and the ability to carry media from other communication modes (Brabham, 2009). All these factors improved with Web 2.0 relative to Web 1.0 (Pedersen et al., 2012). Unlike Web 1.0, users were no longer passive receivers, but active contributors (Brabham, 2010). Web 2.0 and other Internet technologies empowered users with space and temporal flexibility. Web 2.0 facilitated open call, a prerequisite to crowdsourcing (Brabham, 2009).

2.1.6 Typology of crowdsourcing

A typology is a conceptual classification system that combines the greatest information content with the easiest means of information retrieval (Mayr, 1969; Rich, 1992). Organizational typologies provide effective data organization, information retrieval, and development of theory (Rich, 1992). Nickerson, Varsheny, and Muntermann (2013) suggested that classifications of knowledge is important to the IS field, because it structures knowledge of the field. Researchers proposed classifications based on different foci of crowdsourcing, including applications (Brabham, 2013; Howe, 2008), nature of tasks (Schenk & Guittard, 2011), and crowdsourcing systems (Geiger, Rosemann, & Fielt, 2011).

Howe (2008) described a typology of crowdsourcing based on various examples of problems that organizations crowdsourced and problems solved by crowdsourcing. A crowdsourcing problem consists of an initial condition and desired goals (Howe, 2008). The problem is a prerequisite for any crowdsourcing approach, and its characteristics determine the type of crowdsourcing model (Haythornthwaite, 2009; Howe, 2008). Problems may arise from a government, individual, or organization that seeks solutions by crowdsourcing organizations or individuals in the crowd. Problems may be simple, such as a phone number search or the identification of pictures, or the problem may be very complex, such as research and development (e.g., Fiat crowdsourced the design for its 2009 model). The problem may also involve development of enterprise applications. Table 2 presents classification of crowdsourcing as suggested by Howe (2008) along with characteristics and crowdsourcing organizational examples.

Table 2: Types of crowdsourcing (Howe, 2008).

Crowdsourcing type	**Description**
Co-creation	Engagement of customers for new product development. **Example:** Procter and Gamble formed a community in order to open their innovation context to co-create with the crowd.
Crowd creation	Engagement of crowds or organization to solve creative problems. **Example:** 99 design hosted public competitions for design problems and crowds participate in developing end solutions.
Crowd voting	The best artifacts are based on the voting of the crowds. **Example:** Ackuna controlled translation quality by the voting process.
Crowd wisdom	The aggregated decision of the crowd is used to make decisions. **Example:** 7billionideas shared everyday ideas to aggregate the ideas.
Crowd funding	The crowd acts as a funding source for innovative and creative business ideas. **Example:** ActBlue solicited funding for Democratic party candidates in the USA

Brabham (2013) proposed a crowdsourcing typology based on problem types. The problem may range from a gathering, organization, and reporting problem to ideation and scientific problems. Table 3 presents a typology proposed by Brabham (2013).

Table 3: Types of crowdsourcing based on problem types (Brabham, 2013).

Crowdsourcing type	**How it works**

Knowledge discovery and management	Problem owner tasks a crowd with information gathering, organization, and reporting problems.
Broadcast search	Problem owner tasks a crowd with solving scientific problems.
Peer-vetted creative production	Problem owner tasks a crowd with creating and selecting ideation problems.
Distributed human intelligence tasking	Problem owner tasks a crowd with data analysis.

Schenk and Guittard (2011) classified tasks as simple, complex, or creative, and classified crowdsourcing as selective or integrative, based on participation. In selective crowdsourcing, crowdsourcing provides a way to access individual problem-solving skills (Schenk & Guittard, 2011). A firm can choose a solution from a set of options. In integrative crowdsourcing, individual solutions may have very little value, but the amount of complementary input provides valuable solutions for a problem (Schenk & Guittard, 2011). Thuan et al. (2013) combined creative and complex tasks into the concept of skilled tasks because there are few differences between complex and creative tasks.

Geiger, Roseman, Fielt, and Schader (2012) classified the crowdsourcing IS as crowd processing, crowd rating, crowd creation, and crowd solving. They based this classification on two dimensions: crowd contributions and the value of contributions. Crowd contributions may be homogenous (all contributions are equally) or heterogeneous (these contributions are not vetted equally, but are based on the individual’s qualities). The value of contributions may be emergent, if individual contributions are a part of the collective contributions as a whole, or non-emergent, if individual contributions are independent of other contributions and deliver a fixed value (Geiger et al., 2012).

2.1.7 Theoretical trends in crowdsourcing

To determine the state of theoretical research in crowdsourcing, the researcher performed a literature review and categorized selected articles based on Gregor's taxonomy of IS theory types (see Table 4). The findings demonstrated that most research was explanatory in nature and focused on cause-and-effect relationships. Most articles used pre-established theories to justify research questions or hypotheses. Theoretical research to design crowdsourcing related artifacts was least common. Crowdsourcing research had a fairly strong theoretical grounding, but still needs to grow its own theoretical roots. Most studies used theories from other disciplines rather than developing new theories (Tripathi, Tahmasbi, & de Vreede, 2017).

Table 4: Use of theories in crowdsourcing research (Tripathi et al., 2017).

Theory Used	Theory Type	Purpose	Reference Discipline	Referred Article
System Theory	5. Design and Action	Categorization of crowdsourcing system and prescription for design of system	Interdisciplinary	Geiger et al. (2011)
Information Model	2. Explanation	To describe the characteristics of social commerce	Information Systems	Zhang & Wang (2012)
Five factor model or Big Five of personality	4. Explanation and Prediction	Motivations for participation in online communities varied according to personality type	Psychology	Cullen & Morse (2011)
Commitment Theory	4. Explanation and Prediction	Theorizing of how each form of member commitment relates to different kinds of online behaviors.	Psychology and Management	Bateman et al. (2011)

Self Determination Theory	2. Explanation	Motivation for participation in crowdsourcing	Psychology	Brabham (2012)
User Gratification Theory	2. Explanation	Motivation for participation	Communication	Brabham (2012)
Motive incentive-activation-behavior (MIAB) model	5. Design and Action	How to design and implement the ERP software for the activation functionality in idea-based competitions	Social Psychology	Leimeister et al. (2009)
Software platform and Ecosystems Theory	2. Explanation	Evaluation framework for social media exploitation	Software Development	Ferro et al. (2013)
Theory of Structured Imagination	3. Prediction	Effect of exposure to an original or common idea on crowdsourced idea generation	Cognitive Psychology	Wang et al. (2013)
Transaction Cost Theory	4. Explanation and Prediction	Model of workers supplying labor to paid crowdsourcing projects (Horton & Chilton, 2010); Online sourcing (Lu & Hirschheim, 2011)	Economics	Horton & Chilton (2010); Lu & Hirschheim (2011)
Expectancy Theory	4. Explanation and Prediction	Predictors of effort investment in the crowdsourcing context	Management	Sun et al. (2012); Moussawi & Koufaris (2013)
Conflict Theory of Decision-Making	4. Explanation and Prediction	Analyzing effective idea rating and selection mechanisms in online innovation communities	Decision Making	Riedl et al. (2010)
Uncertainty Theory	4. Explanation and Prediction	Service provider pricing for the service in crowdsourced market	Mathematics	Hong & Pavlou (2012)
Theory of Person-Job Fit	4. Explanation and Prediction	Criteria that workers use to choose crowdsourced tasks	Organizational Behavior	Schulze et al. (2012)
Theory of Planned Behavior	4. Explanation and Prediction	Participation intention is positively associated with actual participation	Social Psychology	Zheng et al. (2011)
Absorptive Capacity Theory	4. Explanation and Prediction	IT-enabled knowledge capabilities and firm innovation	Strategic Management, Organizational Behavior	Joshi et al. (2010)
Argumentation Theory	4. Explanation and Prediction	Decision support for climate change	Philosophy, Communication, Artificial Intelligence	Landoli et al. (2007)

Social Capital Theory	4. Explanation and Prediction	Social factors and wiki usage	Sociology, Political Science	Scott (2013)
Democratic Theory	1. Analysis	Crowdsourcing as a possible way to involve the public in urban planning	Political Science	Brabham (2009)

2.2 Complex Problem-solving

CPS is an idea within the field of cognitive sciences. The phrase *complex problem-solving* (CPS) combines two terms that are ubiquitous in fields such as psychology, IS, and economics. Yet, definitions and taxonomies of the terms *complex, problem-solving,* and *CPS* are inconsistent (Quesada et al., 2005. This section reviews two distinct notions: taxonomy of problems, which will corroborate problem-solving, and taxonomy of tasks, which achieves the solution for a problem in which complexity is inherent in tasks. Past researchers attempted to define the taxonomy of problems and problem-solving (Quesada et al., 2005).

2.2.1 Taxonomy of Problems

The origin of the word *problem* stems from Latin and Ancient Greek *problema (proballo),* which means to *throw or lay something in front of someone* or *to put forward*. A problem is the difference between a current situation and a desired situation (Pounds, 1965). Research literature on problems attempted to distinguish between several types of problems (King, 1993; Mascarenhas, 2009; Rittel & Webber, 1973).

Simple problem. This is a problem with clear objectives. Problem solvers can easily map objectives to solutions, because both the problem and the solution are known (Pounds, 1965). These are tame problems and their solution space is well-defined (Mascarenhas, 2009). For example, in a crowdsourcing photo tagging contest to identify the specific person in a picture, the problem and solution are known. Simple problems converge on a scientific solution and reductionist thinking (Mascarenhas, 2009; Senge et al., 1994).

Complex problem. A problem becomes complex when its solution requires responses that deviate from common solutions or previously learned ones (Maier, 1970). In the case of a complex problem, the problem is known but the solution is either unknown or there may be multiple solutions (Maier, 1970; Mascarenhas, 2009). The goal is not yet clear, but upon agreement. The complex problem may transform into a tame problem (Mascarenhas, 2009). A creative person should be a good problem solver of not only routine problems but those that require more than a learning mechanism (Maier, 1970; Mascarenhas, 2009). Complex problems differ from simple problems in the availability of information about the problem, the precision of goal definition, the complexity of a problem in terms of number of variables, the degree of connectivity among variables, the type of functional relationship, time dependencies over the course of achieving the goal, and the richness of the problem's semantic embedding (Sternberg & Frensch, 1991). For example, an organization may want strategic and competitive advantages. The problem is clear if they can define *strategic and competitive advantages*, but understanding how to solve the problem is far from clear (Mascarenhas, 2009).

Pseudo-problems. A pseudo- problem is not formulated (Pounds, 1965). Solutions are freely made and marketed. These types of problems may have morality issues because they can deceive people (stakeholders) (Mascarenhas, 2009). Solutions may solve a piece of the problem, but disregard other solutions. For example, in an organizational financial crisis, many solutions for bailout may disregard the problems of various dynamics that initially led to the crisis (Mascarenhas, 2009). Proposed solutions may be worse than the problem (Mascarenhas, 2009).

Wicked problems. A wicked problem is so complex that there is no definitive statement (Pounds, 1965). There may not be any agreement on the nature and goal of the problem. Hence, without the problem in place, there is no definite solution (Pounds, 1965). Wicked problems are unsolvable because they lack clear goals, formulation, and agreement among stakeholders, and cannot transition into a complex problem to tame the problem (Mascarenhas, 2009). Solvers strive for somewhat effective solutions based upon definitions within the problems (Mascarenhas, 2009). Rittel and Webber (1973) described how to identify that a problem is wicked and developed guidelines to tackle such problems (Mascarenhas, 2009). As shown in Table 5, four factors contribute to the causes and effects of problems (Mascarenhas, 2009).

Table 5: Taxonomy in relation to the causes and effects of problems.

Problem Type	**Example**
Causes known and effects known	7billionideas hosted a platform to share and aggregate everyday ideas.
Causes known and effects unknown	Procter and Gamble formed a community in the open innovation context to co-create with the crowd.
Causes unknown and effects known	InnoCentive worked with customers for problem formulation based on organizational requirements (effects are known but what can be a problem is not known).
Causes unknown and effects unknown	Solving a global climate change problem.

Past researchers proposed different taxonomies of problems, but most problems are either simple or complex. This research focuses on complex problems. *Complex problem* is still an ill-defined term.

2.2.2 Taxonomy of Tasks for CPS

Some researchers used the task as a lens to study CPS. Problem-solving is a task-centered field (Quesada et al., 2005), and some researchers believed *tasks* and *problems* are synonymous (VanLehn, 1996). According to Quesada et al. (2005), it is hard to define a complex problem, but researchers may categorize its manifestation a scientifically useful way. The key attributes of CPS tasks, according to Quesada et al. (2005), appear in Table 6.

Table 6: Taxonomy of CPS tasks (Quesada et al., 2005).

Time Related	Variable Related	System Behavior Related	Psychological Description
Time variant- Time Invariant	Number and Type of variable	Opaque- Transparent	Reactive- Predictive
Continuous Time-Discrete Time	Number and pattern of relationship between variables	Stochastic -Deterministic	Knowledge Lean-Intensive
Degree of Time Pressure	Nonlinear and Linear	Delayed – Immediate Feedback	Understanding – search based
			Decomposability

Time differentiates complex tasks from simple tasks. For a time variant or dynamic system (as opposed to a static system in which effects occur only when the participants intervene), an endogenous variable at time t will have an effect of its own state at time t+1 that would be independent of the other exogenous variables effects (Quesada et al., 2005). With a complex problem, tasks change continuously in real time as the environments change in continuous time (Quesada et al., 2005).

The number, type, and pattern of relationships among variables are ways to classify CPS tasks. As the number of variables increases, task may become more complex (Quesada et al., 2005). Similarly, two systems with an equal number of variables may not have equal complexity; instead, the type of variable and number of state of variables may add complexity. Variables that are highly interconnected may add more complexity than a system with sparsely connected variables (Quesada et al., 2005). A system is nonlinear if the input and output variables are not directly proportional over the entire range of measurement (Quesada et al., 2005). A nonlinear system is more complex than a linear system (Quesada et al., 2005).

System behavior properties such as opaque, stochastic, and delayed feedback can also identify CPS tasks (Quesada et al., 2005). An opaque system has a layer of hidden variables not affected by input variables that affect the output variables (Quesada et al., 2005). Such a system never reveals a complete structure of the system. In a stochastic system, as opposed to a deterministic system, events randomly trigger unrelated to any other changes in the state of the system (Quesada et al., 2005). By taking the same action in the same environment, CPS tasks may produce two different states or values. Feedback from the system can also impair performance. If an action to perform a task cannot be traced back to the value of feedback, it will increase the complexity of a task (Quesada et al., 2005).

Psychological task description is also important to classifying a CPS task. Skill-based tasks or reactive tasks may be more complex than planning tasks (Quesada et al., 2005). A planning task's future states can be anticipated, and this helps participants design a course of action (Quesada et al., 2005). Knowledge-lean tasks can be solved by the instructions for the task and by using general rules (Quesada et al., 2005). Knowledge-intensive tasks, on the other hand, require specific and very narrow skills to solve a problem

(Quesada et al., 2005). Learning is an important attribute of CPS. The initial theory of problem-solving proposed by Newell and Simon (1972) assumed that there is no learning during problem-solving. However, Quesada, Kintsch, & Gomez (2005) argued that learning is an important factor. Decomposability of a task into smaller sub-tasks may be another criterion to identify the level of complexity (Quesada et al., 2005). These various attributes of complex problems guide the present research on the identification and understanding of complexity associated with the complex problem.

Crowdsourcing performs various micro tasks. Micro tasks are executable in minutes and repetitive in nature (e.g., identifying a person in a photo, phone number verification, or writing reviews). In these types of problems, the solution is known and the objective is clear.

An example of complex problem in crowdsourcing, to analyze the genes involved in the production of antibodies and immune-system sentinels called T-cell receptors, genes are formed from dozens of modular DNA segments located throughout the genome (Lakhani et al., 2013). Genes can be mixed and matched to yield trillions of unique proteins, each capable of recognizing a different pathogen or foreign molecule (Lakhani et al., 2013). Harvard researchers crowdsourced this complex problem in the form of a contest with prize money of $6,000 to Topcoder, a crowdsourcing organization. The challenge was to develop software with better computational power that could determine the origin of the segments that make up antibody and T-cell receptor genes, which is typically a slow process (Lakhani et al., 2013). In response to this problem, the researchers received 122 submissions, and 16 were better than the researchers' attempts to solve the problem (Lakhani et al., 2013).

2.3 User Experience

The focus of this research is to examine the different human factors that lead to positive or negative user experience (UX) as a result of interaction with software products. UX is an experience while interacting with or using technological artifacts (Glanznig, 2012). UX research is still evolving. Therefore, UX concepts are not well-defined and various approaches exist to explain the phenomenon (Glanznig, 2012). Most UX definitions include two premises. First, usability (a performance-oriented view of the product) is not sufficient because it is only part of the result due to users' interactions with the technology artifact. Second, experience and UX are very similar (Glanznig, 2012).

Usability relates to quality aspects of products. According to Bevan (1995), usability is a very narrow product-oriented quality such as reliability or portability, or more broadly, a quality of use (the usability of a product based upon its efficiency, effectiveness, and satisfaction of users in given contest). Efficiency and effectiveness are objective, but satisfaction is a subjective assessment (Hassenzahl, 2001). Assuring the effectiveness and efficiency of a product should guarantee satisfaction (i.e., if users perceive a product's effectiveness and efficiency, then they will be satisfied) (Hassenzahl, 2001). The effects of percieved usefulness (usability, utility, and perceived hedonic attributes such as non-task-related fun factors like originality and innovation) on usage and user satisfaction of software product are equal in terms of perceived fun and usfulness, product usage, and satisfaction (Hassenzahl, 2001; Igbaria, Schiffman, & Wieckowski, 1994; Mundorf, Westin, & Dholakia, 1993). Inclusion of hedonic components, such as games and music, may also increases in the usage intention of a software product.

The second premise, experience, is holistic in nature and dependent upon the users' mental effort rather than discipline (Olsson, 2012). Experience is a subjective phenomenon (dependent upon a user) and the outcome of an interaction between the subject (user) and object (the entire world) (Olsson, 2012). Experience may be an outcome of mental processes based on the continuous assessment of the thoughts and action (Olsson, 2012). Experience is a continuous process, which may involve perceiving emotional acts or mental effort. An experience occurs after a temporarily specified activity, such as solving a problem or working on a project (Olsson, 2012).

2.3.1 Defining User Experience

Hassenzahl and Tractinsky (2006) defined UX as a "consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (complexity, purpose, usability, functionality, etc.) and the environment within which the interaction occurs (organizational/social setting, meaningfulness of the activity)" (p. 95). According to Forlizzi and Batterbee (2004), "emotion is at the heart of any human experience and an essential component of user-product interactions and user experience" (p. 264). "UX is a momentary, primarily evaluative feeling (good-bad) while interacting with a product or service" (Hassenzahl, 2008, p. 12). Various definitions and concepts of UX exist; the common theme in all the definitions is that UX is an outcome of interactions between a user and a product in the form of the user's perceptions and emotions.

2.3.2 Model of User Experience

Researchers used two different concepts to define UX. One group of researchers suggested uncovering the objective in the subjective, and developed a model-based approach (a reductionist approach). The other group suggested that UX is subjective and should be inherent to the concept of UX, and thus developed a framework of thought (phenomenological approach) (Glanznig, 2012).

Hassenzahl (2003) presented a hedonic/pragmatic model of UX. This model suggested users first perceive product features, such as content, presentation, functionality, and presentation style to view a personal version of the apparent product character (pragmatic attributes and hedonic attributes). This apparent product character leads to consequences, such as a product's appeal (good-bad), emotional consequences (satisfaction, pleasure-dissatisfaction, and pain), and behavioral consequences (increased-decreased usage). The consequences are not always the same and may reflect specific usage situations.

Pragmatic quality refers to a product's perceived ability to support the fulfillment of functions or intended tasks. Hassenzahl (2008) referred to these functions or tasks as *do goals* in which software performs intended tasks. Pragmatic quality focuses on the utility and usability of products in terms of intended tasks. Hedonic quality refers to individual psychological well-being and pleasure. According to Hassenzahl (2008), hedonic quality refers to a product's perceived quality to achieve the *be goals*, such as being competent related to others. Hassenzahl (2008) proposed that hedonic quality is composed of hedonic quality stimulation and hedonic quality identification. Hedonic quality stimulation refers to an individual quest for personal development, such as proliferation of knowledge and development of skills. Hedonic quality identification refers to individuals' ways to express themselves through physical objects (Hassenzahl, 2008). Hassenzahl (2008) emphasized that good UX stems from the fulfillment of the human needs for autonomy, competency, stimulation (self-oriented), relatedness, and popularity (other-oriented) through interacting with a product or service.

2.4 Conceptual Model

The crowdsourcing of ideas originated from the notion *that the wisdom of a crowd may be better than solutions created by specialists or small groups* (Dalkey & Helmer, 1963; Galton, 1907; Gurnee, 1937; Kittur et al., 2007; Surowiecki, 2004). There are contentions in literature that show crowdsourcing software development can produce better solutions than those developed by professionals, particularly in the case of simple problems. However, there is still very little evidence to support that this is also true for CPS. Therefore, the primary research question driving this dissertation is as follows:

RQ: In the context of complex problems, does software developed by the crowdsourcing business model achieve the same or better quality compared to software developed by professionals?

This research incorporates a conceptual model adapted from Hassenzahl (2003) to address the research question. A conceptual model is a graphical lens for communicating the specification of things, events, or processes (Wand, Storey, & Weber, 1999). The following figures present the conceptual model as the theoretical lens to guide the rest of the research.

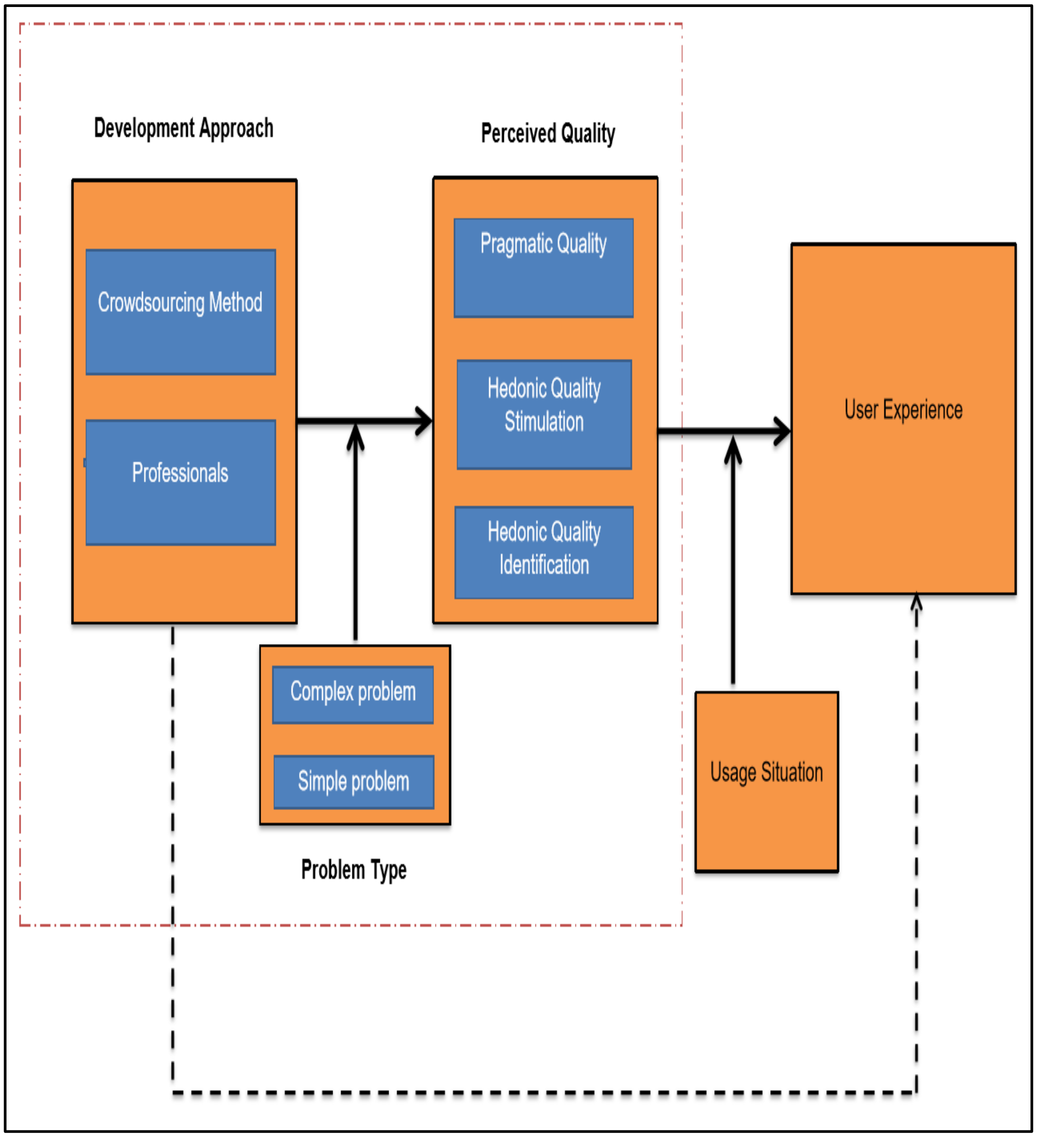

Figure 4 : Extended conceptual model.

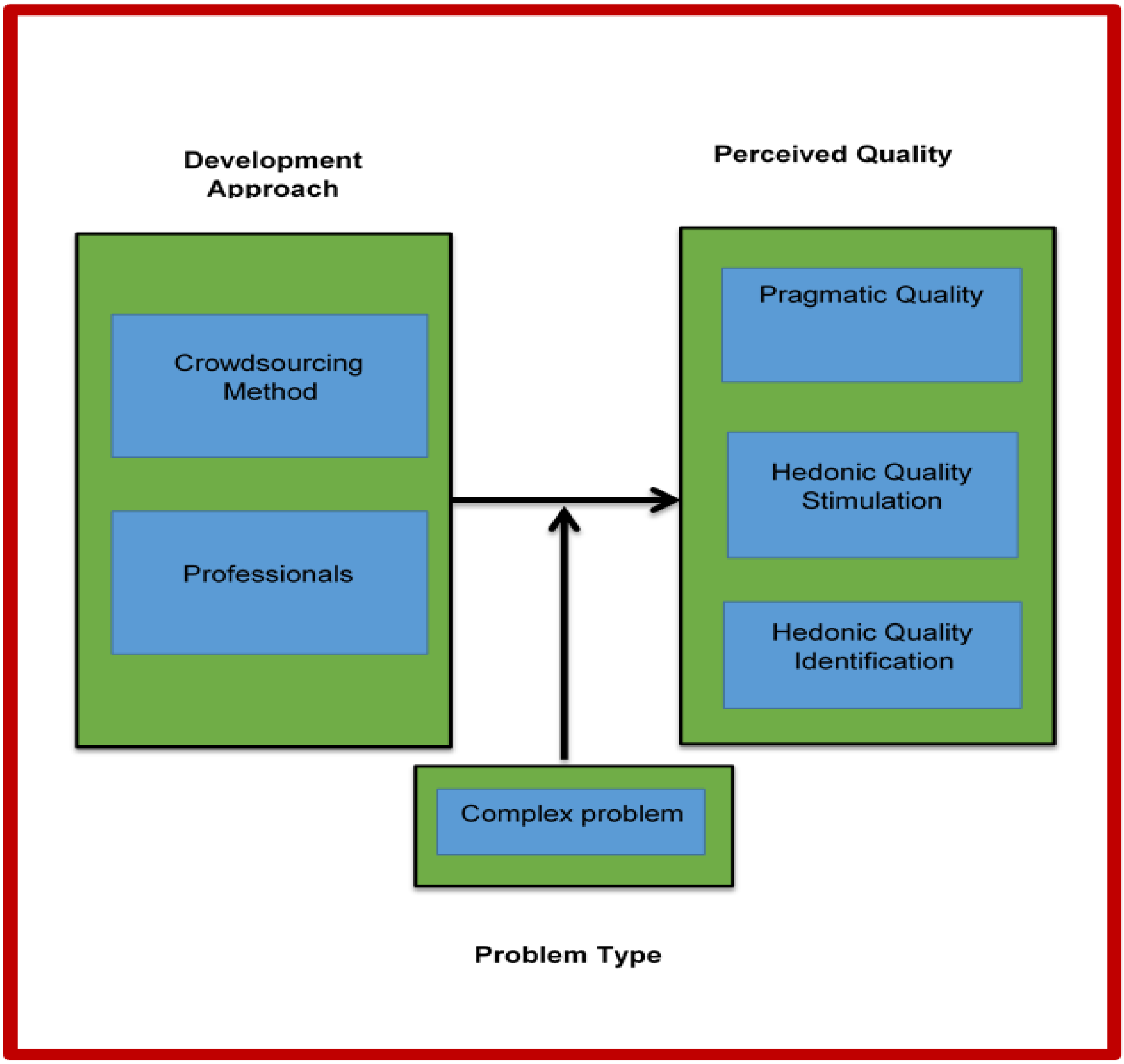

Figure 5: Conceptual model.

Drawing on previous theoretical studies, the researcher assumed that the development approach (by the crowdsourcing or professional method) influences perceived quality, which is moderated by the complexity of the problem. Further, this perceived quality has consequences (i.e., UX is moderated by a specific usage situation whether or not it is a task-oriented usage). The researcher only tested the shaded region of the extended conceptual model shown in Figure 4. The development approach (by crowdsourcing or professionals) may impact perceived quality, which is moderated by the complexity of the problem as shown in Figure 5. This framework guided the design of the study. In summary, pragmatic quality, hedonic quality stimulation, and hedonic quality identification are characteristics of the perceived quality of contest-based crowdsourced software.

2.5 Summary of Chapter 2

This chapter presented the history and current status of literature on crowdsourcing in relation to its ability to solve various types of problems. This dissertation focuses on perceived quality of crowdsourced software design for a complex problem. This chapter reviewed research related to theoretical status and various typologies presented in crowdsourcing environments. The chapter concluded with the presentation of the conceptual model that serves as the theoretical foundation that guides the research. The model illustrates that the development approach (by the crowdsourcing or professional method) influences the perceived quality of software designed by these two methods.

CHAPTER 3: RESEARCH METHOD

This chapter includes the general method to address the research question and research model. This research utilized a quasi-experimental research design using a survey questionnaire to evaluate the research question and associated model. The researcher conducted a pilot study to refine the survey items as necessary. Chapter 3 describes the research design in detail.

3.1 Scope of the Study

Previous research established that crowdsourcing is a problem-solving model (Bonabeau, 2009; Datta, 2008; Howe, 2008; Jack, 2009; Surowiecki, 2004). However, there is no consensus regarding crowdsourcing as a CPS model. Therefore, this dissertation focused specifically on the comparison of perceived quality between a crowdsourced solution and professionals' solution as an outcome of CPS.

3.2 Methods

This dissertation is a quasi-experimental field research design. A quasi-experimental design is ideal for situations in which full experimental control and the full control of a true experimental design or randomized controlled trials are not possible (Sproull, 2002). In this study, the random assignment of subjects to treatments (crowds and professionals) was not feasible. A quasi-experimental design provides an alternative to controlling the assignment of subjects to the treatment by using criterion other than random assignment (Sproull, 2002). In true experiments, researchers have no control over manipulations that may occur. Using self-selected groups in a quasi-experimental design mitigates the chances of ethical and conditional biases. A quasi-experimental design minimizes the chances of external validity because it happens in a natural setting as opposed to a well-controlled laboratory setting (Sproull, 2002). Lack of randomization may pose a threat to internal validity, and it may be difficult to rule out confounding variables (Sproull, 2002).

The study relied on quantitative data to measure perceived quality: pragmatic quality, hedonic quality identification, and hedonic quality stimulation of the solutions developed by crowdsourcing and professionals. Qualitative data supplemented results and provided further explanation of the findings. A combined qualitative and quantitative data analysis approach provides a careful review of combined data sources and offers explanations to improve understanding of the research model (Owens et al., 2011). An overview of research method is presented in figure 6.

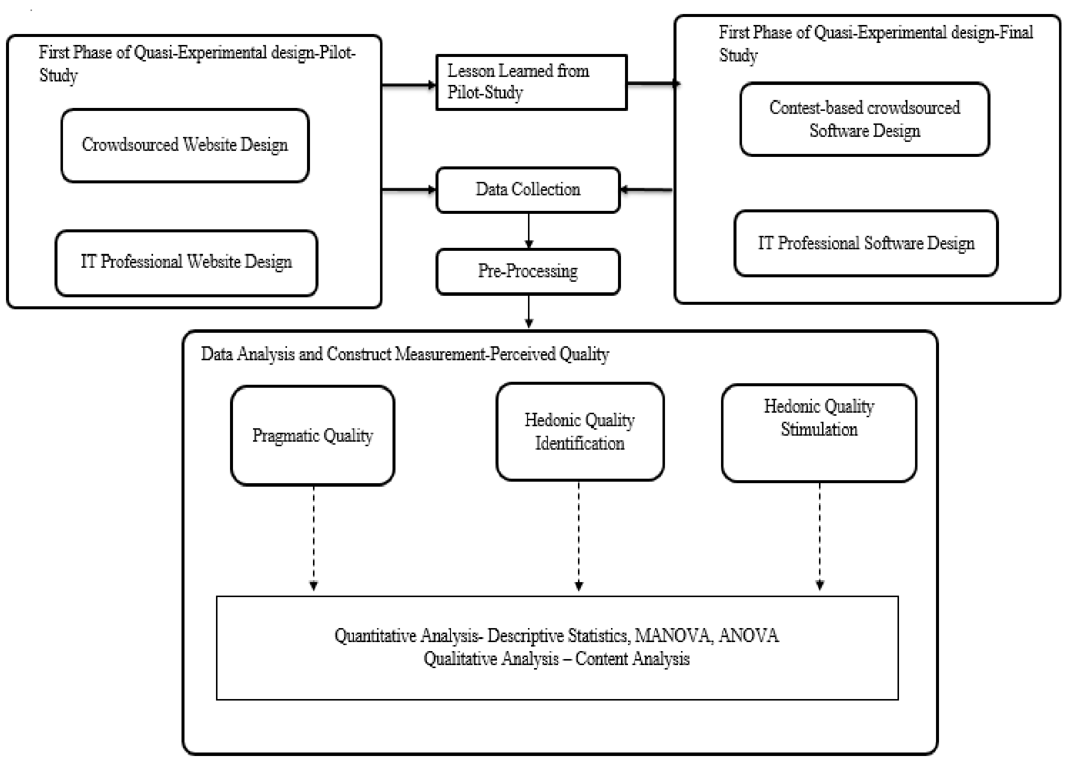

Figure 6: The Research Method

3.3 Research Setting, Participants, and Tasks

3.3.1 Research Setting

Topcoder, a private crowdsourcing organization, formed the crowds for the study. Topcoder is the world's largest competitive software development portal (Archak, 2010). Topcoder has more than one million active users.[2] Organizations such as NASA, DARPA, Honeywell, and HP use Topcoder as their crowdsourcing partner. Topcoder focuses the contest-based crowdsourcing model on completing all tasks in software development (Lakhani, Garvin, & Lonstein, 2010). Topcoder hosts algorithm, software design, coding, development, and data science problems to cater to client needs.

Prior to conducting the full study, the researcher implemented a pilot study with students from the University of Nebraska at Omaha's (UNO's) College of Information Science & Technology's (IS&T). The College of IS&T's professional group represented IT professionals in this study. The Attic, a group supported and housed at UNO's College of IS&T, consists of undergraduate and graduate students managed by full-time professionals learning skills in web development and multimedia presentation technologies. The Attic represented the crowd. The Attic employs an average of 15 to 20 team members each semester. The team successfully completed more than 12 projects of considerable complexity, ranging from website development to mobile application development. The Attic team works closely with client organizations throughout the software development life cycle to provide a high-quality software product. Moreover, the Attic follows standard practices (e.g., Agile development) for software development.

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[2] www.topcoder.com

3.3.2 Tasks

Previous studies identified *the task* as an important variable and used the task as a lens through which to study CPS. Problem-solving is a task-centered field (Quesada et al., 2005). In this study, the researcher crowdsourced a task to develop software; professionals solved the same task.

3.3.2.1 Pilot Study Task

The researcher asked students to design and develop a website for the UNO Alumni Association by means of an open call (an announcement in the UNO's College of IS&T via email). Participation was voluntary. IS&T's web development community, the Attic, was the professional group for this pilot study. The researcher used the pilot study to confirm adequacy of methods and research instruments. This section describes the task for the pilot study.

During the 100th anniversary of the UNO Alumni Association, a marketing campaign required a website to promote the Alumni Association and UNO. The UNO Alumni Association needed a way for UNO alumni to submit images of themselves with a UNO flag. The website must allow users to upload a picture, which would be approved by a content administrator. The pictures should appear on a map to highlight the *current location* of the UNO flag. The site needed to show a large-scale map that geographically represented UNO graduates. A content administrator would manage picture submissions, remove inappropriate submissions, and select the best photo from each submission.

The researcher used the website design and development task for pilot study because understanding and managing of website structures are complex tasks (Coda, Ghezzi, Vigna, & Garzotto, 1998). Like any other software development effort, website development processes can involve requirements analysis, design, and implementation, which makes it a complex, challenging, and creative process (Wu et al., 2013). The pilot study project was 2-weeks long. The goal was to develop a website that met the Alumni Association requirements. The website development project was consistent with the mission of IS&T, which aims to introduce students to various important concepts related to innovative and creative technology to solve real-life challenges and problems.

3.3.2.2 Final Study Task

For this research, the problem was to design a disaster management gaming application. The aim of the game was to educate students about the disaster management information system discipline. The design and development of an educational gaming application that would simulate approaches to managing a disaster is a complex problem.

Good computer and video games are learning machines (Gee, 2003). These games include a set of learning principles, which is in line with research in cognitive science (Bruer, 1993; Clark, 1997). Good games incorporate problems specifically designed to allow learners to form generalizations about what will work later when they face more complex problems (Gee, 2003). Educational researchers frequently use game-based problems to investigate learning (Gee, 2003). Previous IS research rarely takes into account *task complexity* when designing gaming software for learning purposes, particularly tasks that use a simulation model as a substitute for a real-world model or system (Gee, 2003).

When a disaster strikes, the task environment requires multiple organizations to transform from autonomous agents into interdependent decision-making teams (Janssen, Lee, Bharosa, & Cresswell, 2010). Solving disaster-related problems is a complex process with time pressures, a high degree of uncertainty, and many stakeholders (Lee, Bharosa, Yang, Janssen, & Rao, 2010). These dynamics add to the complexity and uncertainty of a disaster management system.

A disaster is a continuously unfolding situation, marked by changes in urgency, scope, impact, the types of appropriate responders, and the responders' needs for information and communication; and to ensure coherent coordination among the responding organizations, relevant information needs to be collected from multiple sources, verified for accuracy and shared with appropriate responding organizations, all within a short time frame. (Janssen et al., 2010, p. 1)

Due to scarce resources, high uncertainty, and involvement of various stakeholders, it is infeasible to develop IS for a disaster situation (Janssen et al., 2010). Any form of response to a disaster, either natural (e.g., floods and earthquakes) or human induced (e.g., terrorist attacks) is a complex process (Bigley & Roberts, 2001) in terms of the number of actors, IS, and the interactions between actors and IS (Janssen et al., 2010). In extreme environments, not all relevant information is known (Janssen et al., 2010).

The researcher gave the project requirement to design a disaster management gaming application to the Topcoder contest website via an open call.[3] Anyone could view the details of the contest. To participate in the contest, participants had to become a member of the Topcoder community. Details of the contest included the challenge description, context, deliverables, resources and constraints, timeline, and reward for the winners. The

[3] https://www.topcoder.com/challenge-details/30054725/?type=design#viewRegistrant

project requirements appear in Table 7. The crowdsourcing participants had four weeks to complete the project. The overall project divided into two phases.

Table 7: Requirements for the disaster management game.

Challenge Description	The final goal of this project is to design the screens for our game. We are looking for the [topcoder] design community to help us with planning our new "user experience" (UX).
Game Context:	The game provides a simulation of a scenario where a town is affected by a disastrous event such as a tornado. The users of the game can access various resources (e.g., a scout team, money, ambulances, base camp, and hospitals) in order to rescue affected persons. This game also tracks and updates the various resources used during rescue operations.
User Flow	When a disaster such as tornado strikes, effective utilization of resources is critically important. Various important resources can be availability of volunteers, ambulances, money, hospitals, and safe places to keep persons who are impacted. The users should have access to this information and be able to use the resources to take decisions and respond appropriately to help in the rescue operations.
Required Screens	1. App Icon: We need an app icon graphic and text for Vitality. - Sizes 120x120, 180×180, 1024×1024. - Show something that conveys the idea clearly and simply as an app icon. 2. Splash Screen: We need a background image for front page; please design one that matches the game theme and don’t use a stock photo for this purpose. - Place a logo text (Disaster Management Game). - Loading status bar. Remains while game is loading. - Should be consistent in appearance and use for

	both an icon and as a logo. 3. Dashboard: User will have a personalized welcome message. - User can logout from the game from this view. - User ranking. - Points gathered by user. - View leaderboard link. - Badges user earned. - “Start Game” button. 4. HUD: This area holds the scoring and various elements like: - Status Score. - Game timer.
Game Characters	The Scout: It is a team of volunteers. You can add the volunteers during the game. - The Vehicles: While the scout team searches, your vehicles (helicopter, ambulance, bus, and car) drive the wounded from the camp to the hospital. There should be some provision (it should have type of vehicle- ambulance, capacity to carry wounded, money needed, volunteers needed) where user can buy vehicles. They will automatically drive to the camp and grab the wounded. - The Camp: This is where your vehicles will pick up the wounded and take them to the hospital. Users can also build mobile hospital tents here for a price. There should be some provision in the game that can show the number of wounded at camp and patients at the medic site. - The Hospital: Your vehicles will head to the hospital from the camp. Once they get to the hospital, there should be provisions to show the new number of survivors. From here, users can track how many people they have saved. - The Media: Media can be used to attract help. Users can spend money to bring volunteers or use

	volunteers to raise money. If users have a shortage of money, they can get help from the media. There should be some way so that users can have an idea what you get, how much you get, and what is the cost. - Accessories: There should be some provision for accessories such as lights. Users should be able to buy lights and use up volunteers. Once built/implemented, most will give back the volunteers but not the money. - The currency: This might be an information provider to the users. Users can see how much money and volunteers are at their disposal. Users will get money and volunteers periodically. Also, if users are building anything, they can see it here. - The Time: Keep an eye out for your time limits. Eight minutes will be the time limit for the game. Save as many people as you can during this time.
App Tutorial Popup	- Design an App Tutorial popup containing the following: -- Explanation of game objective. -- Explaining every game character mentioned in point 5. - In-game screen examples with text explaining how to play the game. - These can be scroll-through screens if you feel it is appropriate. - A “close” button at the end.
Invision App	You need to present your work in InvisionApp so the client can see the workflow you suggest. This should be included for Round 1.
Design Considerations	The page layout should be intuitive and uncluttered. - The designs should be readily scalable to

	different screen sizes and aspect ratios.
Screen Sizes	Tablet Resolution: Design for iPad Retina Display 2048px x 1536px. - Height can expand if needed, but scrolling should be minimal and avoided if possible. Make sure you create graphics in 'shape' format, so when we resize graphics will still look sharp. Important: Keep things consistent. This means all graphic styles should work together. - All of the graphics should have a similar feel and general aesthetic appearance.
Target audience	High school students.
Judging Criteria	How well you plan the user experience and capture your ideas visually. - Cleanliness and “catchiness” of your graphics and design. - Educational and fun experiences!
Submission & Source Files.	Preview Image - Please create your preview image as one (1) 1024x1024px JPG or PNG file in RGB color mode at 72dpi and place a screenshot of your submission within it. Submission File- Submit JPG/PNG for your submission files. Source Files- All original source files of the submitted design. Files should be created in Adobe Photoshop and saved as layered PSD file, or Adobe Illustrator as a layered AI file. Final Fixes- As part of the final fixes phase, you may be asked to modify your graphics (sizes or colors) or modify overall colors. We may ask you to update your design or graphics based on checkpoint feedback. STOCK PHOTOGRAPHY- Stock photography is allowed in this challenge.
How to submit	Upload your submission in three parts (Learn more here). Your design should be finalized and should

	contain only a single design concept (do not include multiple designs in a single submission). If your submission wins, your source files must be correct and "Final Fixes" (if applicable) must be completed before payment can be released. You may submit as many times as you'd like during the submission phase, but only the number of files listed above in the Submission Limit that you rank the highest will be considered. You can change the order of your submissions at any time during the submission phase. If you make revisions to your design, please delete submissions you are replacing.
Winner selection	Submissions are viewable to the client as they are entered into the challenge. Winners are selected by the client and are chosen solely at the client's discretion.
Payments	Topcoder will compensate members in accordance with the payment structure of this challenge. Initial payment for the winning member will be distributed in two installments. The first payment will be made at the closure of the approval phase. The second payment will be made at the completion of the support period.

3.3.3 Participants

Prior to soliciting participants for the study, the researcher obtained IRB approval for the research design (see Appendix E). The participants in the pilot study consisted of a crowd of students and a professional web development community at University of Nebraska at Omaha (UNO). The students at UNO in this research form the crowd; and the professional group is represented by the UNO's web development community called the Attic.

The participants in the final study task were all Topcoder community members. Topcoder designed a disaster management application via contest-based crowdsourcing. The crowds were Topcoder community members who participated via an open call on the Topcoder website. The researcher served as the project sponsor (problem owner). Topcoder assigned a co-pilot (project manager) from the crowd. The co-pilot is a skilled community member responsible for getting the requirements and translating the requirements into a more detailed requirements document. The co-pilot served as a project manager and was responsible for managing the project (contest-based crowdsourcing). The project sponsor could only communicate to the crowds (participants of the contest) via the co-pilot.

A total of 31 Topcoder community members registered to participate in the project; participants could register any time during the contest to participate. Out of the 31 registered users, six users submitted design solutions for the disaster management gaming contest. The following tables and figures provide demographic information about the participants in the crowdsourcing gaming contest.

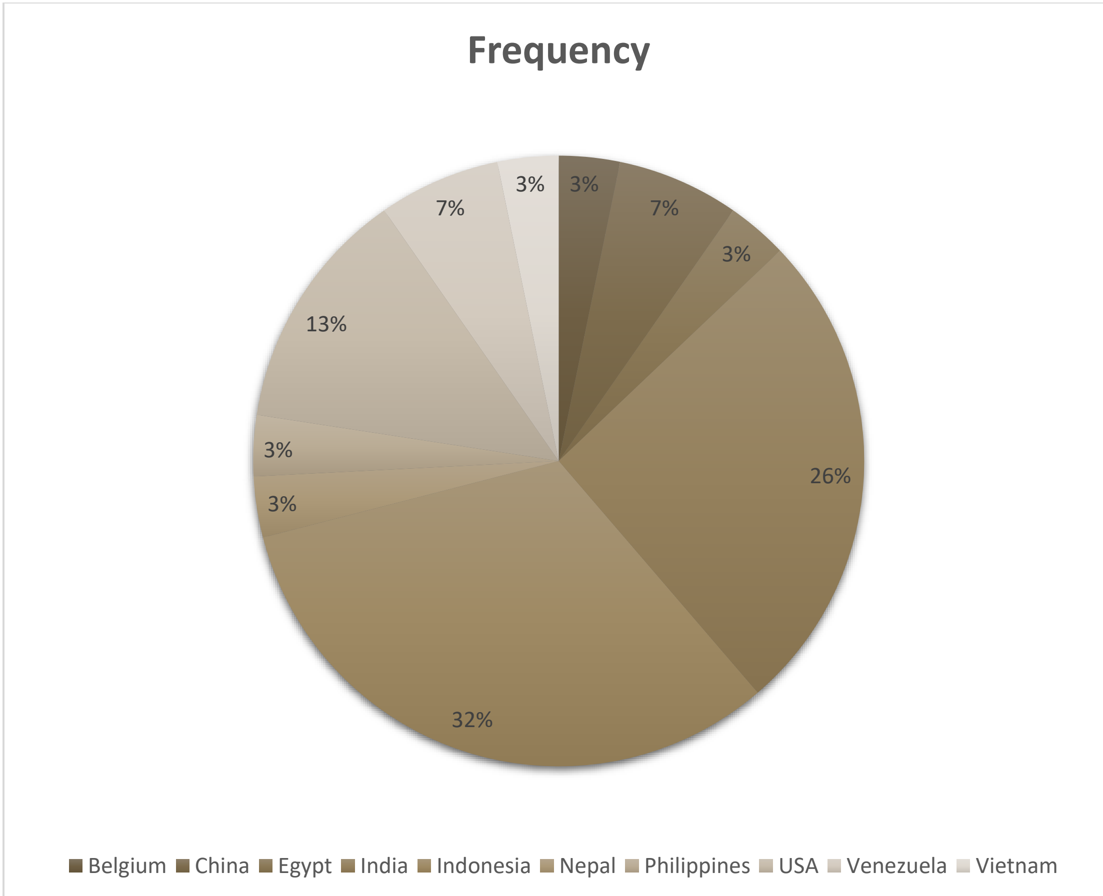

Figure 7: Country of participants.

Of all participants in the contest, 32% were from Indonesia, and 26% were from India. Other participants were from countries such as Belgium, China, Egypt, Nepal, Philippines, the USA, Venezuela, and Vietnam. Participants had a wide variety of skills and expressed interest in fields such as web design, development, idea generation, and data analytics. Of the 31 participants, 11 of them were previous winners in other crowdsourcing contests.

UNO's web development community, the Attic, was the IT professional group. Both parties (the crowd and professionals) designed software independently. The timeline to design the software was approximately four weeks. Once the software was designed by the crowdsourcing model, the researcher worked with an experienced software professional to rank each of the six submitted designs based on the perceived quality survey questionnaire.

3.4 Data Collection and Measurement

The study measured the perceived quality of the software developed by the crowdsourcing development approach and the traditional development approach (by professionals). In this regard, the variables included the following:

1. Independent variable: Development approach.
2. Dependent variables: Pragmatic quality, hedonic quality stimulation, and hedonic quality identity.
3. Moderating variable: Problem type (complex problem).

The researcher collected both quantitative and qualitative data to gain a rich understanding of the data through triangulation. Students at UNO completed a web-based survey to measure the perceived quality.

Table 8 : Data sources for data collection.

Construct	Measures	Source
Pragmatic Quality	Survey instrument Open-ended questions	(Hassenzahl & Monk, 2010).
Hedonic Quality Identification	Survey instrument Open-ended questions	(Hassenzahl & Monk, 2010).
Hedonic Quality Simulation	Survey instrument Open-ended questions	(Hassenzahl & Monk, 2010).

3.4.1 Quantitative Data Collection

The researcher collected quantitative data using web based survey questionnaires.[4,5] This research relied on existing measures to evaluate pragmatic quality, hedonic quality stimulation, and hedonic quality identification. To evaluate perceived quality, the researcher adopted the survey questionnaire developed by Hassenzahl and Monk (2010). Dr. Hassenzahl gave permission to use the survey to assess the perceived quality of software design. The survey instrument included a 7-point Likert-scale measuring perceived quality of a software product (see Appendix C). Table 9 lists details of the survey questionnaire.

Table 9: Survey items and sources.

Concept	Survey Item	Source
Pragmatic Quality	Technical-Human	(Hassenzahl & Monk, 2010).
	Complicated-Simple	
	Impractical-Practical	
	Cumbersome-Straightforward	
	Unpredictable-Predictable	
	Confusing-Clearly structured	
	Unruly-Manageable	
Hedonic Quality Identification	Isolating-Connective	(Hassenzahl & Monk, 2010).
	Unprofessional-Professional	
	Stylish-Tacky	
	Cheap-Premium	
	Separates me from people-Bring me closer to people	
	Unpresentable-Presentable	
	Alienating-Integrating	
Hedonic Quality Simulation	Conventional-Inventive	(Hassenzahl & Monk, 2010).
	Unimaginative-Creative	
	Bold-Cautious	
	Conservative-Innovative	

[4] https://www.surveymonkey.com/r/ATCSQA
[5] https://www.surveymonkey.com/r/ATCSQB

	Dull-Captivating	
	Undemanding-Challenging	
	Ordinary-Novel	

3.4.2 Qualitative Data Collection

Participants answered open-ended questions about the pragmatic quality, hedonic quality stimulation, and hedonic quality identification. Table 10 presents details of the open-ended questions. Qualitative data offers a variety of strengths. Qualitative data supplements and illuminates quantitative data by providing more explaining ability in the same setting (Miles & Huberman, 1994). The qualitative data provide vivid descriptions, richness, and holism. Most importantly, qualitative research does not strip away the local context (Miles & Huberman, 1994).

Table 10: Open-ended questions.

Q1) Pragmatic quality refers to a product's perceived ability to support the fulfillment of functions or intended tasks. Pragmatic quality is functions or tasks as "do goals" (software is performing intended tasks). Pragmatic quality focuses on the utility and usability of products in terms of intended tasks. What do you think about the pragmatic quality of this gaming app prototype design?
Q2) Hedonic Quality Stimulation refers to an individual quest for personal development such as proliferation of knowledge and development of skills. So, software should provide new impressions, opportunities, and insights. Why do you think about the Hedonic Quality Stimulation of this gaming app prototype design?
Q3) Hedonic Quality Identification refers to individuals' ways to express their selves through physical objects. To fulfill this need, a software product has to communicate identity. Why do you think about the Hedonic Quality Identification of this gaming app prototype design?

3.5 Final Project Setup and Procedures

Topcoder community members participated in a contest-based crowdsourced software design project. The choice of Topcoder as a crowdsourcing organization and use of contest-based crowdsourcing reflected lessons learned from the pilot study. The pilot study revealed the importance of contest-based crowdsourcing and the use of a crowdsourcing organization to simulate the crowd, increasing the number of participants and quality of solutions. The reward for the first winner was $1,300. The second winner received $300, and the third winner received $150. There was also a $50 reward for each of five checkpoint solutions. Topcoder suggested the award amounts based on experience with crowdsourcing projects. Topcoder offers a wide range of crowdsourcing product solutions. For the design of a crowdsourced software project, they charge $3,500, which includes reward funds. The Graduate Research and Creative Activity (GRACA) 2016 grant from UNO funded this project.

The disaster management gaming application design contest ran from June 27 to July 21, 2016. The first step for the crowdsourcing project was to upload the initial requirements to the Topcoder web-space. Table 11 includes details of the initial requirements document.

Table 11: Initial requirements.

Name your Project	Disaster Management Game
Select your target devices	IPAD
Define your app (how many pages APP need?)	1
Describe your app	The aim of this game is to educate the user about how information is used in a

	humanitarian crisis decision-making setting in an engaging way. This project is intended to provide an interface with a simulation of a scenario where a tornado has demolished a town and many people are wounded. The objective of the game is to optimally manage resources while saving as many lives as possible.
What are the main features of the application?	The game provides a simulation of a scenario where a town is affected by disastrous events such as a tornado. The users of the game can access various resources (the scout team, money, ambulances, base camp, and hospitals) to rescue affected persons. This game also tracks and updates the various resources used during rescue operations.
Describe the users of this app	The primary target audience is high school students.
Describe what user does (user flow) in the application	When a disaster such as a tornado strikes, effective utilization of resources is critically important. Various important resources can include volunteers, ambulances, money, hospitals, and safe places to keep the impacted persons. The users should have access to this information and be able to use the resources to take decisions and respond appropriately to help in the rescue operations.
Scope Statement	The scope of the project, “Disaster Management Game,” is to design and build an iPad gaming app for

	understanding disaster management during a tornado-like event. The goal is to educate the users about the application of information technology in crises and enhance decision-making abilities in case of such events.
Deliverables	Gaming APP for crisis management.
Timeline	Four weeks to complete the project and deliver the final app.

After the completion of the design specification document, Topcoder asked its community members to participate in the contest. A total of 31 community members registered for the contest and six submitted designs in the first phase of the contest. A professional software specialist worked with the researcher to rank the designs based on the perceived quality questionnaire. Based on the average ratings across the three constructs of perceived quality, the researcher ranked all six designs and communicated the rankings along with the feedback to the co-pilot for improvements to the design for the second round. For the second phase, the previous phase design participants submitted final designs with changes based on the feedback. After the completion of the second round, the researcher and professional software specialist again ranked the designs based on the perceived quality questionnaire and selected a winner.

The professional group, the Attic, also developed a design for the disaster management game. The time duration to design the disaster management gaming application was almost the same for both the development method and the crowdsourced method. The timeline for the development of the design was different. Both the crowdsource participants[6] and IT professionals[7] submitted prototypes of software designs via the InvisionApp.

Table 12: Findings from the Pilot Study

Pilot Study	Finding	Changes to Research Design
Task Design a UNO Alumni Website	The task was not complex enough and did not offer participants to demonstrate the technological expertise.	The task was modified to include a more complex task – to design a disaster management gaming app prototype.
Participants Six undergraduate and graduate-level class of students participated as the *crowd*. Attic served as IT professional group.	Only 3 students submitted solutions. one of the three solutions from the crowd was a prototype. The websites had static features and not all features incorporated into the solution. This submission may be the result of absence of motivation, such as a reward, for participation in the process. The submission of a partial solution could also be due to a lack of specific guidelines in terms of the expectations of the final solution.	The pilot study revealed the importance of contest-based crowdsourcing and the use of a crowdsourcing organization to simulate the crowd, increasing the number of participants and quality of solutions. The final study included contest-based crowdsourcing with rewards for the top three submissions, as well as some rewards for checkpoint submissions. Crowdsourcing participants received specific guidelines for completion of the project.
Timing The pilot was two-week project and timeline to develop the project was not same	The difference in development time to provide a solution may have some research biases.	A three-week design contest to develop a software prototype for the crowdsourcing as well as IT professional method.

[6] https://invis.io/8J82D5RNH
[7] https://projects.invisionapp.com/share/TK84YPJRH#/screens

3.6 Statistical and Data Analysis Methods

This study was a mixed method design using quantitative and qualitative methods that relied on existing measures to evaluate variables: pragmatic quality, hedonic quality stimulation, and hedonic quality identification. Data included responses from surveys, open-ended questionnaires, and focus group discussions. A triangulation approach included analysis of data by examining the content of open-ended questions while simultaneously considering the survey results. Upon obtaining the completed survey questionnaire from the students, the researcher performed a multivariate analysis of variance (MANOVA). MANOVA is simply an analysis of the variance (ANOVA) with several dependent variables. Performing a MANOVA addressed the following issues: (a) the importance of dependent variables; (b) the interactions and main effects of the independent variables; (c) the strength of association between the dependent variables; and (d) the effects of the covariates (French, Macedo, Poulsen, Waterson, & Yu, 2008).

MANOVA is useful in this experimental situation and is advantageous over ANOVA. Using MANOVA, the researcher measured several dependent variables in a single analysis, leading to identification of the factor that is statistically significant. Second, performing a MANOVA helped avoid a Type I error, which cannot be controlled if a researcher simultaneously conducts several independent ANOVAs (French, Macedo, Poulsen, Waterson, & Yu, 2008). Further, the researcher evaluated synthesized observations based on participants' comments and perceived quality perceptions from the survey to develop a holistic assessment of the results (from survey responses and participants' comments).

3.7 Summary of Research Design

This chapter presented the detailed research design and lessons learned from the pilot study. The researcher employed a quasi-experimental research design using mixed methods for data collection. Chapter 4 presents the findings from the analysis of the results of the final study.

CHAPTER 4: ANALYSIS OF RESULTS

This chapter presents the results of this study. First, Chapter 4 includes an analysis of the pilot study results. Next, the chapter provides details of the quantitative and qualitative analysis and discussion of the results of the final study in relation to the research question.

4.1 Pilot Study Data Analysis

The researcher completed quantitative data analysis of the survey results and qualitative data analysis on the focus group interviews. This research involved statistical analysis methods such as descriptive statistics and MANOVA for the survey data. The researcher performed an assumptions test on survey data, which included a test of homogeneity, test of normality, and correlation analysis. For the analysis of qualitative data, the researcher used a strategy suggested by Miles and Huberman (1994). The researcher compiled qualitative data based on constructs, then generated findings based on careful review of the compiled data.

4.2 Pilot Study Results

During the pilot study, the researcher collected data from a sample survey of 66 participants for each website developed by the crowdsourcing method and IT professionals and conducted nine focus group interviews. The survey items for this study included established, validated scales of measurement of the constructs. Three constructs measure the perceived quality of the software product: pragmatic quality, hedonic quality stimulation, and hedonic quality identification. The following sections describe the quantitative analysis results for the multivariate analysis and univariate analysis followed by the results of the focus group data analysis.

4.2.1 Multivariate Results

To compare the perceived quality of the website developed by the crowdsourcing model and professionals, the researcher conducted a multivariate test (MANOVA) because there were three dependent variables: pragmatic quality, hedonic quality stimulation, and hedonic quality identity. The alternative hypothesis was that the development approach (crowdsourcing method and professionals' method of software development) has an effect on pragmatic quality, hedonic quality stimulation, and hedonic quality identity. Table 13 shows that the p-value is very close to zero, which is less than all values of level of significance (alpha). Therefore, the development approach (crowdsourcing method and professionals' method of software development) has a statistically significant result on overall perceived quality.

Table 13: Multivariate tests.

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.977	1840.310[a]	3.000	128.000	.000
	Wilks' Lambda	.023	1840.310[a]	3.000	128.000	.000
	Hotelling's Trace	43.132	1840.310[a]	3.000	128.000	.000
	Roy's Largest Root	43.132	1840.310[a]	3.000	128.000	.000
Development Method	Pillai's Trace	.157	7.960[a]	3.000	128.000	.000
	Wilks' Lambda	**.843**	**7.960[a]**	**3.000**	**128.000**	**.000*****
	Hotelling's Trace	.187	7.960[a]	3.000	128.000	.000
	Roy's Largest Root	.187	7.960[a]	3.000	128.000	.000

4.2.2 Univariate Results

The MANOVA test also provides the ANOVA table to test the mean difference of each of the dependent variables. Table 14 shows that the p-value for the hedonic quality stimulation (HQSL) and hedonic quality identity (HQIL) is close to zero, suggesting that the development approach has an effect on HQSL and HQIL. For pragmatic quality (PQL), the p-value is 0.107 and is greater than any value of level of significance, which suggests that PQL has no effect on the development approach.

Table 14: ANOVA tests of between-subjects effects.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	HQIL	28.29a	1	28.29	23.705	.000
	PQL	2.4b	1	2.4	2.637	.107
	HQSL	12.32c	1	12.32	8.697	.004
Development Method	HQIL	**28.29**	**1**	**28.29**	**23.705**	**.000*** **
	PQL	**2.4**	**1**	**2.4**	**2.637**	***.107***
	HQSL	**12.32**	**1**	**12.32**	**8.697**	**.004*** **
Error	HQIL	155.16	130	1.19		
	PQL	118.34	130	0.91		
	HQSL	184.22	130	1.42		
	HQSL	2,683.89	132			
Corrected Total	HQIL	183.45	131			
	PQL	120.74	131			
	HQSL	196.55	131			

a. R Squared = .154 (Adjusted R Squared = .148)

b. R Squared = .020 (Adjusted R Squared = .012)

c. R Squared = .063 (Adjusted R Squared = .055)

*** (significant at all alpha); ** (Significant at 0.05 and 0.01); * (Significant at 0.01)

Table 15 shows that the average response rate for HQIL and HQSL for the professional-based development approach is 5.2 and 4.6, respectively. This is more than the average response rate for the crowdsourcing model-based approach of 4.27 and 4.03, respectively. For PQL, the average response rate for the professional-based development approach is 5.2, compared to 4.95 for the crowdsourcing model-based approach. The univariate analysis, however, suggests that this difference is not statistically significant.

Table 15: Descriptive Statistics.

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
HQIL	Crowdsourcing Method	66.0000	4.2778	1.3491	.1661	3.9461	4.6094
	Professional Method	66.0000	5.2037	.7530	.0927	5.0186	5.3888
	Total	132.0000	4.7407	1.1834	.1030	4.5370	4.9445
PQL	Crowdsourcing Method	66.0000	4.9515	1.0949	.1348	4.6824	5.2207
	Professional Method	66.0000	5.2212	.7885	.0971	5.0274	5.4150
	Total	132.0000	5.0864	.9600	.0836	4.9211	5.2517
HQSL	Crowdsourcing Method	66.0000	4.0354	1.2758	0.1570	3.7217	4.3490
	Professional Method	66.0000	4.6465	1.0984	0.1352	4.3765	4.9165
	Total	132.0000	4.3409	1.2249	0.1066	4.1300	4.5518

4.2.3 Qualitative Data Analysis

To strengthen the results obtained from the quantitative data analysis, the researcher conducted a focus group study. Nine students participated in the study. They browsed the websites developed by the crowdsourcing method and by professionals, and responded to a questionnaire consisting of four questions (see Table 16).

Table 16: Focus group questions.

Q1) Pragmatic quality refers to a product's perceived ability to support the fulfillment of functions or intended tasks. Pragmatic quality refers to functions or tasks as "do goals" (software is performing intended tasks). Pragmatic quality focuses on the utility and usability of products in terms of intended tasks. Why do you think that there is no difference in the pragmatic quality of both websites?
Q2) Hedonic Quality Stimulation refers to an individual quest for personal development such as proliferation of knowledge and development of skills. So, software should provide new impressions, opportunities, and insights. Why do you think that there is a difference in the Hedonic Quality Stimulation of both websites?
Q3) Hedonic Quality Identification refers to individuals' ways to express their selves through physical objects. To fulfill this need, a software product has to communicate identity. Why do you think that there is a difference in the Hedonic Quality Identification of both websites?
Q4) User Experience is a "consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (complexity, purpose, usability, functionality, etc.), and the environment within which the interaction occurs (organizational/social setting, meaningfulness of the activity)." Why do you think that there is a difference in the User Experience of both websites?

The compiled focus group responses suggested that there is no difference in the PQL of the websites developed by the crowdsourcing method and professionals' method. Both websites are similar in terms of presentation, goals, and standards. Most of the respondents perceived that hedonic quality stimulation (HQSL) was higher for the websites developed by the professionals. For hedonic quality identification (HQIL), the response was mixed. Some respondents suggested that they related to the website developed by the crowdsourced method because it provided an interactive way to display content such as images and more opportunity for users to express themselves. Participants felt that users may be motivated to use this website due to these traits. Other responses suggested that the website developed by professionals provided a high-level functionality and seemed *complete*.

4.3 Descriptive Analysis of the First Phase of the Final Study

This section includes a descriptive overview of how the crowds participated in the project and descriptive statistics of the raking of their solution. Every application designed and developed by Topcoder's crowdsourcing environment followed the standard software development guidelines: project specification, architecture, design, development, assembly, deployment, and bug finding. Each of these phases is posted on the Topcoder website as a contest. Topcoder community members can participate in the contest and submit a solution. The winning solution of the previous phase serves as an initial requirement for the next phase (Li, Xiao, Wang, & Wang, 2013). For this project, Topcoder crowdsourced a complex problem: a disaster management gaming application. Once the design requirement specifications were complete, Topcoder community members received an open contest link. The content of the Topcoder crowdsourcing website, along with the award price, project scope, and deliverable are shown in Figure 8.

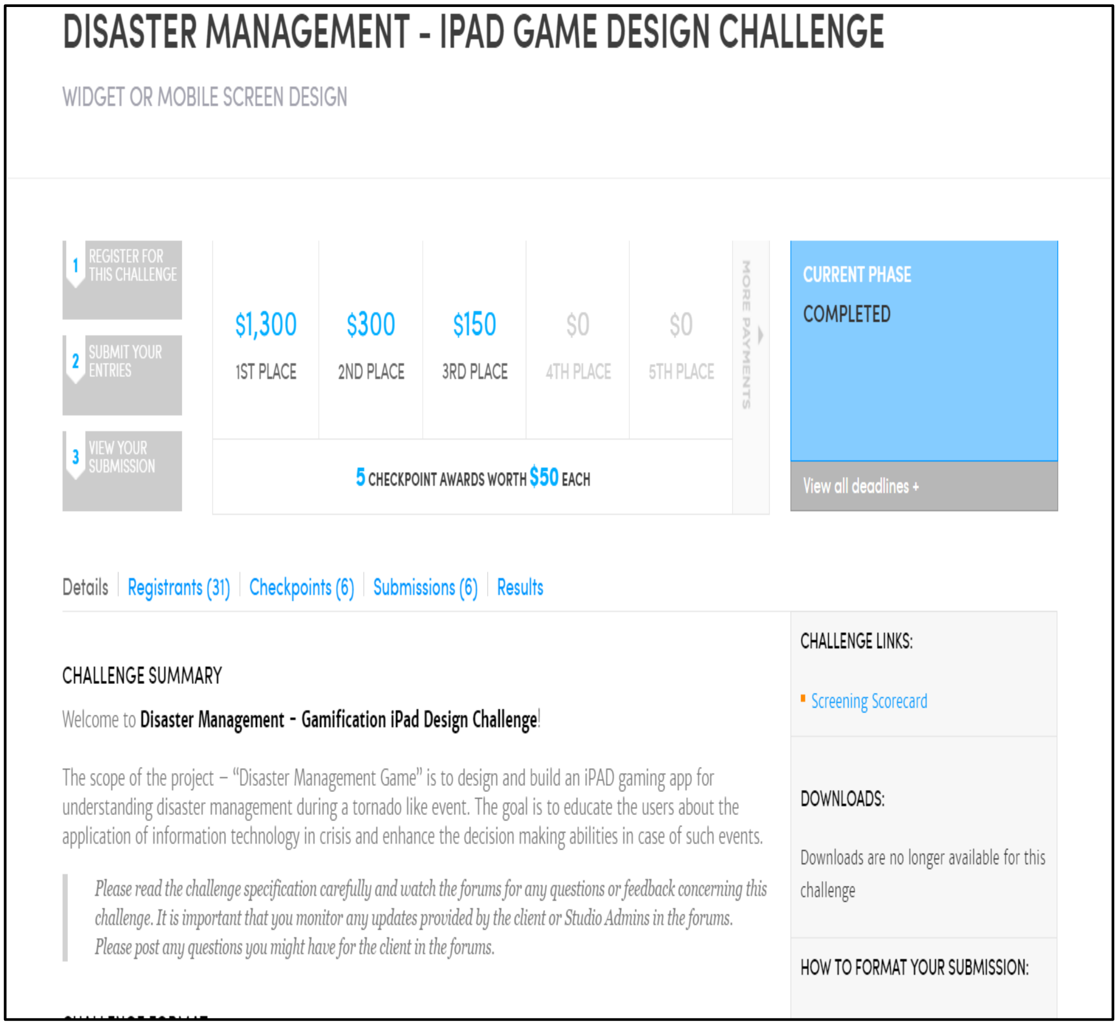

Figure 8: Content of the Topcoder website.

CHALLENGE FORMAT

This competition will be run as a two-round challenge.

Round One (1)

Submit your design for a Checkpoint feedback:
- Your initial design ideas.
- If you have time - please provide us with a click map for your design.
- Readme.jpg : Provide notes about your submission.
- Make sure all pages have correct flow! Use correct file numbering. (00, 01, 02, 03)

Round Two (2)

Final Design plus any Checkpoint feedback:
- Your final design.
- If you have time - please provide us with a click map for your design.
- Readme.jpg : Provide notes about your submission.
- Make sure all pages have correct flow! Use correct file numbering. (00, 01, 02, 03)

Regarding the Rounds:

To be eligible for Round 1 prizes and design feedback, you must submit before the Checkpoint deadline.

A day or two after the Checkpoint deadline, the challenge holder will announce Round 1 winners and provide design feedback to those winners in the "Checkpoints" tab above.

You must submit to Round 1 to be eligible to compete in Round 2. If your submission fails screening for a small mistake in Round 1, you may still be eligible to submit to Round 2.

Every competitor with a passing Round 1 submission can submit to Round 2, even if they didn't win a Checkpoint prize.

Figure 9 : Content of the Topcoder website.

The design contest was a two-round contest. The top five designs after the submission of first round design received a $50 checkpoint reward. The researcher did not provide detailed information about the process to create a design and had no direct contact with the Topcoder community members except the co-pilot. A professional software specialist and the researcher ranked the first-round designs based on the perceived quality questionnaire. For the second and last round, only the six remaining participants were eligible to compete. After the completion of the second round, the researcher again ranked the designs based on the perceived quality questionnaire and selected the winner. Figure

10 shows the statistical means for the PQL, HQIL, and HQSL construct of perceived quality.

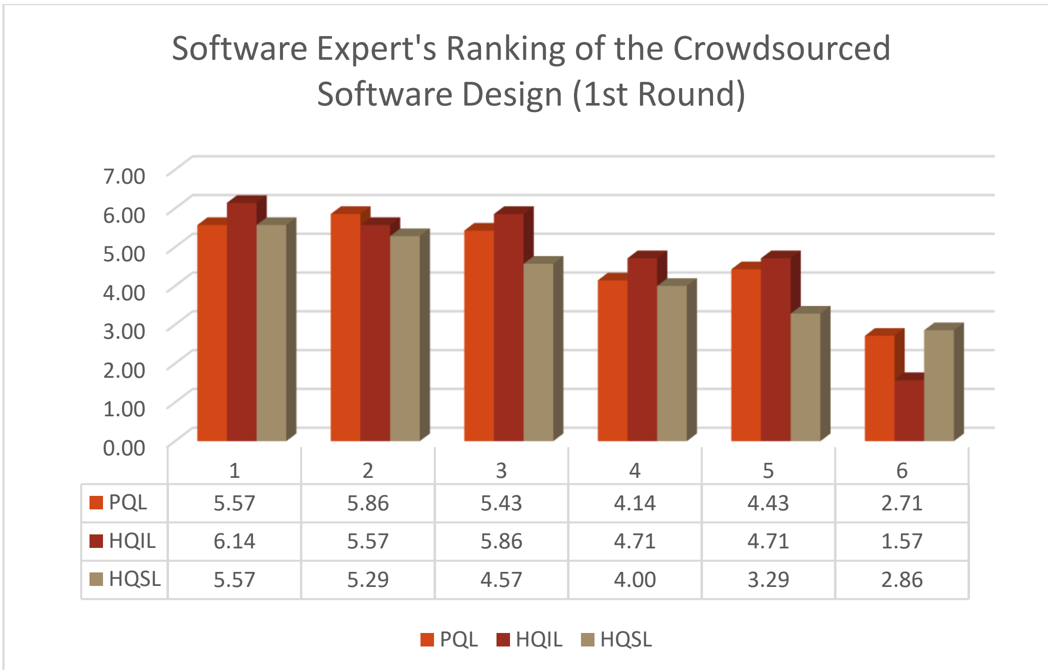

Figure 10: Software expert's ranking of the crowdsourced software design (1st round).

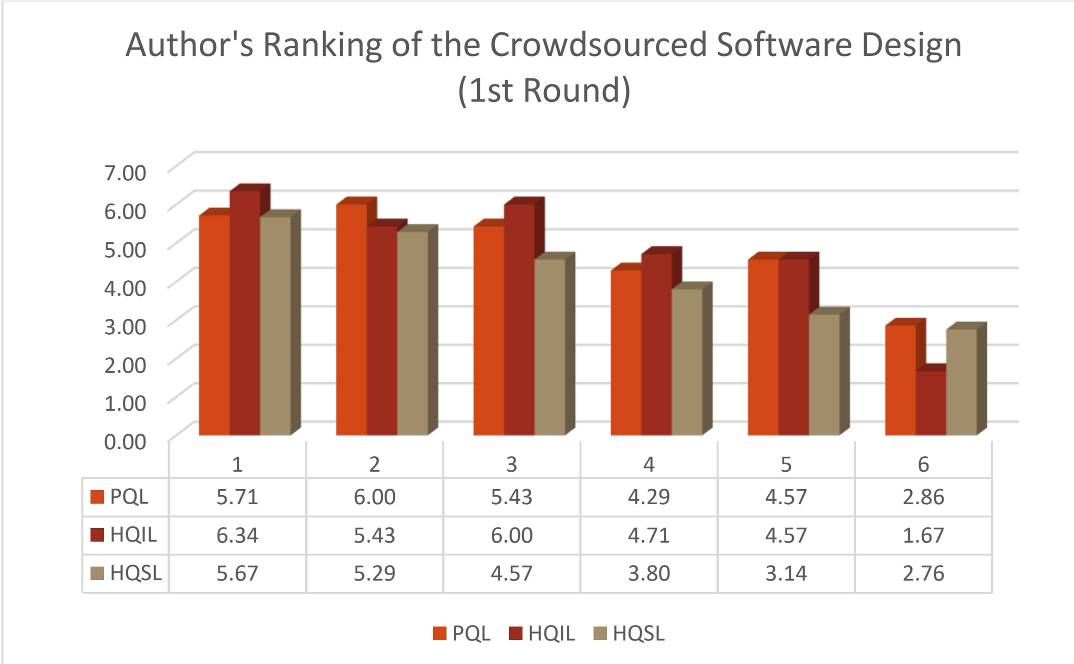

Figure 11: Author's ranking of the crowdsourced software design (1st round)

The researcher and the professional software specialist ranked the six designs independently. The average scores for all six designs for both the researcher and professional software specialist were consistent. The first-ranked design had the highest average hedonic quality identification (HQIL) and hedonic quality stimulation (HQSL) of 6.14 and 5.57 and 6.34 and 5.67, respectively, for the professional software specialist and researcher. The average HQIL and HQSL for the last-ranked (sixth-ranked) design was 1.57 and 2.86 and 1.67 and 2.76, respectively. The first-ranked design was more professional, innovative, creative, self-explaining, and novel than the sixth-ranked design. The average PQL of the first-ranked design was 5.57 and 5.71 for the professional software specialist and researcher, respectively. The average PQL for the last-ranked design was 2.71 and 2.86, respectively. The first-ranked design was simple, clearly structured, and manageable. Figures 12 and 13 show some of the design mockups for the first-ranked and last-ranked designs. The first-ranked design provided 13 unique design screens including the game loading screen, logon screen, and meaningful information to play the game. In contrast, the sixth-ranked design included only two screens, neither of which had any design related to the tornado.

Figure 12: First-ranked design mockup.

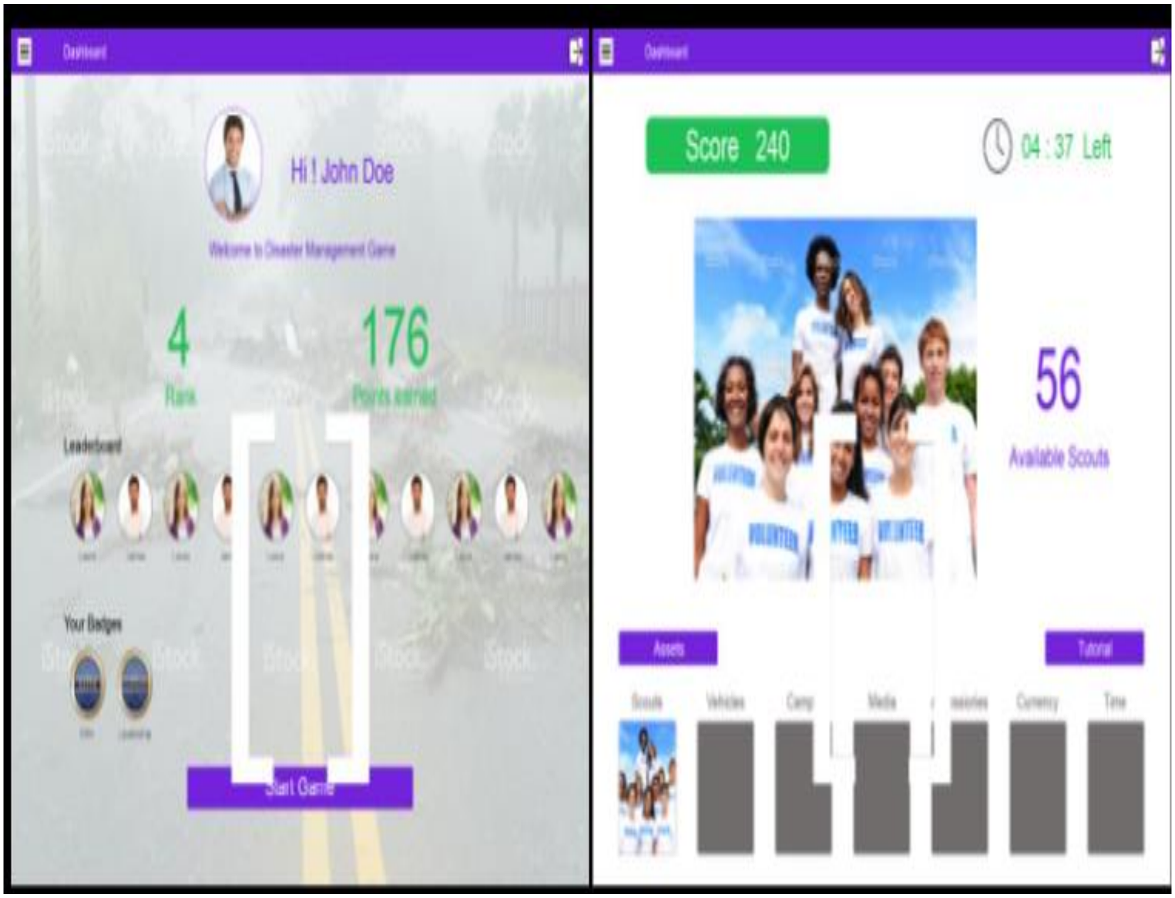

Figure 13: Sixth-ranked design mockup.

For the second-ranked design, the average HQIL and HQSL were 5.57 and 5.29 and 5.43 and 5.29 for the professional software specialist and researcher, respectively. The average PQL was 5.86 and 6 for the professional software specialist and researcher, respectively. The design mockup of the second-ranked design is shown in Figure 14. The second-ranked design offered only two unique screens, a game loading screen and main game screen, after the first round. The main screen was simple, clearly structured, and manageable.

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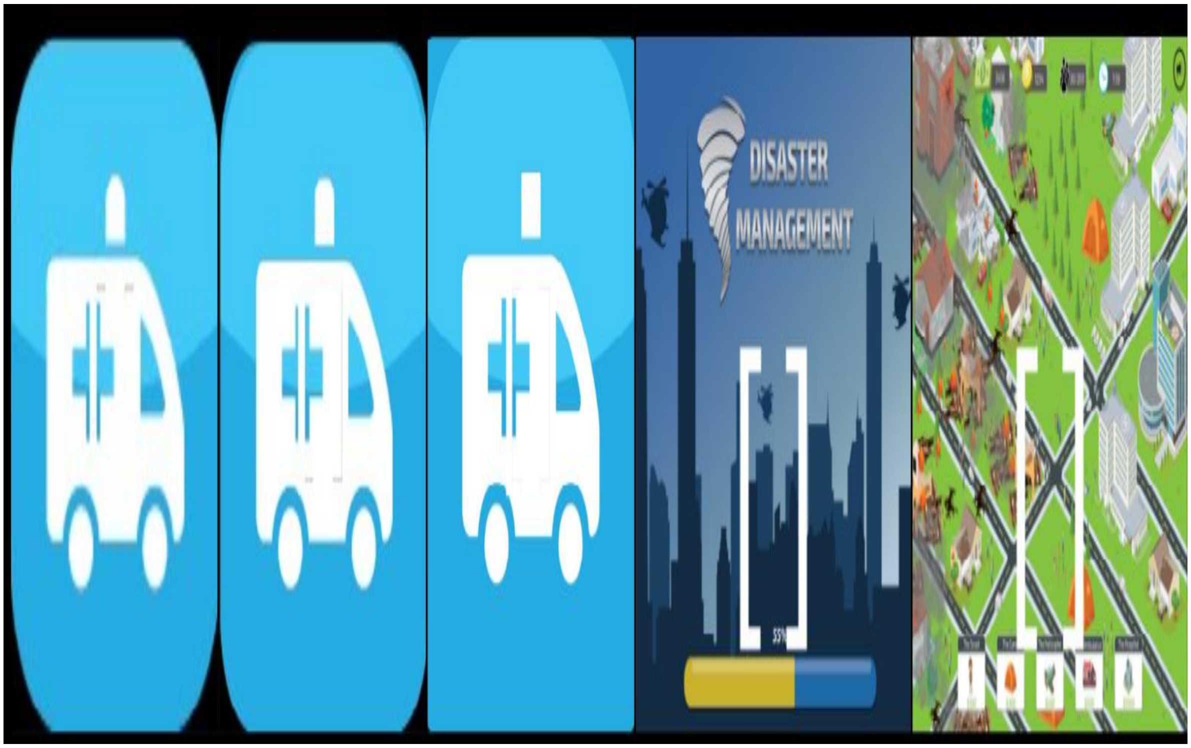

Figure 14: Second-ranked design mockup.

The design mockup of the third-ranked designs is shown in Figures 15. For the third-ranked design, the average HQIL and HQSL were 5.57 and 5.29 and 5.43 and 5.29 for the professional software specialist and researcher. The average PQL were 5.86 and 6 for the professional software specialist and researcher, respectively. The PQL is higher for this design compared to hedonic quality, as this design offered 18 screens mockups and each screen captured a part of the requirements (e.g., selection of team, time duration for the game, information regarding the volunteers, and badges). The lower hedonic quality attributes related to various screens that added complexity to the design.

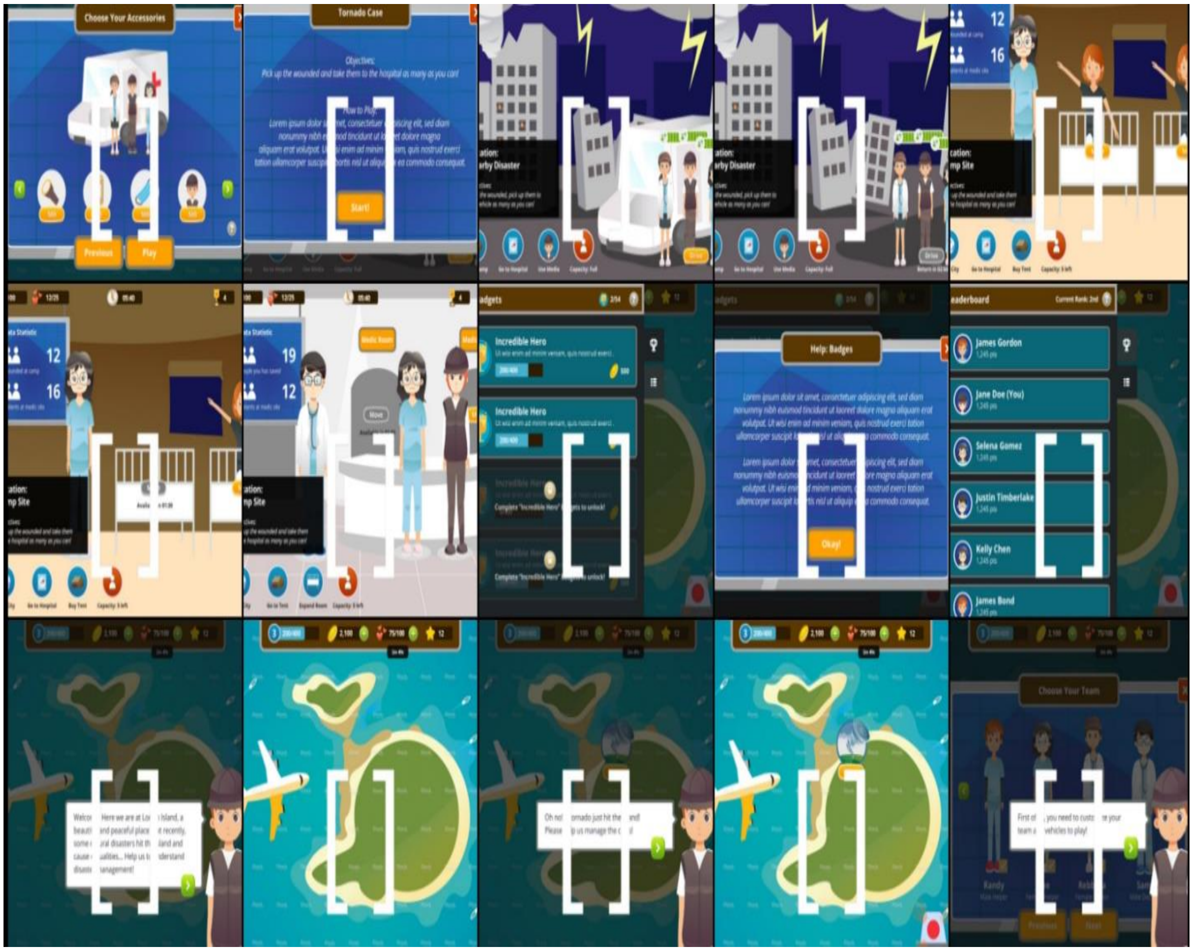

Figure 15: Third-ranked design mockup.

The design mockup of the fourth-ranked and fifth-ranked design are shown in Figures 16 and 16. For the fourth-ranked design, the average HQIL and HQSL were 4.71 and 4.71 and 4.00 and 3.80 for the professional software specialist and researcher, respectively. The average PQL was 4.14 and 4.29 for the professional software specialist and researcher, respectively. Similarly, for the fifth-ranked design, the average HQIL and HQSL were 4.71 and 4.57 and 3.29 and 3.14 for the professional software specialist and researcher. The average PQL was 4.43 and 4.57 for the professional software specialist and researcher, respectively. The fourth-ranked design provided only one screen mockup compared to the 9 screen mockups of the fifth-ranked design. The fourth-ranked design was simpler, creative, and more presentable.

Figure 16: Fourth-ranked design mockup.

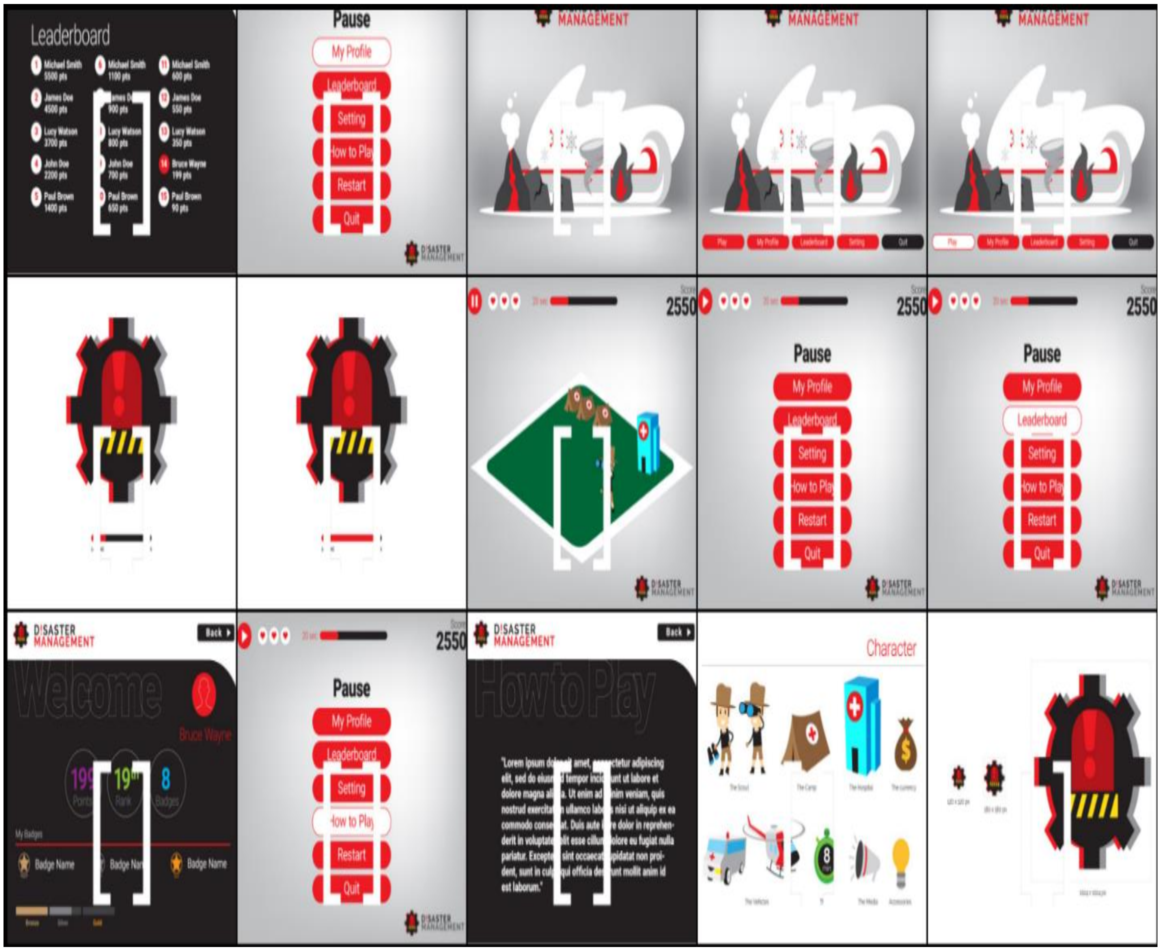

Figure 17: Fifth-ranked design mockup.

After the first round, the researcher provided feedback to the co-pilot for each of the designs (see Table 17).

Table 17: Feedback to each of the design solutions.

Design Solution	Project Result Feedback
1	The main screen is perfect. It would be better to add some initial screens where the various tabs options such as play, leader-board, quit, setting options, etc. can be shown. Some of the screens can show the details of all the tabs. The main screen with some pop-up messages containing details about the various attributes, game rules, and game is desirable. Also, add more details in the form of pop-up guides providing information about the money, time, volunteers, etc. Final presentation should be a prototype completed with the help of the invisionapp.
2	The main screen is perfect. It would be better to add some initial screens where the various tab options such as play, leader-board, quit, settings options, etc. can be shown. Some of the screens can show the details of all the tabs. The main screen with some pop-up messages containing details about the various attributes, game rules, and game is desirable. Also, add more details in the form of pop-up guides providing information about the money, time, volunteers, etc. Final presentation should be a prototype completed with the help of the invisionapp.
3	The design looks good. Please add some details in the disastrous events screen. The details can be about fall of tree, fire etc. Also, add more details in the form of pop-up guides providing information about the money, time, volunteers, etc. Final presentation should be a prototype completed with the help of the invisionapp.
4	I think it is better to add initial screens where the various tab options such as play, leader-board, quit, settings options, etc. can be shown. Some screens can show the details of all the tabs. The main screen can have some pop-up messages that can describe the attributes, game rules and the game.
5	The initial screen, tab options, and their presentations all look good. Additional details on the requirements such as disastrous events and various attributes in the screen 229158-31-7.png will be very helpful.
6	The design needs to be improved. You have provided only two screenshots and both are very introductory. Your submission has not included the following items listed below: Pop-up window Initial screen with some mockup of disastrous events.

In the second round, based on this feedback, each of the six participants made changes to their designs. After the submission of the second-round designs, the professional software specialist and researcher ranked these designs based on the perceived quality survey instrument. Figure 18 shows the statistical means for the PQL, HQIL, and HQSL constructs of perceived quality of the second phase designs. There was a consistency in the researcher's and professional software specialist's rankings, so the following mean for the HQIL, HQS, and PQ is the mean of the average ranking by the researcher and professional software specialist for each of the quality dimensions.

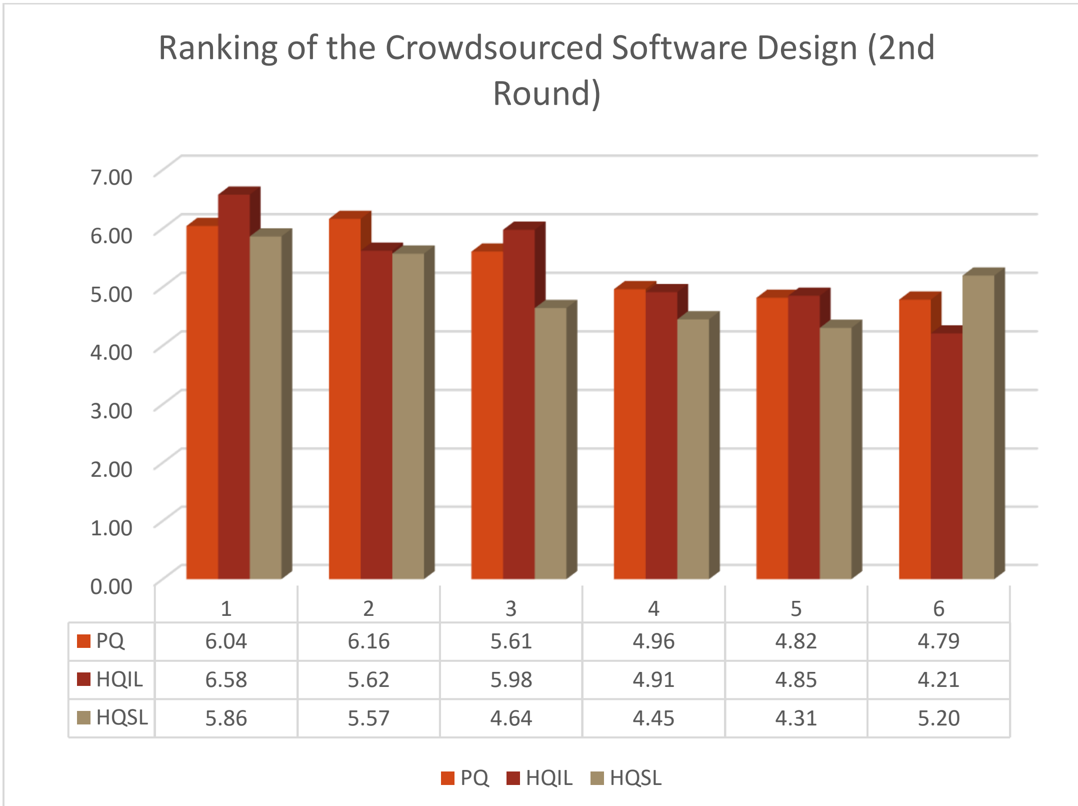

Figure 18: Ranking of the crowdsourced software design (2nd round).

In the second-round, the ranking of the design did not change from the first round. The perceived quality of each of the designs improved after the feedback. Specially, the feedback improved the perceived quality of the lower-ranked design in the first round. Figure 19 shows overall hedonic quality: HQSL and identification in relation to PQL on a 7-point scale. The researcher plotted each design into one of the six quadrants based on its mean score for hedonic quality and PQL. The images in Figures 19 and 20 identify outliers, patterns, and perceived quality after the first and second phase of the submitted designs.

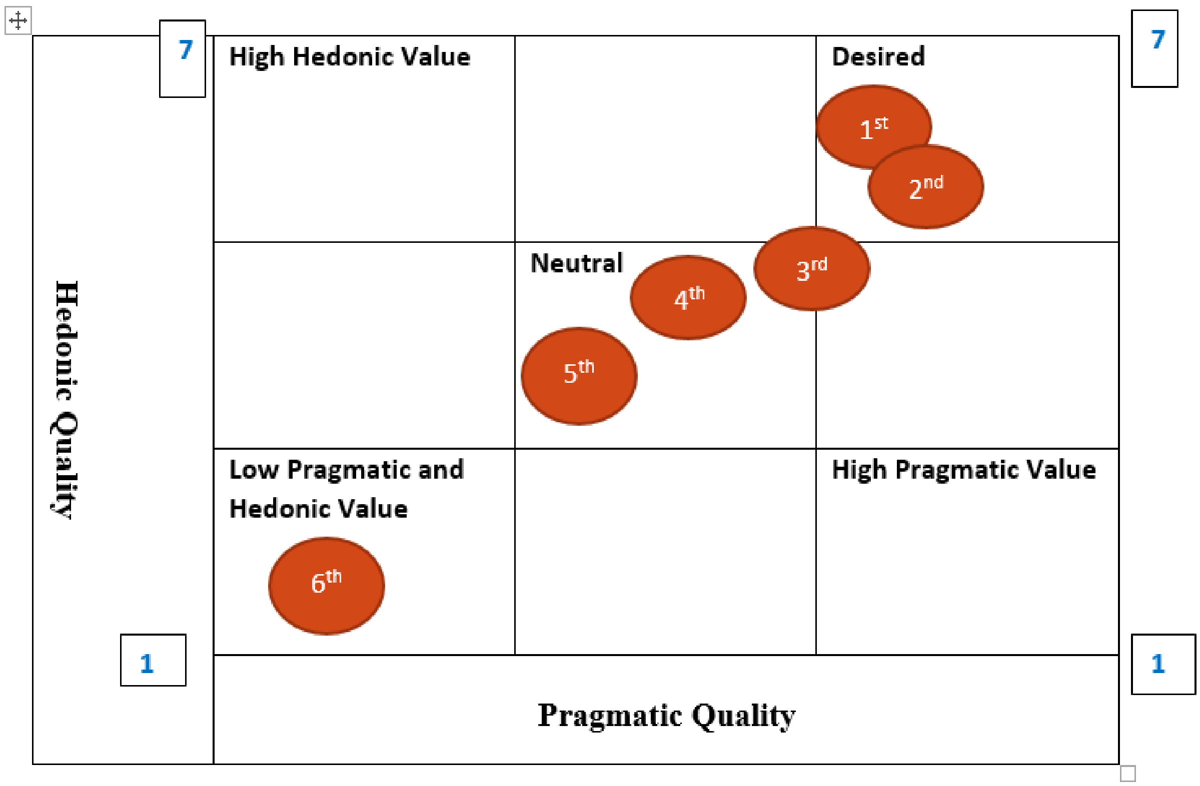

Figure 19: Pragmatic and hedonic quality quadrants of crowdsourced software design (1st round).

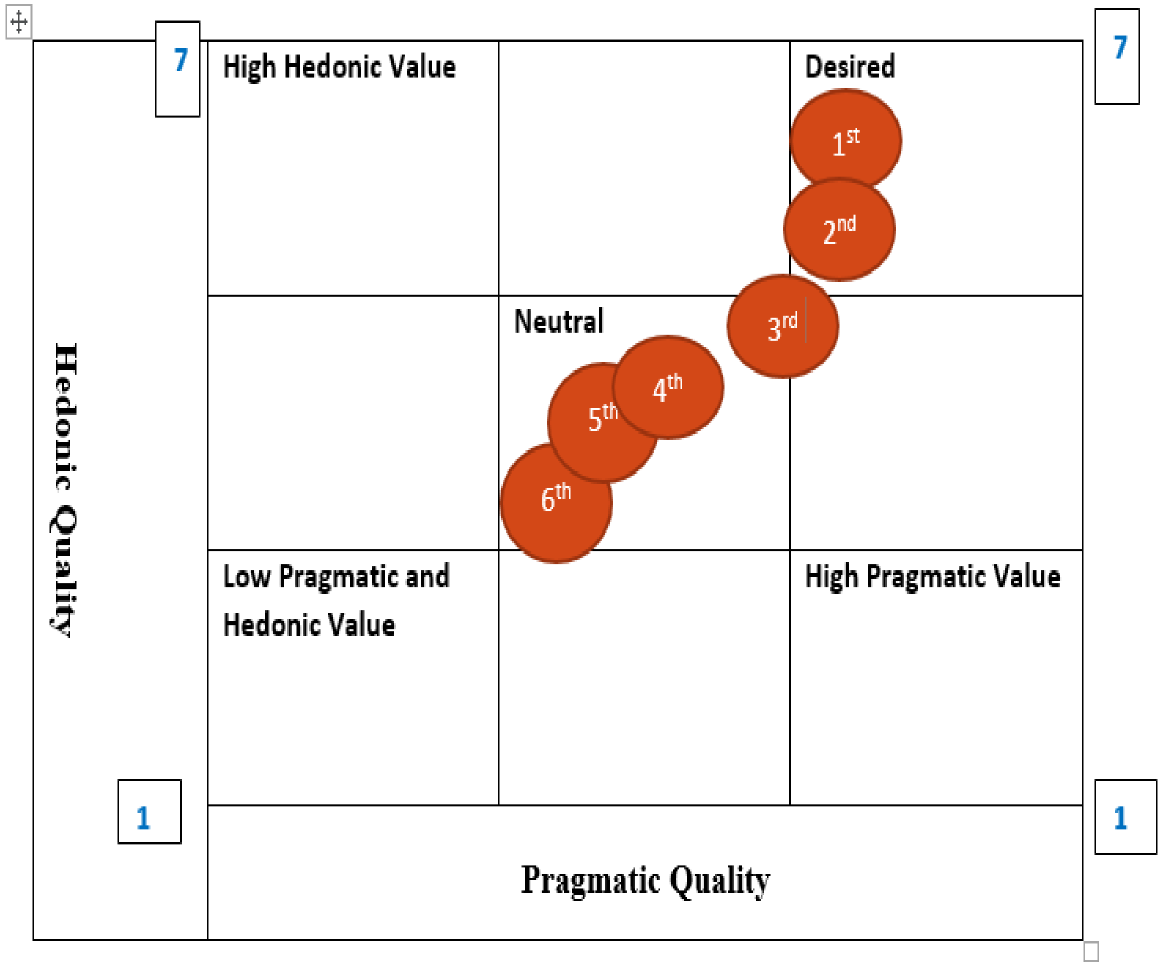

Figure 20: Pragmatic and hedonic quality quadrants of crowdsourced software design (2nd round).

There were no designs with high values of only one of the perceived quality dimensions (high average pragmatic value and low average hedonic value or low average pragmatic value and high average hedonic value). Also, the first- and second-ranked designs were desirable designs, which is of high average pragmatic value and high average hedonic value. However, the third-, fourth-, and fifth-ranked designs were neutral designs because of their average pragmatic and hedonic values. The sixth-ranked design was of low pragmatic as well as hedonic value, and consequently required improvement.

Feedback played an important role. As shown in Figure 20, there was a significant increase in the average value of pragmatic and hedonic quality after the second phase, especially for designs with considerably low values of pragmatic and hedonic quality. Feedback to participants helps participants feel appreciated, which increases the quality of product development (Nambisan, 2002; Shah, 2006). Feedback to participants is an important motivational factor and increases the willingness to contribute (Leimeister, Huber, Brestschinder, & Krcmar, 2009; Nambisan, 2002). The first-ranked crowdsourced design was the basis for the final crowdsourced design to compare the perceived quality to the software design developed by the IT professionals for the second phase of this quasi-experimental research design.

4.4 Analysis and Discussion of Results

The overarching research question was as follows: in the context of complex problems, does software developed by the crowdsourcing business model achieve the same or better quality compared to software developed by professionals? The researcher developed a conceptual model in relation to this research question. The following sections present the analysis of the results in relation to the research question and overall perceived quality (PQL, HQIL, and HQSL) of the crowdsourced software design and IT professional software design.

4.4.1 Reliability and Validity of Scales

University of Nebraska at Omaha's students rated the software designed by the crowdsourcing method and the IT professional method. A total of 110 students rated the crowdsourced design and 91 rated the IT professionals' design. The researcher maintained reliability measures for scales with multiple items of PQL, HQIL, and HQSL, and used the statistical package SPSS® to measures reliability of the scales. Cronbach' s alpha assessed the internal consistency across items within a scale. The researcher calculated alpha values for each of the perceived quality constructs. Table 18 is a summary of scales that shows the calculated alpha values, all of which were above 0.6.

Table 18: Reliability analysis of study constructs.

Study Construct	N of Item	Cronbach's Alpha	Scale Range
Pragmatic Quality	7	0.643	1 to 7
Hedonic Quality Identification	7	0.615	1 to 7
Hedonic Quality Stimulation	7	0.657	1 to 7

4.4.2 Multivariate Results

To compare the perceived quality of the disaster management gaming application designed by the crowd and IT professionals, the researcher conducted a multivariate test (MANOVA) because of the three dependent variables: PQL, HQSL, and HQIL. MANOVA requires that the observations are independent, the response variables are multivariate and normally distributed within the group, dependent variables exhibit homogeneity of variance across the range of predictor variables, and the co-variance matrix of the dependent variables is homogenous across the groups (Finch, 2005). Overall, the F-test is robust for non-normal distribution, if non-normality is due to skewness. If the non-normality is due to outliers, the outliers should either be transformed or removed (French et al., 2008).

The researcher performed the test of assumptions for the MANOVA. It passed the Leven's test of homogeneity, but it was non-normal for the two response variables, HQIL and HQSL. A closer analysis of the data suggests the presence of outliers as the reason of non-normality. The researcher performed various transformation techniques such as log, inverse, and square, but these transformations did not help achieve normality. As suggested by French et al. (2008), the researcher removed the outliers, which helped achieve the test of normality. These outliers were due to relatively high or low ratings of the hedonic attributes of the product. Tables 19 and 20 show the result of the test of normality and test of error variance. Based on the Kolmogorov-Smirnov and Shapiro-Wilk test of normality, the researcher concluded that all three response variables are normality distributed. However, for the crowdsourced design method, the HQSL is only normal based on the Shapiro-Wilk test at the level of significance of 0.01.

Table 19: Test of normality.

	Development Approach	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
PQL	0 (IT Professional Method)	.075	85	**.200**	.982	85	**.295**
	1 (Crowdsourced Method)	.080	98	**.133*** **	.974	98	**.053** **
HQIL	0 (IT Professional Method)	.125	85	**.002*** **	.974	85	**.087** **
	1 (Crowdsourced Method)	.094	98	**.031***	.976	98	**.065** **
HQSL	0 (IT Professional Method)	.141	85	**.000*** **	.966	85	**.023***
	1 (Crowdsourced Method)	.083	98	**.096** **	.984	98	**.273**
*** (significant at all alpha); ** (Significant at 0.05 and 0.01); * (Significant at 0.01)							

Table 20: Levene's test for equality of error variances.

	F	df1	df2	Sig.
PQL	.126	1	176	**.723**
HQIL	.157	1	176	**.693**
HQSL	.162	1	176	**.688**
*** (significant at all alpha); ** (Significant at 0.05 and 0.01); * (Significant at 0.01)				

Table 21: Box's Test of Equality of Covariance Matrices.

Box's M	8.323
F	1.361
df1	6
df2	213700.170
Sig.	**.226**
*** (significant at all alpha); ** (Significant at 0.05 and 0.01); * (Significant at 0.01)	

Box's M tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups. This is another required test of assumptions, and the results suggest that the covariance matrices of the dependent variables are equal across groups. These results also suggest that linear relationships exist among all pairs of perceived quality dimensions, all pairs of covariates, and all perceived quality dimensions (covariate pairs in each cell). This test is important to ensure that the power of the analysis is not compromised (French et al., 2008). The descriptive statistics suggest that the average values of PQL and HQIL were higher for the IT professional method than the crowdsourced method (see Table 22). The average value of the HQSL was higher for the crowdsourced method.

Table 22: Descriptive statistics.

	Development Approach	Mean	Std. Deviation	N
PQL	0 (IT Professional Method)	4.34	.77	85
	1 (Crowdsourced Method)	3.89	.77	98
	Total	4.10	.80	183
HQIL	0 (IT Professional Method)	4.24	.67	85
	1 (Crowdsourced Method)	4.03	.63	98
	Total	4.13	.66	183
HQSL	0 (IT Professional Method)	4.25	.63	85
	1 (Crowdsourced Method)	4.11	.70	98
	Total	4.18	.67	183

The multivariate test MANOVA suggests that there was a statistically significant difference in the development approach (crowdsourcing method and IT professionals' method of software development) based on a perceived quality dimension, F (3, 179) = 5.25, $p <$ all level of significance; Wilk's Λ = 0.919 (see Table 23). Therefore, the development approach (crowdsourcing method and professionals' method of software development) has an effect on overall perceived quality. The pilot-study multivariate tests confirmed the same results.

Table 23: Multivariate tests.

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.984	3742.813[b]	3.000	179.000	.000
	Wilks' Lambda	.016	3742.813[b]	3.000	179.000	.000
	Hotelling's Trace	62.729	3742.813[b]	3.000	179.000	.000
	Roy's Largest Root	62.729	3742.813[b]	3.000	179.000	.000
Development Approach	Pillai's Trace	.081	5.252[b]	3.000	179.000	.002
	Wilks' Lambda	**.919**	**5.252[b]**	**3.000**	**179.000**	**.002*** **
	Hotelling's Trace	.088	5.252[b]	3.000	179.000	.002
	Roy's Largest Root	.088	5.252[b]	3.000	179.000	.002

4.4.3 Perceived Quality

This section presents key descriptive results from the survey on the individual-question level ANOVA table to test the mean difference of each of the dependent variables along with the qualitative analysis of the individual responses to the open-ended questions. Combining the quantitative and qualitative data sources created a holistic assessment of the findings.

Table 24: ANOVA - Tests of between-subjects effects.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	PQL	9.245[a]	1	9.245	15.484	.000
	HQIL	2.102[b]	1	2.102	4.865	.029
	HQSL	.923[c]	1	.923	2.056	.153
Intercept	PQL	3094.488	1	3094.488	5182.777	.000
	HQIL	3121.822	1	3121.822	7224.788	.000
	HQSL	3192.094	1	3192.094	7114.215	.000
Development Approach	PQL	**9.245**	**1**	**9.245**	**15.484**	**.000*** **
	HQIL	**2.102**	**1**	**2.102**	**4.865**	***.029****
	HQSL	**.923**	**1**	**.923**	**2.056**	***.153***
Error	PQL	108.070	181	.597		
	HQIL	78.210	181	.432		
	HQSL	81.213	181	.449		
Total	PQL	3203.393	183			
	HQIL	3206.411	183			
	HQSL	3282.675	183			
Corrected Total	PQL	117.315	182			
	HQIL	80.312	182			
	HQSL	82.136	182			

a. R Squared = .079 (Adjusted R Squared = .074)
b. R Squared = .026 (Adjusted R Squared = .021)
c. R Squared = .011 (Adjusted R Squared = .006)
*** (significant at all alpha); ** (Significant at 0.05 and 0.01); * (Significant at 0.01)

4.4.3.1 Pragmatic Quality

Tables 25 and 26 list the results of the seven items measuring the pragmatic quality (PQL) construct for the crowdsourced and IT professionals' designs. Based on the descriptive statistics, the results of the items of the PQL showed that:

1. Overall users (participants of the survey) did not perceive a high level of PQL for the crowdsourced software design. They did feel that the product was practical and manageable (mean is 4.07 and 4.33), although they were neutral about whether the design was simple, human, straightforward, and clearly structured; feeling that the design was somewhat manageable (mean is 4.33).
2. For the IT professional software design overall users (participants of the survey), PQL perception was high compared to the crowdsourced software design. They felt that the product was practical, manageable, simple, human, straightforward, and clearly structured.

Table 25: Items measuring pragmatic quality for the crowdsourced software design.

Survey Items of Pragmatic Quality (Crowdsourced Software Design)	Min	Max	Mean	Standard Deviation
Technical-Human	1	7	3.65	1.67
Complicated-Simple	1	7	3.51	1.72
Impractical-Practical	1	7	4.07	1.70
Cumbersome-Straightforward	1	7	3.88	1.84
Unpredictable-Predictable	1	7	3.95	1.64
Confusing-Clearly structured	1	7	3.86	1.91
Unruly-Manageable	1	7	4.33	1.45

Table 26: Items measuring pragmatic quality for IT professional software design.

Survey Items of Pragmatic Quality (IT Professional Software Design)	Min	Max	Mean	Standard Deviation
Technical-Human	1	7	4.36	1.72
Complicated-Simple	1	7	3.90	1.65
Impractical-Practical	1	7	4.20	1.50
Cumbersome-Straightforward	1	7	4.79	1.40
Unpredictable-Predictable	1	7	4.05	1.35
Confusing-Clearly structured	1	7	4.68	1.6
Unruly-Manageable	1	7	4.74	1.3

3. The univariate result analysis confirmed the descriptive statistics result. The ANOVA result from the Table 24 confirm that development approach has a statistically significant effect on PQL ($F (1, 181) = 15.484$; $p <$ for all values of level of significance). The PQL of the IT professional software design is better than the crowdsourced software design.
4. A careful review of the qualitative data based on the open-ended PQL question revealed that most of the users did not find any PQL attributes to the crowdsourced design, although some of users found the crowdsourced design useful. The following examples of PQL of crowdsourced software design are from users' open-ended question responses. Participants comments included, "Poor. Many functions do not work and its graphic interface is mostly unresponsive." "I think the pragmatic quality of this is very poor. I do not see myself playing this game in the future. I feel like the utilities in the game are poorly developed and could be done much better." "I thought the game was very confusing. I had trouble

figuring out what the game was trying to get me to do in the very beginning." "I thought this game was confusing with no real objective." "This product or game looks really superb and easy to use and at the same time very innovative. This game is very realistic in nature." Lastly, one participants stated, "This game looks very professional and looks like it could be an actual app at the Apple store or Play store."

5. For the IT professional design, most of the users reported better PQL compared to the crowdsourced design. The following examples of PQL of IT professional software design are from users' open-ended question responses. "I think that the pragmatic quality of this gaming app prototype design is much improved compared to the first example. I feel as if the clear instructions and interactive visuals make this game look more life-like and therefore makes the tasks hold more purpose/ function." "I think this game does pragmatic quality very well because it explains to the user everything that they have to do in order to be successful in the game. The explanations in the game and how to use each position is exactly what needs to be done in the game." "The pragmatic quality is solid as it fulfills its function well and serves its overall purpose without any infringement or clear obstacles. The usability is very high, which is definitely a positive as users are likely to use it on a regular basis when it is convenient." "I believe this prototype was a little less informative compared to the first example that I evaluated. However, this still got straight to the point and told the prospectors exactly what they needed to do." "The UI is not very good, and I think that should be the primary focus of making a game. Making someone want to continue looking at the screen is as important as the gameplay itself."

The descriptive statistics, ANOVA result, and excerpts from the qualitative data confirmed that perceived PQL of IT professional software design is better than the PQL of crowdsourced software design.

4.4.3.2 Hedonic Quality Identification

Tables 27 and 28 provide the results of the seven items measuring the hedonic quality identification (HQIL) construct for the crowdsourced software design and IT professional design. The descriptive statistics results of the items of the HQIL showed that:

1. Overall users (participants of the survey) perceived an average level of HQIL for the crowdsourced software design. They felt that the product was integrating, connective, and well presented. They were neutral about whether the design was premium; participants felt that the design was less than professional and tacky.
2. For the IT professional software design, overall users' (participants of the survey) HQIL perception was high compared to the crowdsourced software design. They felt that the product was integrating, connective, well presentable, and professional, but remained neutral about whether the design brings them close.

Table 27: Items measuring hedonic quality identification for crowdsourced software design.

Survey Items of Hedonic Quality Identification (Crowdsourced Software Design)	Min	Max	Mean	Standard Deviation
Isolating-Connective	1	7	4.15	1.69
Unprofessional-Professional	1	7	3.99	1.72

Stylish-Tacky	1	7	4.01	1.69
Cheap-Premium	1	7	3.46	1.58
Separates me from people-Bring me closer to people	1	7	4.03	1.67
Unpresentable-Presentable	1	7	4.25	1.67
Alienating-Integrating	1	7	4.25	1.54

Table 28: Items measuring hedonic quality identification for IT professional software design

Survey Items of Hedonic Quality Identification (IT Professional Software Design)	Min	Max	Mean	Standard Deviation
Isolating-Connective	1	7	4.40	1.48
Unprofessional-Professional	1	7	4.23	1.56
Stylish-Tacky	1	7	4.11	1.61
Cheap-Premium	1	7	4.36	1.59
Separates me from people-Bring me closer to people	1	7	3.79	1.48
Unpresentable-Presentable	1	7	4.64	1.5
Alienating-Integrating	1	7	4.68	1.28

3. The ANOVA result from the Table 24 confirmed that development approach has a statistically significant effect on HQIL ($F (1, 181) = 4.865$; $p <$ level of significance $= .05$) and no statistical significant effect on HQIL, the 90% confidence level. The descriptive statistics result of the HQIL of the IT professional software design is better than the crowdsourced software design.
4. A careful review of the qualitative data based on the open-ended HQIL question revealed that users had mixed responses. Some users did not find any HQIL in the crowdsourced design, but some of users found that they identify with the crowdsourced design. The following examples of HQIL of crowdsourced software design are from users' open-ended question responses. "The hedonic quality identification is not good. I do not use physical objects to express myself when using the game." "The gaming app prototype design did not have any hedonic quality identification. Maybe for others it did, but for myself, I could not express myself through the physical objects. The game did not relate to me in any way, shape, or form." "I think its identity is in its charm. It has a unique style and I don't think it is trying too hard to be something that it is not. It is a new idea and seems to have been executed in a fresh and innovating way. In short, I think its identity is a charming application with some classic mobile gaming ideals." "I think it does well in that regard. It communicates a certain persona about itself and there is an immediate understanding about the type of application you are using and what its intentions are."
5. The HQIL for the IT professional design also received mixed responses. Some users could identify with this design while others could not. The following examples of HQIL of IT professional software design are from users' open-ended question responses. "The hedonic quality identification of the gamming app prototype design was not relevant to me. As

previously mentioned, I do not go out saving wounded people from a tornado disaster. Maybe to people that live in a tornado prone area the gamming app porotype design would apply. Personally, I could not ideally express myself through the physical objects." "The hedonic quality identification is lack luster since customization is not a large portion of the game. Users wants express themselves and this does not allow them to." "App is bit bore to use. I always feel that any gaming app should be such a way it should attract people to play again and again. This app is kind of OK but not that great." "The hedonic quality identification is good in that users do have the ability to express themselves using this game app prototype design. One has the ability to customize this type of experience to their liking." "I think its identity completely lies in its design. It looks like a construction set and implies that the game will involve a lot of creativity and critical thinking. I enjoyed playing it and felt that its identity was apparent from the start."

The descriptive statistics, ANOVA result (level of significance =0.05), and excerpts from the qualitative data confirmed the perceived HQIL of IT professional software design is better than the crowdsourced software design.

4.4.3.2 Hedonic Quality Stimulation

Tables 29 and 30 provide the results of the seven items measuring the hedonic quality stimulation (HQSL) construct for the crowdsourced software design and IT professional design. The descriptive statistics results of the items of the HQSL showed that:

1. Overall users (participants of the survey) perceived a somewhat high level of HQSL for the crowdsourced software design. They felt that the product was creative, innovative, challenging, and captivating, but only somewhat inventive and novel.
2. For the IT professional software design, overall users' (participants of the survey) HQSL perception was high compared to the crowdsourced software design. They felt that the product was creative, innovative, challenging, and captivating.

Table 29: Items measuring hedonic quality stimulation for crowdsourced software design.

Survey Items of Hedonic Quality Stimulation (Crowdsourced Software Design)	Min	Max	Mean	Standard Deviation
Conventional-Inventive	1	7	3.83	1.61
Unimaginative-Creative	1	7	4.67	1.56
Bold-Cautious	1	7	4.00	1.43
Conservative-Innovative	1	7	4.07	1.64
Dull-Captivating	1	7	3.97	1.57
Undemanding-Challenging	1	7	4.46	1.47
Ordinary-Novel	1	7	3.88	1.56

Table 30: Items measuring hedonic quality stimulation for IT professional software design.

Survey Items of Hedonic Quality Stimulation (IT Professional Software Design)	Min	Max	Mean	Standard Deviation
Conventional-Inventive	1	7	4.10	1.52
Unimaginative-Creative	1	7	4.74	1.39
Bold-Cautious	1	7	4.02	1.45
Conservative-Innovative	1	7	4.08	1.52
Dull-Captivating	1	7	4.59	1.43
Undemanding-Challenging	1	7	4.52	1.31
Ordinary-Novel	1	7	3.88	1.56

3. The univariate result analysis confirmed the descriptive statistics result. The ANOVA result from the Table 24 confirmed that development approach has a statistically no significant effect on HQSL ($F (1, 181) = 2.056$; $p >$ all level of significance). The average HQSL of the IT professional software design was a little more (mean =4.27) compared to the crowdsourced software design (mean = 4.12).

4. A careful review of the qualitative data based on the open-ended HQSL question revealed that users has mixed responses. Some users did not find any HQSL to the crowdsourced design, and some of users felt the skills and learning from this design would help them prepare for disasters. The following examples of HQSL of crowdsourced software design are from users' open-ended question responses. "I do not think that the hedonic quality stimulation of this gaming app prototype is very strong. The design of the actual game physically looked unappealing and simple, not unique or distinctive. Also, I do not think that this game would help me to develop any important knowledge or skills." "I think the hedonic quality of this gaming application is inadequate since it doesn't enhance and previous skills I had. It seems very ordinary to me that the software helps gamers with instructions in order to complete the game." "This game does seem challenging because there are a lot of people who need to be saved and you are given limited resources. I like that this game gives you gold every time you save someone, so that is an opportunity to get more gold. This motivates the player to keep saving people and keep playing the game. This game helps people develop their time management and multitasking skills." "I think this is an intriguing concept, especially with hurricane Matthew about to hit Florida in the next few days. I would love to learn more about the rescue efforts after a tornado and I think this is a great way of spreading the word. It helps people understanding the challenges and struggles of mitigating disaster." "There is value in the app in teaching resource and time management, and perhaps also in teaching users about what occurs in emergency situations. Overall, the hedonic quality stimulation of this app is satisfactory."

5. The HQSL for the IT professional design also received mixed responses. Some users could identify with this design while others could not. The following examples of HQSL of IT professional software design are from users' open-ended question responses. "Hedonic quality stimulation is also not that good on this one since it doesn't develop any skills or knowledge I previously had. This game is very simple and doesn't require a lot of thought

to complete." "This app does not give the same motivation as the last app. The last app said they will give the user gold if they save each person, but in this app that did not show up. It did not seem like there was a motivating factor like the gold incentive." "I feel like this game has many opportunities and lets you think for yourself a little more than just doing as the game says. You basically make up how you want the game to go. This game seems to be made by a more advanced programmer then the first. It is attractive and well put together." "As with the previous demo, this app does seem to be effective in teaching resource and time management in users." "This software provides new impressions, opportunities, and insights. The app allows for the personal development and acquiring of knowledge by the user. However, it may be harder for the user to find this development and knowledge with this design of the app."

The descriptive statistics, ANOVA result, and excerpts from the qualitative data confirmed that there is no difference between perceived HQSL of the IT professional software design and the crowdsourced software design.

4.5 Summary of Analysis and Results

This chapter presented detailed results of this study including quantitative and qualitative research findings. The findings relate to the conceptual model and the research question. Overall, there is a statistical significant difference in the perceived quality of crowdsourced software design and IT professional software design. The PQL and HQIL of the IT professional software design is better than the crowdsourced software design. There is no statistical significant difference for the HQSL of the crowdsourced software design and IT professional software design. The next chapter includes a detailed discussion and interpretation of the research results based on these finding.

CHAPTER 5: IMPLICATIONS, CONTRIBUTIONS, AND CONCLUSIONS

In recent years, “innovation is being democratized” (Hippel, 2002, p. 17). The source of innovation shifted to an open innovation model (Chesbrough, 2003), meaning that crowds/customers of products and services know their requirements, can contribute to development of a product, and can solve complex problems (Brabham, 2009; Guinan et al., 2013; Kittur, 2010; Hippel, 2002). However, Lanier (2010) argued that crowd wisdom is inadequate to solve creative or innovative problems. Lanier’s (2010) hypothesis aligned with traditional research findings that suggest solving a complex problem is within the exclusive domain of professionals within organizational boundaries. The focus of this dissertation was to test the Lanier (2010) hypothesis and increase understanding of crowdsourcing and complex problem- solving in relation to the perceived quality of design solutions by crowdsourcing and professional methods. Since the inception of the word crowdsourcing (Howe, 2006), many researchers studied crowdsourcing in general. However, very few researchers studied crowdsourcing and CPS, especially in a software design and development context.

A conceptual model guided the present research. The researcher proposed that development approach (by crowdsourcing or professionals) has an effect on perceived quality. A quasi-experimental research study combining both quantitative and qualitative research methods answered the overall research question. The following sections discuss the implications of the research along with the expected contributions. This chapter also includes the strengths and limitations of the research followed by a discussion of possible future research.

5.1 Implications

The purpose of this dissertation was to expand understanding of the use of contest-based crowdsourcing for CPS by focusing on software design via a crowdsourcing platform (Topcoder). Contest-based crowdsourcing may be the best method for complex and creative problem-solving (Terwiesch & Xu, 2008), and monetary rewards encourage participants to engage in CPS (Boudreau & Lakhani, 2013). The results of the present research support the conceptual model and indicate that software design for a complex task by the crowdsourcing method and by IT professionals influences overall perceived quality of the designed software. However, the results also reveal important information about three constructs of perceived quality.

The quantitative data revealed that there is a statistically significant difference in the perceived quality of a crowdsourced software design and IT professional design. The PQL and HQIL of the IT professional software design are better than the crowdsourced software design, but there is no statistically significant difference for the HQSL of the crowdsourced software design and IT professional software design. The qualitative data supports the findings from the quantitative data through a detailed explanation. The researcher used an open source data analytic tool R to create a data visualization word frequency cloud based on the common themes and phrases embedded in the survey participants' responses (see Figures 21 and 22). These themes provided insights into the PQL, HQIL, and HQSL of the two software designs. The frequency of words such as "confusing," "hard," and "somewhat" to describe the crowdsourced designs suggests that the PQL of the crowdsourced designs was somewhat confusing and hard to understand.

The responses regarding PQL of the IT professional design frequently included words such as “good,” “better,” “like,” and “easy,” implying this design was less confusing.

Figure 21: Word cloud for PQ of crowdsourced design created using open-ended responses.

Figure 22: Word cloud for PQ of IT professional design created using open-ended responses.

The frequency of words such as “good,” “much,” “lot,” and “helping” in both the crowdsourced and IT professional designs suggests that some users could identify with these two software designs. However, the occurrence of the word “don’t” in the case of the crowdsourced design suggests that certain users did not identify with the crowdsourced design (see Figures 23 and 24).

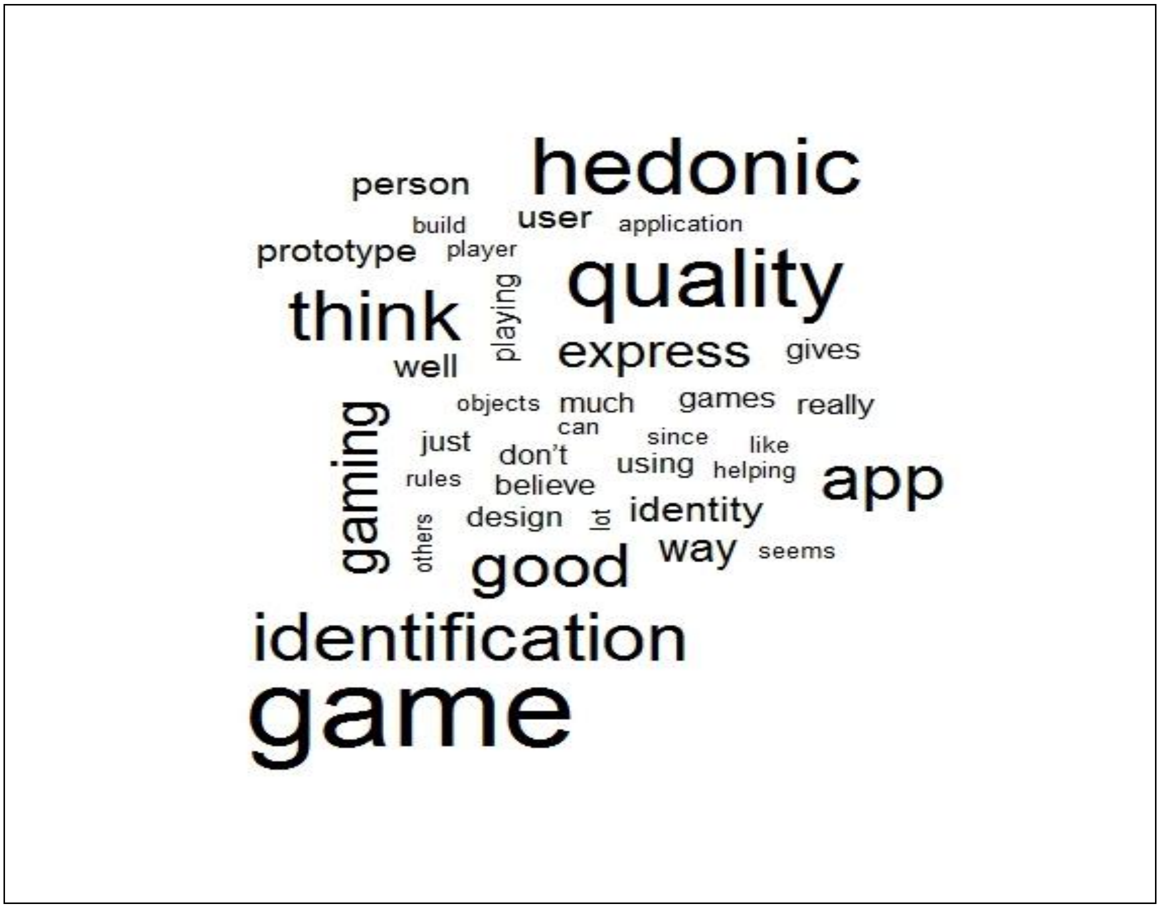

Figure 23: Word cloud for HQI of crowdsourced design created using open-ended responses.

Figure 24: Word cloud for HQI of IT professional design created using open-ended responses.

The frequency of words such as “good,” “skills,” “knowledge,” and “develop” suggest that in the case of both the crowdsourced and IT professional designs achieved the users’ need for novelty, stimulating functions, content, and presentation style (see Figure 25 and 26).

Figure 25: Word cloud for HQS of crowdsourced design created using open-ended responses.

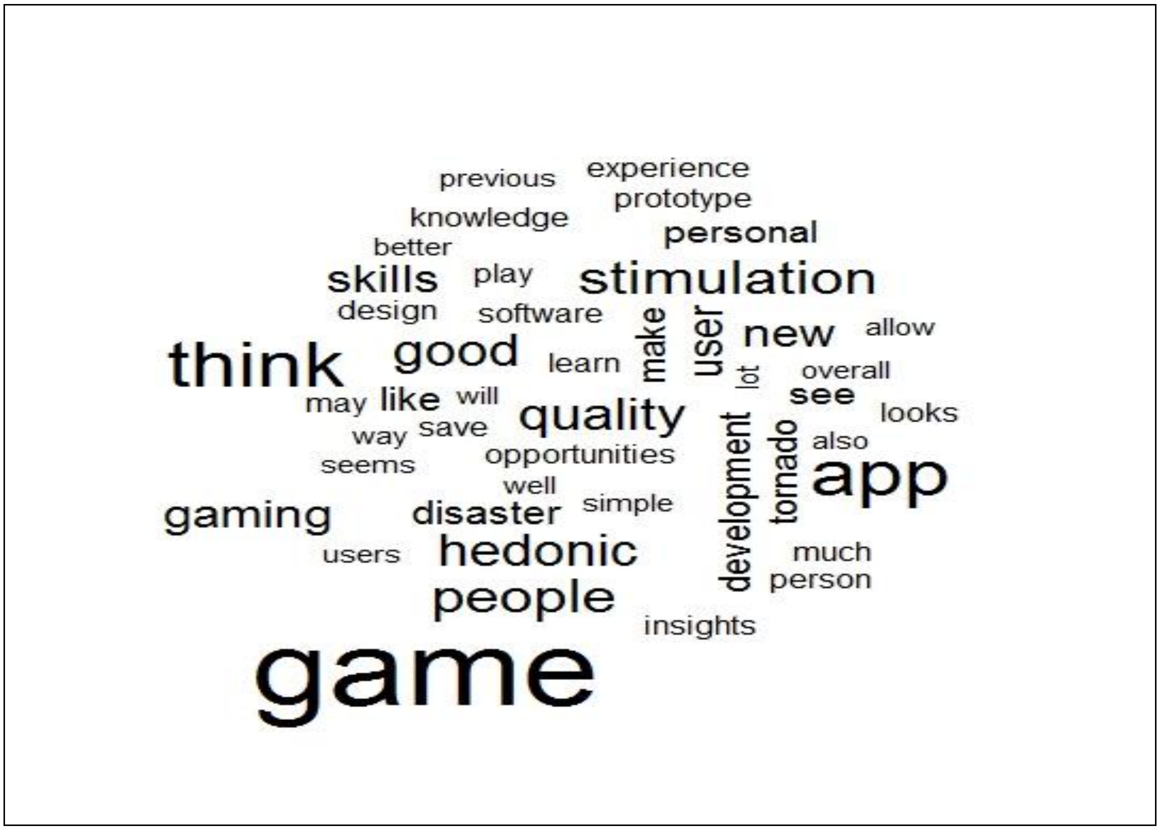

Figure 26: Word cloud for HQS of IT professional design created using open-ended responses.

The findings from the results of this research suggest a new way of thinking about using crowdsourcing in a CPS contest. Many previous studies suggested that the crowdsourcing method provides a better solution than IT professionals (Afuah & Tucci, 2012; Boudreau & Lakhani, 2013; Terwiesch & Xu, 2008). This dissertation combined the two alternative streams of research related to crowdsourcing and IT professionals' abilities to solve complex problems, including the potential for value creation.

This research also offers a new way of ranking the perceived quality of crowdsourced design in contest-based crowdsourcing and selecting the best crowdsourced design. This method selects the best crowdsourced product in terms of utility and usability, and also in terms of hedonic quality, “general human needs such as novelty and change, personal growth, self-expression and relatedness” (Hassenzahl, 2008, p. 2).

The results suggest that feedback to the participants of the crowdsourcing task plays an important role in the design and development of a high-quality product. In this research, after providing feedback to the participants, the average value of pragmatic and hedonic quality significantly increased, especially for designs with considerably low pragmatic and hedonic quality. Feedback to the participants helps them feel that their work is useful, which increases the quality of development (Nambisan, 2002; Shah, 2006). Feedback to the participants is an important motivational factor that increases willingness to contribute (Nambisan, 2002; Leimeister et al., 2009).

5.2 Limitations of the Research

There are several limitations to this study. First, a single study (the disaster management game design contest) may raise issues of methodological rigor, research subjectivity, and external validity. Replicating multiple complex tasks would address these concerns.

Second, the study suffers from the common criticisms of quasi-experimental research design. Some of the difficulties of quasi-experimental design are the lack of random assignment of subjects into test groups, which can limit the generalizability of results to a large population and is a threat to internal validity (Sproull, 1995). Another drawback due to lack of randomization is less control of the variables that may affect the outcome of an experiment (Sproull, 1995).

Third, this study did not consider the effect of the crowdsourcing platform. The researcher selected Topcoder as the crowdsourcing platform. The crowdsourcing platform may influence the quality of a product, but the study did not include an examination of this potential effect. For example, Innocentive is another popular crowdsourcing platform, and its community members may produce different solutions.

5.3 Contributions

The results of this study contribute to literature on crowdsourcing and CPS. The research results have relevance in the theoretical and practical understanding of CPS in relation to crowdsourcing and IT professional development practices. The study also contributes new ways to measure and define perceived quality.

5.3.1 Contributions to Research

This study offers several contributions to research. The conceptual model developed in Chapter 2 is the first outcome of the study. Past researchers never used the UX model in the IS discipline, especially in the crowdsourcing domain. This dissertation goes beyond existing studies in crowdsourced software development by offering a deeper understanding of perceived quality in terms of utility, usability, and general human needs. Existing studies on crowdsourced software development addressed the phenomenon based on crowdsourcing organizations such as Topcoder and Innocentive (Lakhani et al., 2013). The present study emphasized the need for a more detailed study on crowdsourcing and complex problem-solving in software development (Lakhani et al., 2013; Lanier, 2010).

A systematic literature survey of the top IS conferences and journals revealed that the theoretical research on what motivates the design of crowdsourcing-related artifact is least common. There is still very little research on traditionally popular topics such as adoption of CPS in the crowdsourcing context. The conceptual model provided in this study provides a solid starting point for continuing crowdsourcing research by extending knowledge of traditional work arrangements of organizations using crowdsourcing model to solve complex problems. The results of this experiment support that crowdsourcing design work can achieve hedonic goals (i.e., crowdsourced software presents novelty, content presentation, and interaction goals).

A major contribution of this study is its interdisciplinary nature. The study builds on relevant research on CPS, UX, and crowdsourcing. The researcher examined CPS, software design and development, and perceived quality of crowdsourcing by drawing on insights from relevant literature in cognitive psychology of problem-solving, software design and development, and human computer interaction of UX. The research design offered a unique approach to study crowdsourcing and CPS by combining multiple data sets. Both quantitative and qualitative data presented a holistic view of this phenomenon.

5.3.2 Contributions to Practice

The results of this study suggest important guidelines for solving complex problem via crowdsourcing in a way that maximizes the development of high-quality solutions. For example, feedback to the crowd after the first round of the contest increased the perceived quality of the software design in the next round. The researcher used the perceived quality questionnaire to select the best crowdsourced software design from the Topcoder platform to compare with the IT professional design. This is a new way to assess the quality of crowdsourced software. On a practical level, the findings indicate that there is a hedonic value in software for a complex task designed via crowdsourcing development. This information could be useful to organizations that want to develop new or creative products with hedonic attributes.

5.3.3 Future Research

There is still much to explore regarding crowdsourcing and problem-solving. For example, there are opportunities for further exploration of perceived quality of crowdsourced simple problems and more complex problems. Future research might explore questions such as is there a difference between perceived quality of a simple problem and perceived quality of a complex problem solved by crowds? Future research could explore an extended research model for software development by crowds and professionals or explore the influence of types of problems (simple and complex) in this relationship, specifically the moderating role of types of problems.

The research question in the present study could remain for future studies using other complex problems, such as a shuttle management problems - The scope of the project is to design an application for the mobile phone to monitor shuttle service (shuttle's location and estimated pickup time) on a university campus with fixed routes. Crowdsourcing literature includes various types of crowdsourcing, such as collaborative crowdsourcing and internal crowdsourcing. Future research could explore the research question in the context of various types of crowdsourcing.

5.4 Conclusion

This dissertation presented a discussion of the theoretical background and research method for addressing the following research question: In the context of complex problems, does software developed by the crowdsourcing business model achieve the same or better quality compared to software developed by professionals? A conceptual model guided the results. The researcher proposed that development approach has an effect on the overall perceived quality of solutions to a complex problem. The results of this study add to the literature on complex problem-solving, user experience, and crowdsourcing.

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APPENDIX A: Summary of Key Definitions

Concept	**Definition**
Crowdsourcing	Act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call.
Contest-based crowdsourcing model	A problem owner who faces an innovation-related problem posts this problem to a large independent crowd and then provides a reward to the agent who produces the best solution.
Problem owner	The problem owner is an entity that has a problem that needs to be solved. The problem owner may be a government organization, a business, or an individual.
Crowd	Dynamically formed group of an undefined large number of Internet users who participate in a crowdsourcing problem.
Technology	Web 2.0 and other Internet technologies have empowered users with space and temporal flexibility. In addition, Web 2.0 facilitates an open call, a prerequisite to crowdsourcing.
Crowd wisdom	The aggregated decision of the crowd is used to make decisions.
Problem	Difference between some current situation and some desired situation.
Simple Problem	This is a problem with clear objectives, and (problem) solvers can easily map objectives to solutions. Both the problem and the solution are known.

Complex Problem	A problem becomes complex when its solution requires responses that deviate from common solutions or from previously learned ones. In the case of a complex problem, the problem is known but the solution is either unknown or there may be multiple solutions.
User Experience	A consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (complexity, purpose, usability, functionality, etc.), and the environment within which the interaction occurs (organizational/social setting, meaningfulness of the activity).
Pragmatic Quality	A product's perceived ability to support the fulfillment of functions or intended tasks. Pragmatic quality refers to functions or tasks as "do goals" (software is performing intended tasks). Pragmatic quality focuses on the utility and usability of products in terms of intended tasks.
Hedonic Quality Stimulation	An individual quest for personal development such as proliferation of knowledge and development of skills.
Hedonic Quality Identification	Individuals' ways to express their selves through physical objects.
Professionals	"Software professionals are described as having high technical and computational knowledge, a high level of social skills, and as using a method-oriented working style. They have a broader but not longer professional experience." (Sonnentag, 1995)

APPENDIX B: Informed Consent Letter

Informed Consent Letter

Title of Study - Myth or Reality? Crowdsourcing as a Complex Problem-Solving Model: Evidence from Software Developed by Crowd and Professionals

Principal Investigator
Name – Abhishek Tripathi (PHD student)
Advisors: Dr. Deepak Khazanchi and Dr. L. Najjar

Department: Information Science and Qualitative Analysis

Background
You are being invited to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information.

The purpose of study
The purpose of the study is to compare the quality perceptions between disaster management gaming app prototype designed by two different method. The study involves collecting information from students at University of Nebraska at Omaha using a survey of questions developed by Dr. Marc Hassenzahl and his associates. Dr. Hassenzahl gave us permission to use his survey for the purpose of assessing the quality of software along dimensions of perceived quality. The Invisionapp prototype link of first method design (design A) is – https://invis.io/8J82D5RNH

You have to fill out the survey questionnaire based on your design experience (survey questionnaire link is - https://www.surveymonkey.com/r/ATCSQA)

Similarly, The Invisionapp link of second method prototype design is – https://projects.invisionapp.com/share/TK84YPJRH#/screens and corresponding survey link is –

https://www.surveymonkey.com/r/ATCSQB

In order to participate in this research study, you have to fill out both the survey.

Voluntary participation
Your expected time commitment for this study is 30 minutes.
Your participation in this study is voluntary. You may decline to participate in this survey or if you decide to participate, please answer all the questions. You may terminate your involvement at any time if you choose.
Choose an answer between 1 and 7 with 1 being “Not at all” and 7 being “Completely”.
Confidentiality
Your responses will be anonymous. No personal information will be linked to your answers.
This study is already approved by the IRB and approval number is **- IRB #:** 737-13-EX
Person to contact

Should you have any questions about the research or any related matters, please contact the researcher at
Abhishek Tripathi (atripathi@unomaha.edu, 402-955-9222) (or)

Lotfollah Najjar (lnajjar@unomaha.edu, 402-554-2233) and Dr. Deepak Khazanchi (khazanchi@unomaha.edu, 402-554-2029)

APPENDIX C: Survey Questionnaire

Following, are pairs of words to assist you in your evaluation. Each pair represents extreme contrasts. The possibilities between the extremes enable you to describe the intensity of the quality you choose. Do not spend time thinking about the word-pairs. Try to give a spontaneous response. You may feel that some pairs of terms do not adequately describe the product. In this case, please still be sure to give an answer. Keep in mind that there is no right or wrong answer. Your personal opinion is what counts!

Human	○ ○ ○ ○ ○ ○ ○	Technical
Isolating	○ ○ ○ ○ ○ ○ ○	Connective
Pleasant	○ ○ ○ ○ ○ ○ ○	Unpleasant
Inventive	○ ○ ○ ○ ○ ○ ○	Conventional
Simple	○ ○ ○ ○ ○ ○ ○	Complicated
Professional	○ ○ ○ ○ ○ ○ ○	Unprofessional
Ugly	○ ○ ○ ○ ○ ○ ○	Attractive
Practical	○ ○ ○ ○ ○ ○ ○	Impractical
Likeable	○ ○ ○ ○ ○ ○ ○	Disagreeable
Cumbersome	○ ○ ○ ○ ○ ○ ○	Straightforward
Stylish	○ ○ ○ ○ ○ ○ ○	Tacky
Predictable	○ ○ ○ ○ ○ ○ ○	Unpredictable
Cheap	○ ○ ○ ○ ○ ○ ○	Premium
Brings me closer to people	○ ○ ○ ○ ○ ○ ○	Separates me from people
Unpresentable	○ ○ ○ ○ ○ ○ ○	Presentable
Rejecting	○ ○ ○ ○ ○ ○ ○	Inviting
Unimaginative	○ ○ ○ ○ ○ ○ ○	Creative
Good	○ ○ ○ ○ ○ ○ ○	Bad
Confusing	○ ○ ○ ○ ○ ○ ○	Clearly structured

Repelling	○ ○ ○ ○ ○ ○ ○	Appealing
Bold	○ ○ ○ ○ ○ ○ ○	Cautious
Innovative	○ ○ ○ ○ ○ ○ ○	Conservative
Dull	○ ○ ○ ○ ○ ○ ○	Captivating
Undemanding	○ ○ ○ ○ ○ ○ ○	Challenging
Motivating	○ ○ ○ ○ ○ ○ ○	Discouraging
Novel	○ ○ ○ ○ ○ ○ ○	Ordinary
Unruly	○ ○ ○ ○ ○ ○ ○	Manageable
Alienating	○ ○ ○ ○ ○ ○ ○	Integrating
Fulfils needs and expectations	○ ○ ○ ○ ○ ○ ○	Do not fulfils my needs and expectations
Satisfies needs	○ ○ ○ ○ ○ ○ ○	Do not satisfies needs
overall satisfactory	○ ○ ○ ○ ○ ○ ○	Not satisfactory
I will use in future	○ ○ ○ ○ ○ ○ ○	I will not use in future
I will use frequently	○ ○ ○ ○ ○ ○ ○	I will not use frequently

In the following section we ask for information about yourself and your own experience with the product.

Please circle only one of the options for each question below.

Gender: Male Female

Age: 19-25 25-35 35-50 50-60

Education: B.S. in IT Innovation, B.S. in Computer Science, B.S. in Management Information System, B.S. in Information Assurance, B.S. in Bioinformatics, M.S. in Computer Science, M.S. in Biomedical Informatics, M.S. in Management Information System, M.S. in Information Assurance, PhD in IT, PhD in BMI

Profession:

How long have you already been using this type of product?

Product experience: less than a month, less than a year, more than 1 year

Please answer the following questions

Pragmatic quality refers to a product's perceived ability to support the fulfillment of functions or intended tasks. Pragmatic quality is functions or tasks as "do goals" (software is performing intended tasks). Pragmatic quality focuses on the utility and usability of products in terms of intended tasks. What do you think about the pragmatic quality of this gaming app prototype design?

Hedonic Quality Stimulation refers to an individual quest for personal development such as a proliferation of knowledge and development of skills. So, software should provide new impressions, opportunities, and insights. What do you think about the Hedonic Quality Stimulation of this gaming app prototype design?

Hedonic Quality Identification refers to individuals’ way to express their self through physical objects. To fulfill this need, a software has to communicate identity. What do you think about the Hedonic Quality Identification of this gaming app prototype design?

APPENDIX D: IRB Certificate for Pilot Study

Nebraska
UNIVERSITY OF
Medical Center

NEBRASKA'S HEALTH SCIENCE CENTER

Office of Regulatory Affairs (ORA)
Institutional Review Board (IRB)

December 19, 2013

Abhishek Tripathi, MS
ISQA
UNO – Via Courier

IRB #: 737-13-EX
TITLE OF PROTOCOL: Myth or Reality? Crowdsourcing as a Complex Problem Solving Model:Evidence from Software Developed by the Crowd and Experts

Dear Mr. Tripathi:

The Office of Regulatory Affairs (ORA) has reviewed your application for *Exempt Educational, Behavioral, and Social Science Research* on the above-titled research project. According to the information provided, this project is exempt under 45 CFR 46:101b, category 2. You are therefore authorized to begin the research.

It is understood this project will be conducted in full accordance with all applicable HRPP Policies. It is also understood that the ORA will be immediately notified of any proposed changes for your research project.

Please be advised that this research has a maximum **approval period of 5 years** from the original date of approval and release. If this study continues beyond the five year approval period, the project must be resubmitted in order to maintain an active approval status.

Sincerely,

Gail D. Kotulak

Gail Kotulak, CIP
IRB Administrator
Office of Regulatory Affairs (ORA)

gdk

Academic and Research Services Building 3000 / 987830 Nebraska Medical Center / Omaha, NE 68198-7830
402-559-6463 / FAX: 402-559-3300 / Email: irbora@unmc.edu / http://www.unmc.edu/irb

APPENDIX E: IRB Certificate for Final Study

NEBRASKA'S HEALTH SCIENCE CENTER

Office of Regulatory Affairs (ORA)
Institutional Review Board (IRB)

June 22, 2016

Abhishek Tripathi, MS
ISQA
UNO - VIA COURIER

IRB # 737-15-EX

TITLE OF PROPOSAL: Myth or Reality? Crowdsourcing as a Complex Problem Solving Model: Evidence from Software Developed by the Crowd and Experts

RE: Request for Change, dated *06/16/2016*

DATE OF REVIEW: *06/22/2016*

Dear Abhishek Tripathi

The UNMC ORA has completed its review of the above-mentioned Request for Change involving modifying the advisor, adding the GRACA grant, increasing accrual from 175 to 550,and moving from the pilot to to a 2 phase method.

This letter constitutes official notification of approval of the revised application, development of an email and survey consent (letter), upload of two project descriptions, and provided the GRACA grant.

You are authorized to implement this change accordingly.

Respectfully Submitted,

Signed on: 2016-06-22 10:24:00.000

Gail Kotulak, BS, CIP
IRB Administrator III
Office of Regulatory Affairs

Academic and Research Services Building 3000 / 987830 Nebraska Medical Center / Omaha, NE 68198-7830
402-559-6463 / FAX: 402-559-3300 / Email: irbora@unmc.edu / http://www.unmc.edu/irb

APPENDIX F: GRACA Grant Contract

University of Nebraska Omaha

OFFICE OF RESEARCH AND CREATIVE ACTIVITY

TO:	**Abhishek Tripathi**
FROM:	Beth White, Coordinator, Internal Research Resources
DATE:	March 8, 2016
SUBJECT:	**Research and Creative Activity (GRACA) Student Award Contract**

Dear Abhishek,

Congratulations! We are pleased to inform you that, based on the recommendation of the Graduate Research and Creative Activity (GRACA) review committee, the Office of Research and Creative Activity (ORCA) has approved funding your proposal entitled, **"Myth or Reality? Crowdsourcing as a Complex Problem Solving Model: Evidence from Software Developed by the Crowd and Professionals"** to assist you in your research. As with all research and creative activity funds at UNO, a contract is required.

The committee is able to provide **$5000** to be spent according to your proposed budget. All expenditures must be incurred within the budget period of the project (April 1, 2016 April 1, 2017). Goods and other tangible property must be received, services must be performed, and travel must be completed before April 1, 2017. No project deadline extensions are permitted. It is the responsibility of both you and your faculty mentor to ensure you remain within your budget.

Recipients of the GRACA awards will adhere to established policies and procedures at the University of Nebraska at Omaha.

For projects involving humans (IRB), animals (IACUC), or biohazardous materials (IBC), funding is contingent upon ORCA receiving a copy of your IRB/IACUC/IBC approval letter. If compliance approval is not obtained by December 1, 2016, your award may be rescinded. Please communicate with ORCA to address any delays in obtaining approval. On your behalf, this contract will be administered by your faculty mentor. However, you are responsible for communications with our office.

All requests for reimbursement must be signed by your mentor and forwarded to Accounting Services, EAB 208. Stipends are paid via direct-deposit. If you are not already a UNO employee, you will be required to submit additional HR paperwork.

Publication and other means of circulation emanating from this project should acknowledge the support of the Graduate Research and Creative Activity (GRACA) program. You should provide ORCA with one copy of any manuscript, publication, or other relevant documentation resulting from research funded by your GRACA grant.

Students receiving awards are required to present the results of their research at the 9th Annual Student Research and Creative Activity Fair in spring 2017. Please plan your calendar, accordingly.

In order to receive this award, please complete page two (2) of this contract letter. All signatures indicate acknowledgement of the above-noted terms of this award.

Congratulations, again.

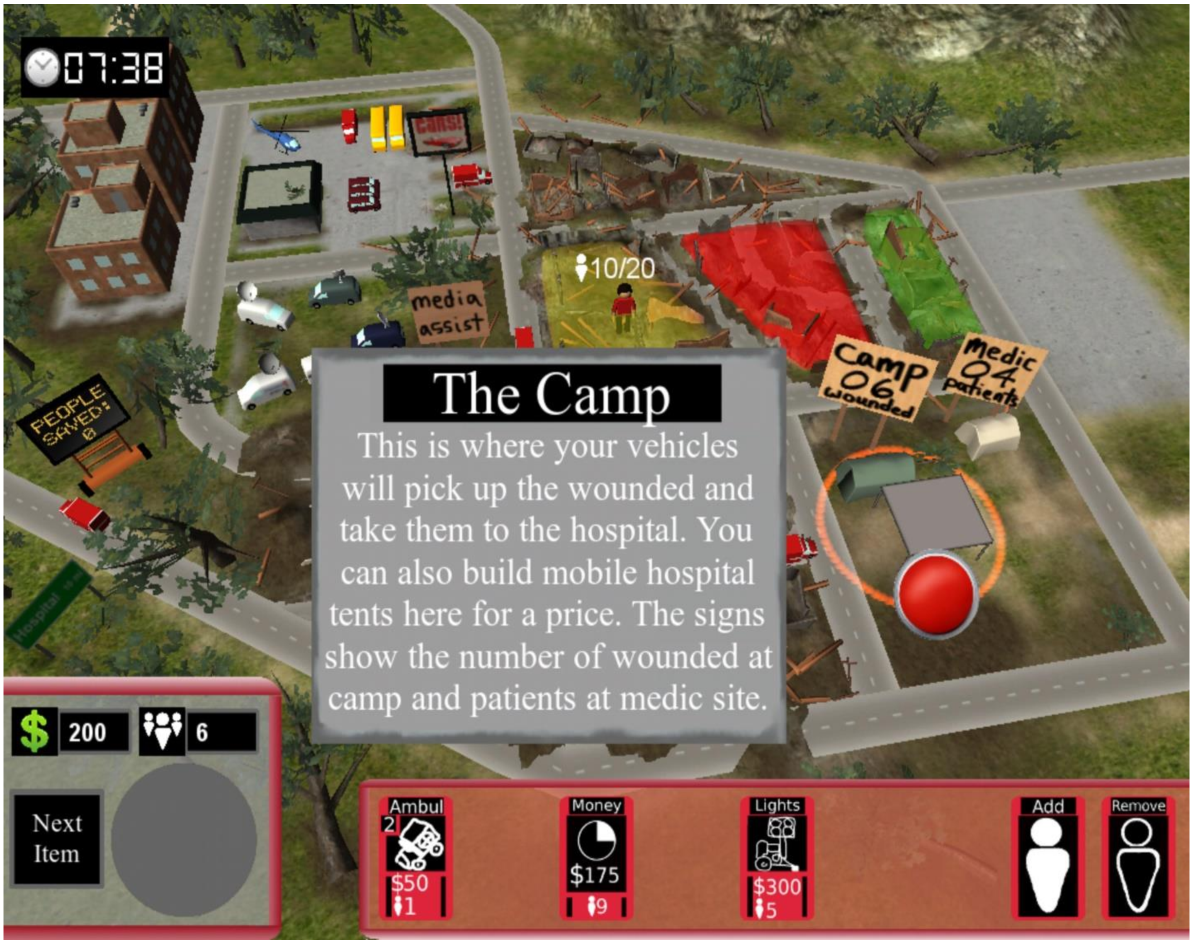
The Office of Research and Creative Activity

APPENDIX G: IT Professional's Software Design

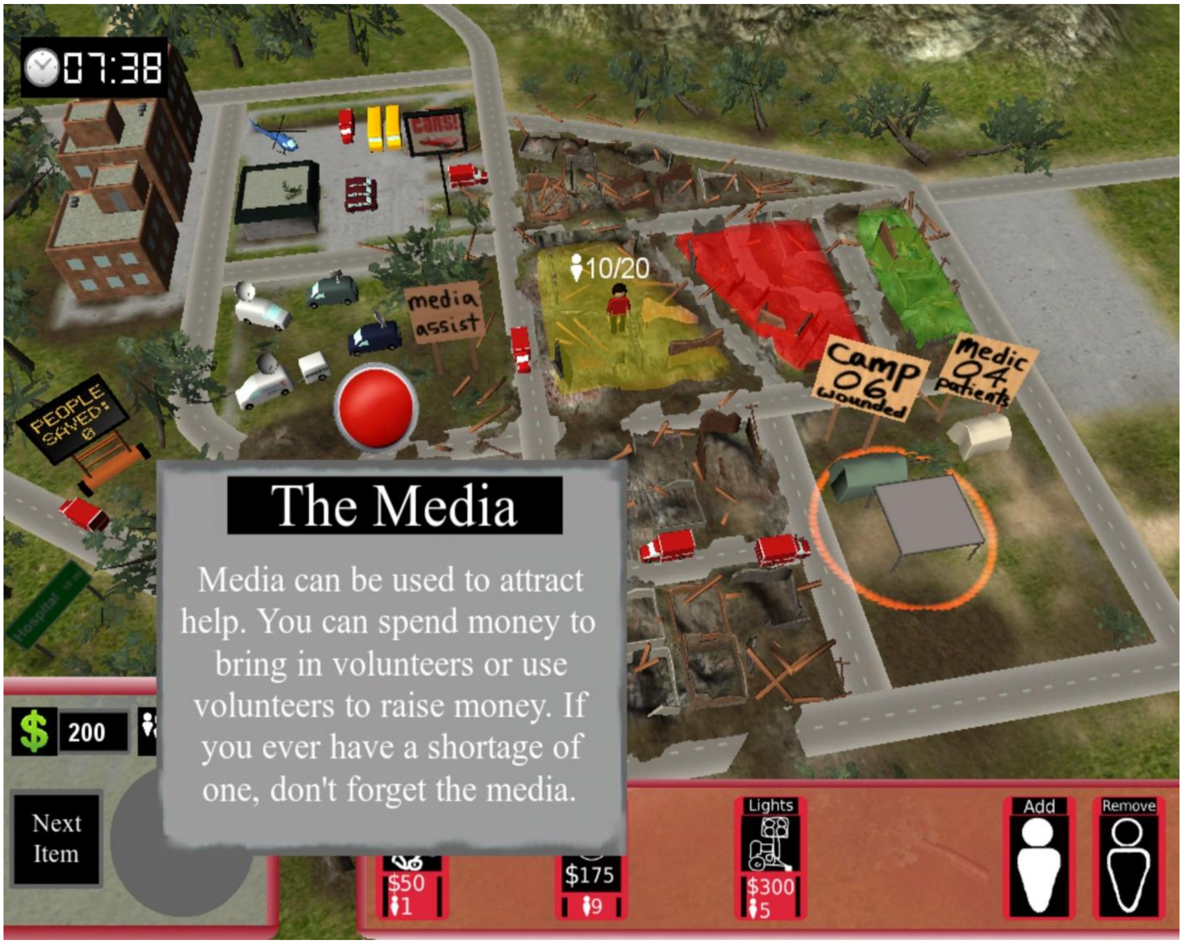

07:38
The Scout
This is your scout team. The number of volunteers in the scout team out of the max capacity is above the head. Touch a colored area to find wounded people. The green areas give you the most time to search.
10/20
Camp 06 wounded
Medic 04 patients
200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


07:38
10/20
The Vehicles
While the scout team searches, your vehicles drive the wounded from the camp to the hospital. Touch here to buy a vehicle. They will automatically drive to the camp and grab the wounded.
Camp
06
wounded
Medic
04
patients
200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


07:38
10/20
media
Camp 06 wounded
Medic 04 patients
PEOPLE SAVED: 0
Vehicle Button
Ambu 1
2 2
$50 3
1 4
1) Type
2) # wounded can carry
3) Money needed
4) Volunteers needed
$ 200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


07:38
The Camp
This is where your vehicles will pick up the wounded and take them to the hospital. You can also build mobile hospital tents here for a price. The signs show the number of wounded at camp and patients at medic site.
10/20
media assist
Camp 06 wounded
Medic 04 patients
PEOPLE SAVED: 0
200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


07:38
10/20
The Hospital
Your vehicles will head to the hospital from here. Once they get to the hospital, the sign will change to add the new survivors. Keep track of how many people you have saved.
PEOPLE SAVED: 0
Camp 06 wounded
Medic 04 patients
$ 200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove

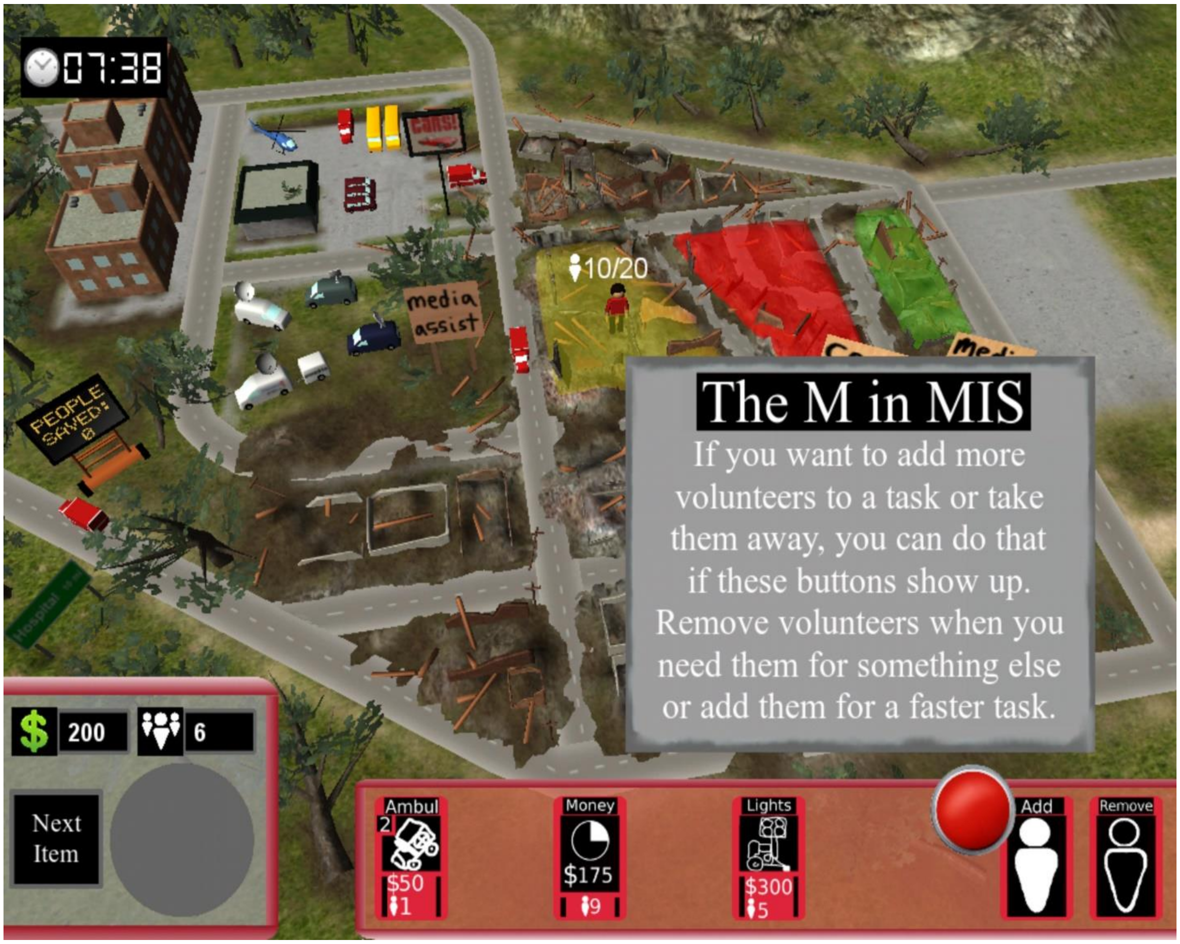

07:38
media assist
10/20
Camp 06 wounded
Medic 04 patients
PEOPLE SAVED: 0
The Media
Media can be used to attract help. You can spend money to bring in volunteers or use volunteers to raise money. If you ever have a shortage of one, don't forget the media.
200
Next Item
$50
1
$175
9
Lights
$300
5
Add
Remove


07:38
Media Button
Money
1
2
$175
3
9
4
1) What you get
2) White shows conversion time
3) How much you get
4) What it costs
10/20
Camp
06
Wounded
Medic
04
Patients
PEOPLE SAVED:
0
200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


07:38
10/20
media assist
PEOPLE SAVED: 0
The Lights
You will be able to buy lights among other things. These have cost money and use up volunteers. Once built, most will give back the volunteers, but not the money.
200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


07:38
10/20
The Currency
Here you can see how much money and volunteers are at your disposal. You will get money and volunteers periodically. Also, if you are building anything, you will be able to see it here.
Camp 06 wounded
Medic 04 patients
PEOPLE SAVED: 0
200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


07:38
The Time
Keep an eye out on your time limit. Eight minutes will go by faster than you might think. Save as many people as you can during this time.
PEOPLE SAVED: 0
Camp 06 wounded
Medic 04 patients
200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


07:38
10/20
media assist
PEOPLE SAVED: 0
The M in MIS
If you want to add more volunteers to a task or take them away, you can do that if these buttons show up. Remove volunteers when you need them for something else or add them for a faster task.
200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


07:38
START
The Redo
If you need to revisit any of the buttons again, here's your chance. When you are confident with how the game works, tap the Start button to start the game.
PEOPLE SAVED: 0
Camp 06 wounded
Medic 04 patients
Hospital
200
6
Next Item
Ambul
2
$50
1
Money
$175
9
Lights
$300
5
Add
Remove


08:48
Edgar
I noticed a tree leaning bad by the North side of the road on the way to the hospital.
media assist
Camp 4 wounded
PEOPLE SAVED: 0
10/20
250
10
Next Vehicle
Ambul
2
$50
1
Bus
8
$70
2
Van
4
$65
1
Heli
2
$85
2
Lights
$300
5
Add
Remove


04:37
media assist
Camp 78 wounded
PEOPLE SAVED: 58
Park
10/20
+1
+1
415
16
Next Vehicle
Ambul
2
$50
1
Bus
8
$70
2
Van
4
$65
1
Heli
2
$85
2
Lights
$300
5
Add
Remove

APPENDIX H: Crowdsourced Software Design


TORNADO
DISASTER MANAGEMENT
START GAME
SIGN IN
LEADERBOARD


EXIT
GAME STATS
8:00
0/5
ACTIVE VOLUNTEERS
0/500
PEOPLE RESCUED
250
COINS AVAILABLE
0
DEATH TOLL
PAUSE


EXIT
GAME STATS
8:00
SCAN BUILDINGS
Tap the destroyed building and tap the search icon, search would require a minimum of 1 volunteer and a duration of 10 seconds, adding volunteers will speed it up.
0 / 5
ACTIVE VOLUNTEERS
0 / 500
PEOPLE RESCUED
250
COINS AVAILABLE
0
DEATH TOLL
PAUSE


EXIT
GAME STATS
8:00
BUILD ORDER
Build Camps and Vehicle Factory First so that you can have a tansport point for your refugees
150
75
100
75
ASSIGN VOLUNTEERS
The more the volunteer the faster the vehicle transfer rate and the search for survivors.
ADD ACCESSORY
A ruined building can have accessories for the volunteers, you can add 2 items only
BACK TO STATS
1/5
0/2
NO ACCESSORIES EQUIPED
PAUSE


EXIT
GAME STATS
8:00
PROGRESS
Here the icon is shown for the duration of the search.
AFTER SEARCH
Mortality rate is introduce every 10 second a person dies, there are 100 people trapped in this building
Player should now build a camp and a factory for vehicle transport
0
100
BACK TO STATS
1/5
0/2
NO ACESSORIES EQUIPED
PAUSE

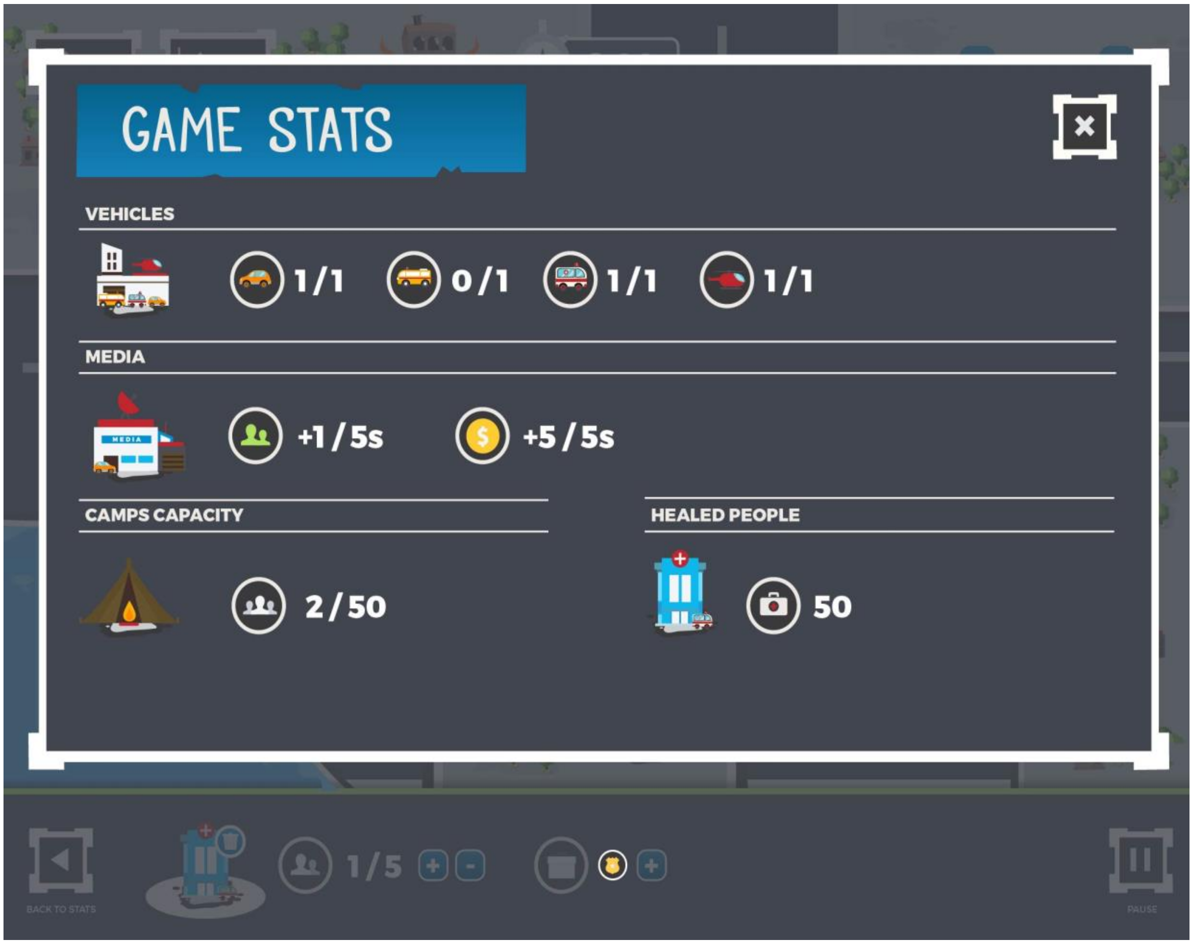

EXIT
GAME STATS
8:00
DELETE
Delete Structure, it will reset to the build icon and half of the gold will be refunded
ASSIGN VEHICLES
You can assign vehicles to camps and ruined buildings. Maximum of 2 vehicles only.
CAMP CAPACITY
This is the capacity of your camp, avoid getting it full to make a continious rescue
BACK TO STATS
1/5
0/2
2/50
NO ACCESSORIES EQUIPED
PAUSE

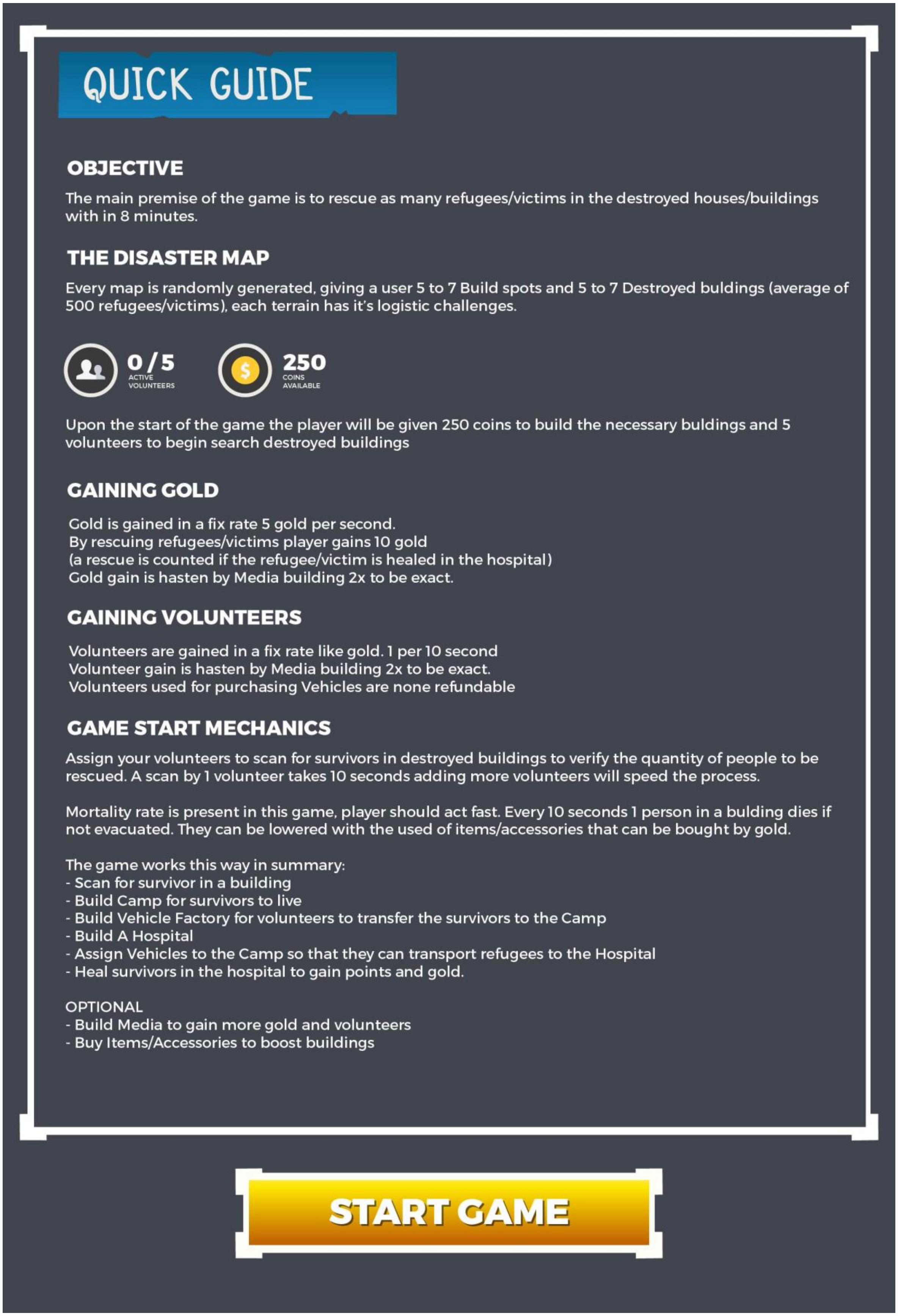

EXIT
GAME STATS
8:00
0
75
0
100
VOLUNTEER GAIN
With media building the volunteer gain will be speed up twice instead of 1 per 10 second
GOLD GAIN
With media building the gold gain will also be speed up instead of 5 per 10 seconds
+1 / 5s
+5 / 5s
BACK TO STATS
PAUSE

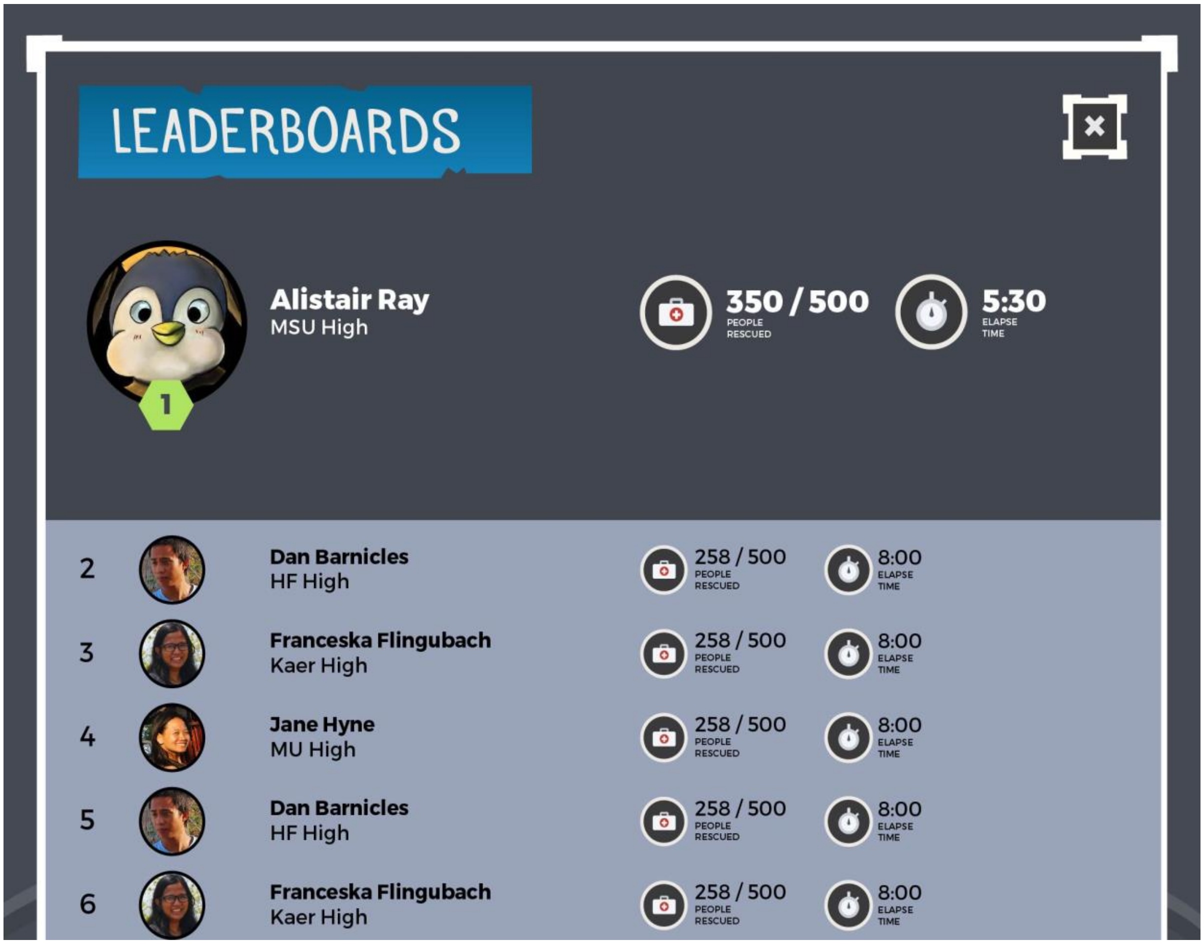

EXIT
GAME STATS
8:00
VEHICLE ICON
Icons are added to quick statistics to let you know there a certain vehicle is added
VEHICLE PURCHASE
Vehicles cost gold and volunteers they vary in travel time, capacity & cost. Destoryed buildings that are surrounded by water can only use helicopters for rescue.
1/1
0/1
1/1
1/1
50
75
100
200
BACK TO STATS
PAUSE

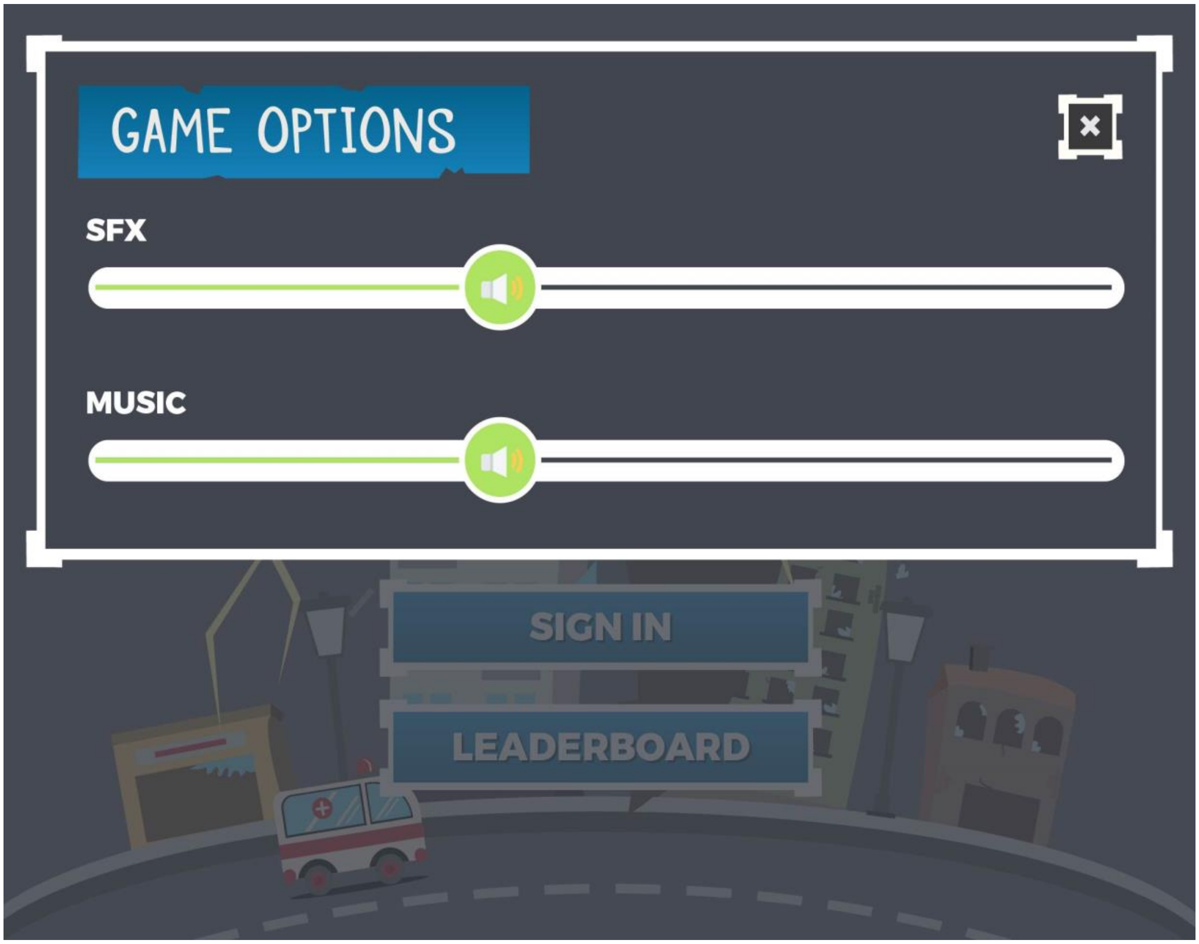

EXIT
GAME STATS
8:00
0
75
0
100
ASSIGN VOLUNTEERS
The more the volunteer the faster healing rate of the patient
ADD ACCESSORY
Adding certain accessories to an hospital will speed up the healing process.
1/5
NO ACCESSORIES EQUIPED
BACK TO STATS
PAUSE


DISASTER SHOP
ADD ACCESSORY
TAP to buy and automatically add to the building, can only be used onced.
250
GOLD ROCKET
Vehicle travel time greatly reduced
300
SHERIFF IN TOWN
Max volunteer efficiency
300
MEDIC KIT
Reduces mortality rate
(Destroyed building only)
175
STIMPACK
Faster patient healing
(Hospital only)
175
CAFFINATED
Twice efficiency for volunteers
100
FUEL TANK
Reduces vehicle travel time
100
1/5
BACK TO STATS
PAUSE


GAME STATS
VEHICLES
1/1
0/1
1/1
1/1
MEDIA
+1/5s
+5/5s
CAMPS CAPACITY
2/50
HEALED PEOPLE
50
1/5
BACK TO STATS
PAUSE

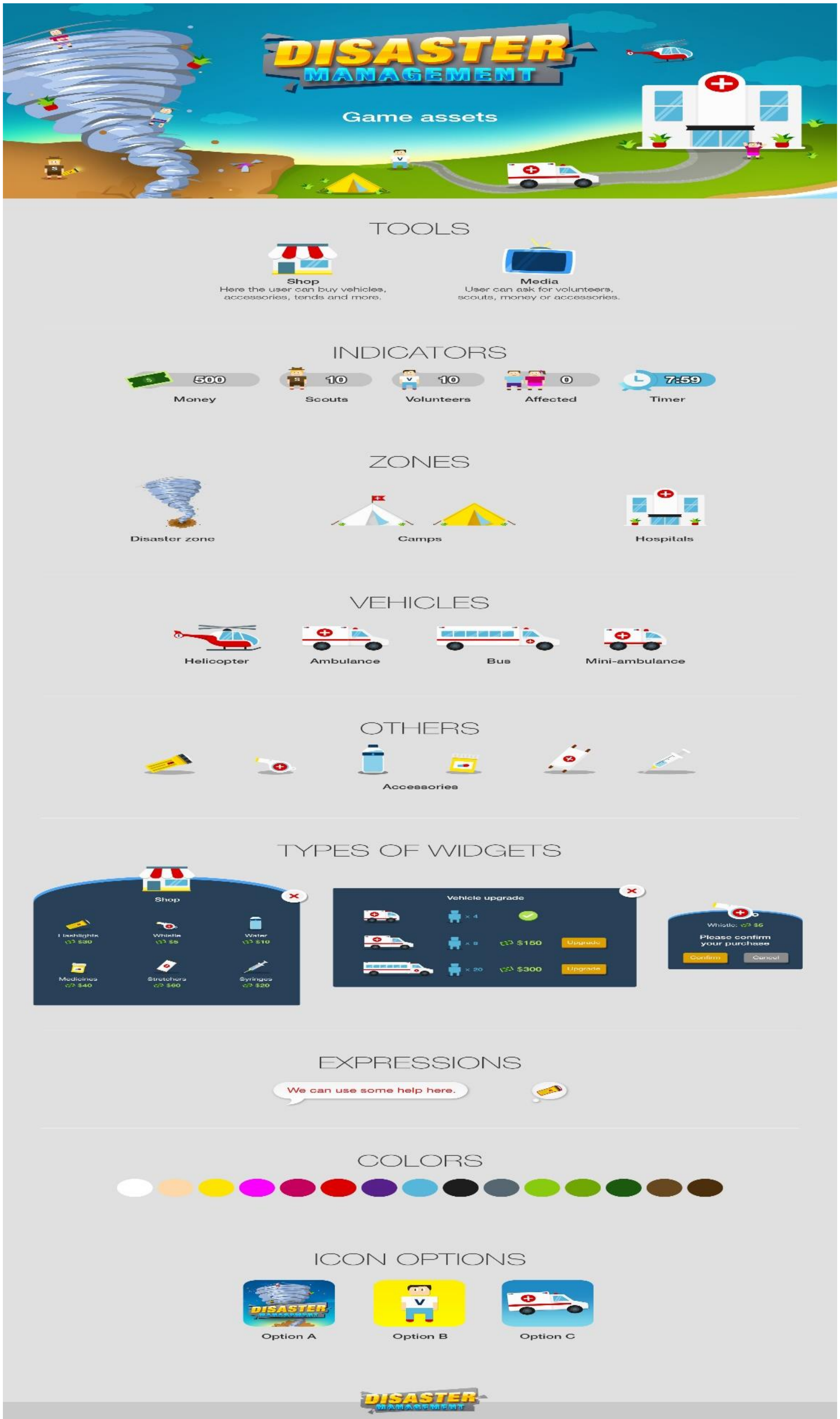

QUICK GUIDE
OBJECTIVE
The main premise of the game is to rescue as many refugees/victims in the destroyed houses/buildings with in 8 minutes.
THE DISASTER MAP
Every map is randomly generated, giving a user 5 to 7 Build spots and 5 to 7 Destroyed buldings (average of 500 refugees/victims), each terrain has it's logistic challenges.
0 / 5
ACTIVE VOLUNTEERS
250
COINS AVAILABLE
Upon the start of the game the player will be given 250 coins to build the necessary buldings and 5 volunteers to begin search destroyed buildings
GAINING GOLD
Gold is gained in a fix rate 5 gold per second.
By rescuing refugees/victims player gains 10 gold
(a rescue is counted if the refugee/victim is healed in the hospital)
Gold gain is hasten by Media building 2x to be exact.
GAINING VOLUNTEERS
Volunteers are gained in a fix rate like gold. 1 per 10 second
Volunteer gain is hasten by Media building 2x to be exact.
Volunteers used for purchasing Vehicles are none refundable
GAME START MECHANICS
Assign your volunteers to scan for survivors in destroyed buildings to verify the quantity of people to be rescued. A scan by 1 volunteer takes 10 seconds adding more volunteers will speed the process.
Mortality rate is present in this game, player should act fast. Every 10 seconds 1 person in a bulding dies if not evacuated. They can be lowered with the used of items/accessories that can be bought by gold.
The game works this way in summary:
- Scan for survivor in a building
- Build Camp for survivors to live
- Build Vehicle Factory for volunteers to transfer the survivors to the Camp
- Build A Hospital
- Assign Vehicles to the Camp so that they can transport refugees to the Hospital
- Heal survivors in the hospital to gain points and gold.
OPTIONAL
- Build Media to gain more gold and volunteers
- Buy Items/Accessories to boost buildings
START GAME


LEADERBOARDS
Alistair Ray
MSU High
350 / 500
PEOPLE RESCUED
5:30
ELAPSE TIME
1
2
Dan Barnicles
HF High
258 / 500
PEOPLE RESCUED
8:00
ELAPSE TIME
3
Franceska Flingubach
Kaer High
258 / 500
PEOPLE RESCUED
8:00
ELAPSE TIME
4
Jane Hyne
MU High
258 / 500
PEOPLE RESCUED
8:00
ELAPSE TIME
5
Dan Barnicles
HF High
258 / 500
PEOPLE RESCUED
8:00
ELAPSE TIME
6
Franceska Flingubach
Kaer High
258 / 500
PEOPLE RESCUED
8:00
ELAPSE TIME


GAME OPTIONS
SFX
MUSIC
SIGN IN
LEADERBOARD


ACHIEVEMENTS
A LIVE SAVED
Completed 1 Gameplay
CAMP SITE
Build and rescued 50 people in a camp
IN TIME
Rescued 10 people in 1 minute
FOREMAN
Constucted 10 Buildings
THE DOCTOR
Saved 30 people
ITEMIZED
Used All acessories in the game


EXIT
GAME STATS
TIME'S UP!
299
PEOPLE RESCUED
135
DEATH TOLL
CONTINUE
1/5
NO ACCESSORIES EQUIPED
BACK TO STATS
PAUSE


DISASTER
MANAGEMENT
Game assets
TOOLS
Shop
Here the user can buy vehicles, accessories, tends and more.
Media
User can ask for volunteers, scouts, money or accessories.
INDICATORS
500
Money
10
Scouts
10
Volunteers
0
Affected
7:59
Timer
ZONES
Disaster zone
Camps
Hospitals
VEHICLES
Helicopter
Ambulance
Bus
Mini-ambulance
OTHERS
Accessories
TYPES OF WIDGETS
Shop
Whistle
$5
Water
$10
Medicines
$40
Stretchers
$60
Syringes
$20
Vehicle upgrade
x 4
x 8
$150
Upgrade
x 20
$300
Upgrade
Whistle: $5
Please confirm your purchase
Confirm
Cancel
EXPRESSIONS
We can use some help here.
COLORS
ICON OPTIONS
Option A
Option B
Option C
DISASTER
MANAGEMENT