An Integrative Perspective and Analysis for Crowdsourcing Science and Innovation

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Declaration

This thesis is submitted to the University of Portsmouth for the degree of Doctor of Philosophy.

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

This thesis is the result of my independent work and investigation, except where otherwise stated. A reference list is included.

If accepted, I hereby consent for my thesis to be available for inter-library loan, photocopying, and availability online.

David Adjetey Boye

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Abstract

Crowdsourcing is a multidisciplinary research area and a technological innovation that represents a rapidly expanding field in which new applications are continually emerging, enabling organizations to leverage the wisdom of the public. Prior studies have emphasized categorizing the field based on qualitative methods and focused more on technology and crowd perspectives. Few studies examine the organizational integration of crowdsourced based science to innovation activities as well as categorize the entire field using quantitative publication analysis. This study aims to examine the process and organizational use of crowdsourcing activities in a comprehensive way, including science and innovation activities, especially identifying the integration of both activities. Based on data from a mixed-method approach, the quantitative analysis's key findings show its usage is majorly in the three domains of innovation, engineering, and science with their underlying main categories and sub-categories. The qualitative analysis's key findings and comparing crowdsourcing science and innovation (SI) show that organizational management is similar. However, organizations' motives in both activities are fundamentally different, but the integration of crowdsourcing science to innovation allows an interactive and iterative process to occur. This study contributes to the field's knowledge by proposing a framework that integrates crowdsourcing activities during the entire innovation process, an organizational crowdsourcing management perspective, theoretically unifying the organizational enablers and barriers for crowdsourcing usage, and methodologically maps the crowdsourcing field.

Disseminations

Published Outputs

- David Boye, Sercan Ozcan, Paul Trott and Jbid Arsenyan (2017): A bibliometric mapping of crowdsourcing field: Uncovering new domains at the CiNet Conference, Potsdam, Germany, September (2017)

- David Boye, Sercan Ozcan, Tobi Fajana (2018): A Text Mining Approach to Examine Crowdfunded Innovations for Consumer-oriented New Product Development at the Global Tech Mining Conference, Netherlands, September (2018)

- Sercan Ozcan, David Boye, Jbid Arsenyan and Paul Trott (2020): A scientometric exploration of crowdsourcing: emerging themes and applications (IEEE Transaction on Engineering Management)

Working Papers

- David Boye, Sercan Ozcan, Tobi Fajana (2020): Text Mining Integrated Technology Roadmapping Approach using Crowdfunded Projects: The case of 3D Printers (Journal of the Association for Information Science and Technology)

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Glossary of Terms and Abbreviations

Abbreviations and Terms	Description
BAL	Business and Law
Barriers	Factors that are identified to have negative influence
CAD	Computer-Aided Design
CEO	Chief Executive Officer
CSO	Crowdsourcing science outputs
CIO	Crowdsourcing innovation outputs
CINAHL	Cumulative index to nursing and allied health literature
CS	Crowdsourcing Science
D&M	Delone and McLean IS success model
DARPA	US Defense Advanced Research Project Agency
DCS	Direct Current Stimulation
Determinants	Umbrella term covering related enabler and barriers
DITOS	Doing It Together Science
DOI	Diffusion of Innovation
EC	European Commission
ECSA	European Citizen Science Association
Enablers	Factors that are identified to have a positive influence
ERP	Enterprise Resource Planning
FFE	Fuzzy Front End
IBM	International Business Machines
IMS	Integrated Management System
IP	Intellectual Property
IPO	Input-Process-Output
IPR	Intellectual Property Rights
IT	Information Technology
LED	Light Emitting Diode
MCS	Mobile Crowdsourcing
NCATS	National Centers for Advancing Translational Sciences
NIH	National Institutes for Health
NOAA	National Oceanic and Atmospheric Administration
NPD	New Product Development
OSS	Open Source Software
P&G	Procter and Gamble
PDD	Product Design and Development
QoE	Quality of Experience
R&D	Research and Development
RBV	Resource-Based View
SERP	Search Engine Result Page
SGM	Stage Gate Model
SI	Science and Innovation
SME	Small and Medium Enterprises
TAM	Technology Acceptance Model
TDCS	Transcranial Direct Current Stimulation
TOE	Technology, Organisation and Environment
TRA	Theory of Reasoned Action
TRIZ	Theory of Inventive Problem Solving
UI	User Interface
UK	United Kingdom
US	United States of America
USAID	United States Agency of International Development
UX	User Experience
WOS	Web of Science

Chapter 1: Introduction

1.1 Overview

This introduction explains the various aspects of this research, such as the literature's limitations, its theoretical background, research context, research methods, and contributions. This section provides brief and relevant coverage of the literature and the research questions as well as presenting an outline of the thesis. This chapter presents the study's scope, which is within the field of innovation management regarding the general area of research and more specific subject matter, as well. Due to the lack of empirical research examining the crowdsourcing process from a seekers perspective, this research aims to broaden the understanding of crowdsourcing and its use by revealing how it develops and integrates activities. This study will begin by explicating its background and literature's limitations, guiding the research, methods, and objectives.

1.2 Background of the Study

The demand for individualized value creation and production calls for changeable production systems. Clear demarcation between customers and producers within companies' traditional boundaries is no longer possible in today's society. The shift to a more open approach of integrating external sources brings with it desirable qualities (West & Gallagher, 2006). The introduction of mechanisms that progressively enable bottom-up collaborations allows for more robust innovations (Lakhani & Panetta, 2007). Mechanisms such as open innovation, crowdsourcing, crowdfunding, social product development, 3D printing, user innovation, open-source systems, and others have caused a shift in traditional methodologies, and have staged an attack on the organizations' social division's primary structure of labour (Redlich et al., 2015). This, in turn, has led to the need for organizations to make fundamental changes to their established business models to achieve success beyond their internal capacity by using emerging mechanisms for developing innovations (Von Hippel, 2009; Forbes & Schaefer, 2017).

The two main factors for the shift are the proliferation of IT-mediated technologies and the knowledge-based economy, which encourage collaboration between different actors ranging from suppliers, public agencies, users, stakeholders, customers, and citizens. The proliferation of these IT-mediated technologies sounds like the "signals of change" for group activities to be performed in such a way that the transfer of capabilities vary from professional classes to the general public (O'Reilly, 2007; Redlich et al., 2015). As these IT-mediated technologies facilitate information sharing, creativity, and collaboration from varying perspectives, organizations can arrive at breakthrough solutions compared to independently solving problems (which can also be accompanied by bias and self-serving beliefs) (Lakhani et al., 2007; Bonabeau, 2009). Figure 1.1 below illustrates emerging mechanisms within this era of globalization.

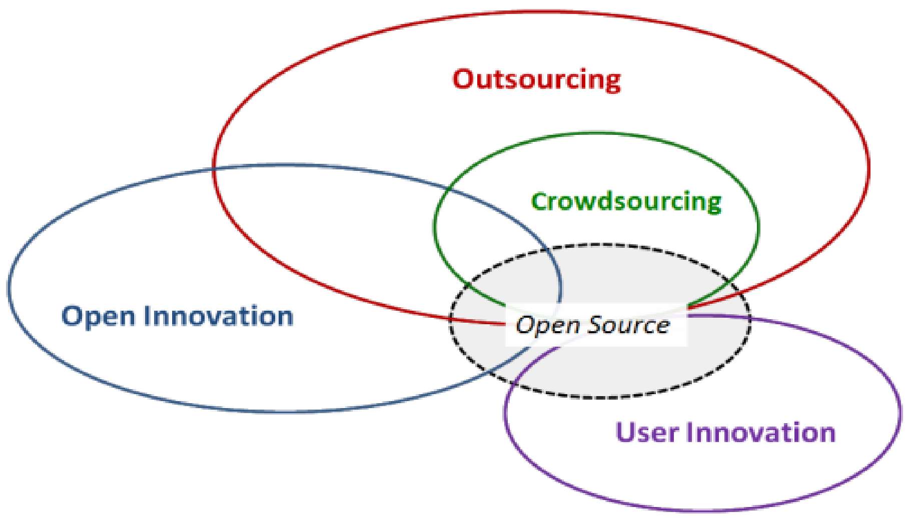

Figure 1.1. The interrelationship between emerging mechanisms (Schenk & Guittard, 2009)

The interrelationship between these mechanisms allow for similarities; however, differences also exist. These differences stem from the actors involved, their motivation to participate, the contractual framework, and the innovation process (Schweisfurth, Raasch & Herstatt, 2011). For example, although open innovation and crowdsourcing are similar in terms of external partnerships, open innovation's partnership occurs on an organization-to-organization basis. In contrast, crowdsourcing offers both organization-to-organization relationships as well as organization to consumer relationships during problem-solving sessions (Schenk & Guittard, 2009).

Despite the benefits, difficulties exist in adapting to these emerging mechanisms (Palacios et al., 2016). The literature reveals the slow adoption of these mechanisms by organizations due to their lack of transparency about internal issues and unsuccessful implementations (Lakhani & Panetta, 2007; Forbes & Schaefer, 2018). This study focuses on exploring crowdsourcing in the context of its role as an emerging mechanism to better understand its application and the process of achieving valuable outcomes.

1.3 Limitations of the Literature: Understanding the Integration and Use of Crowdsourcing

A more in-depth look into the literature on the integration of crowdsourcing into organizations reveals challenges in studying the field as a whole, as well as in managing crowdsourcing during the innovation process (Lakhani & Panetta, 2007; Chesbrough, 2015; Bartumeus, Oltra & Palmer, 2018). This might be due to the perception that crowdsourcing is multifaceted and multidisciplinary, fuelled by emerging forms of applications (Hosseini et al., 2014; Zhao & Zhu, 2014).

An overview of available studies reveals some limitations. Firstly, previous scholars have attempted to study its boundaries and development by utilizing various methodologies such as case studies, surveys, statistics, and systematic literature reviews (Trumbull et al., 2000; Brabham, 2008; Yuen, King & Leung, 2011; Zhao & Zhu, 2014; Hossain & Kauranen, 2015; Hosseini et al., 2015; Kim, Park & Sawng, 2016; Sivula & Kantola, 2016; Palacios et al., 2016; Lenart-Gansiniec, 2018; Ghezzi et al., 2018; Malik, Aftab & Ali, 2019). This study identifies only one other study—conducted by Malik, Aftab, and Ali— which attempts to quantify the field. This emerging field lacks a holistic quantitative examination to map its entirety without using domain-specific limitations where all crowdsourcing scientific domains are mapped and categorized. Such a study would reveal applications across different domains and intersections between them (Boye et al., 2017).

Secondly, after examining the streams of literature on crowdsourcing, a divide emerges. Previous scholars specifically examine the use of crowdsourcing for scientific activities (Evans et al., 2005; Wiggins & Crowston, 2011; Paul et al., 2014; Hecker et al., 2018) while some scholars examine its use for innovation activities (Chanal & Fasan, 2008; Afuah & Tucci, 2012; Marjanovic, Fry & Chataway, 2012; Mehtala et al., 2016; Palacios et al., 2016). There is an evident lack of empirical work examining the integration of crowdsourcing activities during the innovation process. Although scientific activities are performed mainly for knowledge discovery, further development can potentially improve commercial outcomes (Blackwell et al., 2009). There also seems to be a growing interest in scientists who want to see their research outcomes change the world (Parcak, 2015; Williams et al., 2018). The literature shows the promise of innovations that have emerged from the application of basic science (Hochachka et al., 2012; Tinati et al., 2015; Shirk & Bonney, 2018). Involving the crowd during science, however, does not always lead to commercial value, and, if it does, this tends to take a long time due to the difficulties faced (Chesbrough, 2015; Bartumeus, Oltra & Palmer, 2018). As the process of moving from science to innovation is linked with myriad activities, efforts involving the crowd are influenced by varying market-driven or technology-driven forces (Kline & Rosenberg, 2010; Czarnitzki & Thorwarth, 2012). Organizations that seek to involve the crowd in knowledge discovery and then arrive at technological applications for research outputs through open approaches must realize that new capabilities, decision-making procedures, and structures are needed (West & Gallagher, 2006; Schlagwein et al., 2017). Most studies examine crowdsourcing science and innovation activities separately, but this study proposes to comparatively examine crowdsourcing for science and innovation activities to understand the similarities and differences. Once this is clear, understanding the general crowdsourcing process, enablers, barriers, and the success factors in terms of the seeker's skills and capabilities are proposed. Furthermore, integrating both activities reveals how science can lead to innovation outcomes that can potentially provide commercial value.

Although crowdsourcing's benefits are varied and well known, the slow adoption of crowdsourcing is prevalent throughout the literature, with organizations portraying skepticism when integrating the phenomenon due to their perceptions of crowdsourcing as complicated with its implementation requiring more profound organizational cultural changes (Estermann, 2014). Other critical arguments have also been raised, such as the potential harm to innovation output, in the long run, concerns over data security and privacy, the production of average quality outcomes, lukewarm solutions, and the questionability of the data collected (Leitner, Warnke & Rhomberg, 2016). The reasons, why organizations tend to struggle with the use of crowdsourcing, can be related to them being unaware of how to approach it, or due to information overload, lack of financial resources, low technical expertise or weak management procedures (Boudreau & Lakhani, 2009; Sieg, Wallin & von Krogh, 2010; Maiolini & Naggi, 2011) which can all be reasons for the slow adoption to practice (Almirall, Lee & Majchrzak, 2014).

Most studies have generalized their findings based on whether they examined open innovation as a whole or crowdsourcing's use in a single industry, one country, one application typology or one research field such as focusing on the fashion industry or the research field of dolphins monitoring (Marjanovic, Fry, & Chataway, 2012; Chun, Song & Ko, 2014; Schlagwein & Andersen, 2014; Mehtala et al., 2016; Qin et al., 2016). This study, however, comparatively investigates crowdsourcing science and innovation uncover the key influential factors that act as enablers or barriers for effective crowdsourcing utilization. It is important to not only identify the underlying factors that have either a positive or negative effect, but also to attempt unifying them under their contextual determinants. "The contextual determinants" are the umbrella terms that enable unifying the uncovered enablers and barriers. Figure 1.2 below gives an overview of this research study.

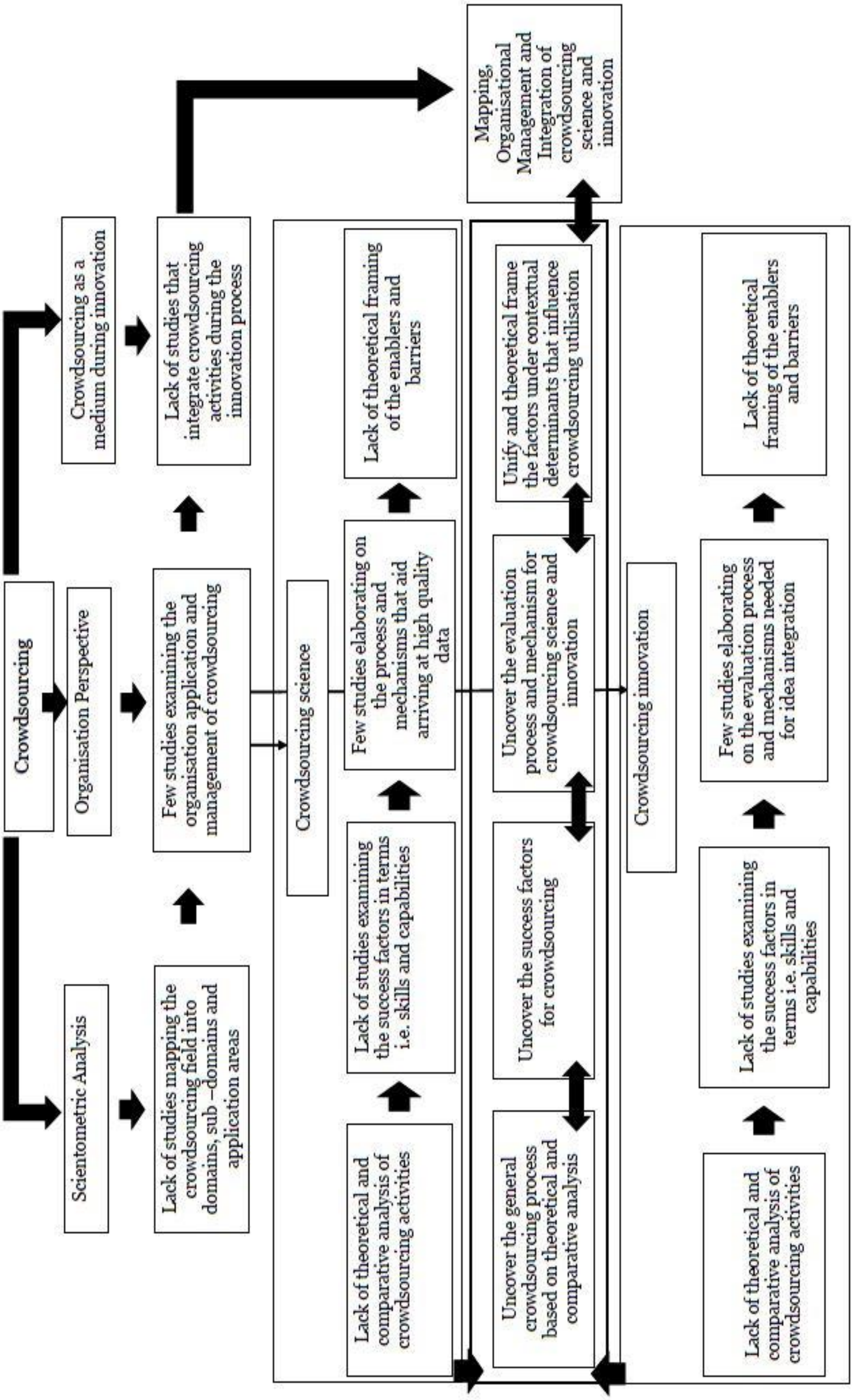

Figure 1.2. Overview of research study

1.4 Theoretical Background

To broaden the understanding of organizations effectively using and managing crowdsourcing during the innovation process, levels of analysis are required. That is to say, it can be assumed that the use of crowdsourcing might involve some technical, organizational, process or industry level input; hence, some levels of this analysis will touch these areas, but not entirely in-depth, as this study focuses on a process and organizational (seeker) perspective.

This study comparatively examines two crowdsourcing processes (science and innovation) based on the input-process-output (IPO) model (Marjanovic, Fry & Chataway, 2012) which contends that a system can be analyzed to uncover its general process, components and the seeker's underlying activities to achieve outputs (Scheerens, 1990; Gregor, 2006). The IPO model can provide a base for studying a phenomenon such as crowdsourcing to uncover its specific characteristics (Pedersen et al., 2013). Furthermore, identifying the factors that act as enablers or barriers to the use of crowdsourcing when examining more than one crowdsourcing activity would be a good contribution to the available literature (Zhao & Zhu, 2014). From this perspective, crowdsourcing is viewed as a technological innovation. Many factors under varying contexts emerge, however, influencing organizations capabilities. Organizations are required to understand elements of crowdsourcing like the need to define the problem, reasons for crowd participation, defining the rules of initiatives, establishing and maintaining engagement.

This study takes a factorial angle that influences the application of crowdsourcing from an organizational perspective. Theories such as Diffusion of Innovation (DOI), Technology Acceptance Model (TAM), Theory of Reasoned Action (TRA) were considered, however, due to these theories focus techno-centric determinism or individual factors (Eze et al., 2013; Venkatesh, Davis & Morris, 2007), the technology-organization-environment (TOE) is selected as the most suitable due to its more flexible constructs and focus on organizational factors. This helps in identifying and unifying broader factors that not only emphasize on technology-related factors but also organization, industrial and individual factors which is an identified gap in the study (Lüttgens et al., 2014). The TOE is selected as it helps to achieve the aim of this study. For the purpose of this study, a TOE approach to unifying and clustering the inhibiting and enabling factors under their respective contextual determinants is proposed. The TOE framework provides flexibility in assumptions due to the unpredictability of people, organization actions, and capabilities during innovation utilization (Tornatzky & Fleischer, 1990; Oliveira & Martins, 2011; Awa, Ukoha & Igwe, 2017; Chauhan et al., 2018).

The majority of studies sparingly examining crowdsourcing in an integrated fashion. To resolve the limitation in the literature, this study combines perspectives from innovation management based on the input-process-output (IPO) model, which allows for comparison and uncovering a holistic view of crowdsourcing during organization's innovation process. This attempt would allow for examining how science can lead to achieving innovative outcomes by leveraging the crowd (Stodden, 2010; Chesbrough, 2015).

1.5 Research Questions

The principal aim of the research thesis is "**to examine the process of crowdsourcing use, the key factors that influence the effective use and its integration during the innovation process**."

To examine the process, the study seeks to cluster the crowdsourcing field to identify the main domains and theoretically construct a holistic framework of the crowdsourcing process comparing crowdsourcing activities (Marjanovic, Fry & Chataway, 2012; Randhawa, Wilden & West, 2019). In general, studies revealing the general process from a seekers' perspective based on varying activities to identify organizations management procedures, barriers, needed success factors in terms of skills and capabilities are rare (Cox et al., 2015; Ghezzi et al., 2018). The study also attempts to theoretically identify the enablers and barriers that influence organizations effective use of crowdsourcing (Lüttgens et al., 2014; Zhao & Zhu, 2014).

In addition, it also seems the literature on innovation management has examined separate crowdsourcing use for innovation and science. The integration of crowdsourcing science and innovation activities allows for examining the integrated crowdsourcing nature during the entire innovation process, which relatively starts from science and ends with an innovative outcome. This study aims at being the first to propose its combined use during the entire innovation process, which relatively starts from science to innovation (Stodden, 2010; Chesbrough, 2015; Smart et al., 2019). In support of the aim and objectives of this research, the following research questions will be addressed:

1. What are the key domains and sub-domains of the crowdsourcing field?
2. What is the general crowdsourcing process as well as the enablers and barriers for the application of crowdsourcing science and innovation activities?
3. How can organizations manage crowdsourcing activities and integrate crowdsourcing science to innovation?

1.6 Overview of Research Methods, Types of Data and Analysis

To fulfil the scope and goals of this study, a large set of publications and interview data in the field has been gathered for analysis. To examine the large volume of publication data, the study utilized text-mining techniques through the use of VOSviewer software.

The software proved immensely valuable in achieving a variety of objectives, such as the mapping of the crowdsourcing field, as well as identifying emerging crowdsourcing applications, crowdsourcing tasks, emerging trends and linkages. This study contributes to publication collection methods. Although a number of difficulties arose from this attempt, it improves the current publication collection methods on the field of crowdsourcing.

Publications are used as a data source because they reveal the growth and development of scientific fields. This approach relates to a quantitative method of conducting research, and, although a vast number of researchers utilize approaches like surveys and questionnaires to understand happenings within a social construct, the use of publications can emphasize the trends within a research field (Kovács et al., 2015). Generally, three publication analysis methods exist: bibliometric, scientometric and infometrics. This study utilizes a scientometric approach to analyze publications in order to achieve the research objectives. Publications can better represent the trends and focuses of research amongst researchers, which might not be uncovered during other quantitative methods. This can help to provide more descriptive results and to understand a research field better, because of the more insightful perspective one gets when text is clustered and analyzed based on the observable nature of a field, subfields, and linkage between subfields in a research domain. Considering this view, scientometric publication analysis was considered the best approach for this study.

Scientometric publication analysis of crowdsourcing can be beneficial to various individuals, organizations and institutions — professional scientists, academics, research and development managers, policymakers, managers and academics, to name a few. The crowdsourcing field has evolved to be viewed with a multidisciplinary, multidimensional and many-sided perspective (Cullina, Conboy & Morgan, 2015).

Accordingly, text-mining methods were applied to gather publications on crowdsourcing, insights and statistics on the research domain and sub-domains, in combination with scientometric techniques, were used to understand the intellectual structure of the field. The Web of Science database was sourced with an optimized data gathering methodology. The gathered data was analysed with VOSviewer software through text co-occurrence analysis to determine emerging clusters and themes. Further details of this process are provided in the methodology section of this study.

To increase the depth of the findings and fulfil the study's objectives, a mixed-method research approach — utilizing both quantitative and qualitative data — was used, whereby the quantitative component comes from publication data analysis and the qualitative data is collected through key informant interviews. This study followed a sequential explanatory mixed-method approach in which the publication data was analyzed, and the results were followed up with interview data analysis (Ivankova, Creswell & Stick, 2006).

Although this approach has its weaknesses in terms of the length of time needed, the advantages of its straightforwardness and the opportunity to explore an emerging area such (crowdsourcing) provided much insight. Thus, certain individuals in organizations were interviewed based on the identified research clusters and application activities according to the publication data analysis. Following this, semi-structured key informant interviews were used to collect the required qualitative data with interview questions designed based on the review of the literature, as well as the aims and objectives of the study. The qualitative data were coded and analyzed with the use of Nvivo (11 and 12) software, and the findings are presented in a key informant design based on the comparative cross-examination of crowdsourcing activities.

1.7 Contribution to the Research Study

This research study contributes to the existing literature on crowdsourcing by providing a conceptually developed and evidence-based research. The contributions of this study are theoretical, practical and methodological. This section will give a summary of the contributions of this study.

The theoretical contributions of this study are related to the theoretical frameworks that have been adapted and tested in this research, and can be used in future studies. The first relates to the holistic crowdsourcing process by proposing a model based on a comparative examination of two crowdsourcing activities (crowdsourcing science and crowdsourcing innovation) to uncover and understand the entire process's phases, management activities and relationships. This research study builds upon perspectives from the input-process-output (IPO) model (Scheerens, 1990; Gregor, 2006). This model was the first to identify the relationship between phases, including their similarities and differences. Furthermore, the model features merging both crowdsourcing science and innovation into one holistic framework, which is broken down into input, process and output. In addition, the essential success factors (managerial skills and capabilities) and contribution evaluation mechanisms are identified as new contributions (Marjanovic, Fry & Chataway, 2012; Ghezzi et al., 2018).

Secondly, this study built upon the perspective of the crowdsourcing process for science purposes (Cooper et al., 2007; Devictor, Whittaker & Beltrame, 2010; Newman et al., 2012; Shirk et al., 2012; Parrish et al., 2018) and the crowdsourcing process for innovation purposes (Ebner, Leimeister & Krcmar, 2009; Saldanha et al., 2014; Zhu, Sick & Leker, 2016; Ghezzi et al., 2018), bringing together both forms to propose that the crowd can be utilized during the innovation process. Based on the I-P-O theory, this study proposes an integrated framework that illustrates how organizations integrate crowdsourcing activities by leveraging the crowd for crowd-based science which can lead to crowd-based innovation (CS S – CS I) or, conversely, crowd-based innovation leading to crowd-based science (CS I – CS S) (Stodden, 2010; Redlich et al., 2015; Chesbrough, 2015; Bartumeus, Oltra & Palmer, 2018; Nascimento et al., 2018; Hecker et al., 2018). The proposed integrated CSCI model is the first to illustrate how the involvement of the crowd through the use of crowdsourcing allows for an inclusive, participatory and iterative process. In this process, science that leads to knowledge discovery can be developed into commercial innovation and vice versa. In addition, the use of the crowd for innovation activities can also further lead to continuous science activities such as testing of hypotheses and further knowledge discovery. This is a novel contribution of this study as the proposed framework enables a pictorial view of how organizations can manage open processes integrating crowdsourcing.

The review of previous studies has clearly identified barriers that separately influence crowdsourcing for innovation and science activities. This study classified and unified the barriers and enablers based on the technology, organization, environment framework and their relative contexts, which is a significant input to the field (Maiolini & Naggi, 2011; Lukyanenko, Parsons & Wiersma, 2011; Simula, 2013; Lewandowski & Specht, 2015; Zahay, Hajli & Sihi, 2018). This study contributes the identified enablers and barriers for the effective use of crowdsourcing by comparing its use for science and innovation activities (Zhao & Zhu, 2014).

This study also provides methodological contributions proposing the mapping of the crowdsourcing research field into domain clusters and applications (Ozcan et al., 2020). The clustering of sub-domains is further linked with the relevant applications and tasks; hence it provides a hierarchical taxonomy for other scholars and industrial practitioners. The linkage between research domains and sub-domains is examined to show the interrelated nature of crowdsourcing research. The results are illustrated with examples showing a broad spectrum of crowdsourcing applications and methods in different conditions (Tripathi et al., 2014; Kullenberg & Kasperowski, 2016; Hossain & Kauranen, 2015).

In summary, the contributions of this study are as follows:

- Organizations' management and integration of crowdsourcing SI during the crowd-based innovation process;
- The comparative examination of crowdsourcing activities (science and innovation) based on I-P-O theory to uncover the general crowdsourcing process, evaluation mechanisms and success factors in terms of skills and capabilities;
- Uncovering and unifying the underlying factors that act as barriers and enablers to the effective use of crowdsourcing based on theoretical contexts;
- The search string and conceptual framework to arrive at a mapped crowdsourcing field, as well as it's boundaries, domains, sub-domains, emerging applications and tasks.

The next section will give a breakdown and outline of the thesis.

1.8 Thesis Outline

Chapter 1 provides an overview of the limitations of the existing literature on crowdsourcing's process and integration, a theoretical background, an overview of the research approach, and the contributions of the study. **Chapter 2** provides a background of the study by elaborating more on the history of crowdsourcing, its pillars, and applications as well as explaining related theories and frameworks that would assist in achieving the aim and objectives of this study. **Chapter 3** summarises the literature reviewed on the use of crowdsourcing during the innovation and science stages to uncover the process, success factors, enablers, and barriers. **Chapter 4** provides the methodological approach utilized to achieve the research objectives with justifications for the methodological choices. **Chapter 5** outlines the findings of the quantitative section of this research study by revealing the main research domains, sub-domains, and related tasks of the crowdsourcing field. **Chapter 6** outlines the findings of the qualitative research by revealing the holistic process, key phases, components, enablers, barriers and integrated crowd-based innovation process. **Chapter 7** provides an avenue to discuss the findings and conclusions.

Chapter 2: Background of the Study

2.1 Introduction

This chapter outlines this research's background, the desire to extend the knowledge of crowdsourcing and its applications. This chapter examines the existing literature concerning the emergence and development of crowdsourcing. This is done to clarify what crowdsourcing means, exploring its roots and relationships with outsourcing and innovation management, since the concept can mean different things to different people. This chapter will highlight crowdsourcing's definitions, as well as its pillars, tasks, and benefits found within the existing literature. This chapter also gives overviews of the existing literature on innovation management techniques, models and research processes; this will reveal the key phases of innovation and research process relevant to best observe the application of crowdsourcing.

2.2 Brief History of Crowdsourcing

Although the Web 2.0 revolution and social media can be seen as leading factors in the development of crowdsourcing, its origins stretch back to an era before the advent of the internet. Examples include the Longitude Prize in 1730, the creation of the US's first weather map in 1856, Toyota's logo design competition in 1936 and the design of Sydney, Australia in 1955 are strongly linked to the concept (Proctor, 2013; Wu, Corney & Grant, 2014). By revealing its prior applications throughout history, the benefits of utilizing the masses as a resource for achieving a common goal can be realized.

According to Howe (2012), crowdsourcing began as a blended practice that combined concepts of outsourcing and the crowd. The concept of outsourcing is the contraction of various internal organizational business functions and business needs—for example, the purchase of services from outside service providers (Rouse, 2010).

However, the similarity between outsourcing and crowdsourcing is the solving of business needs by means of sourcing solutions from external providers (Saxton, Oh & Kishore, 2013). A variety of models can also be linked to outsourcing such as insourcing, rightsourcing, offshoring, business process outsourcing, massive outsourcing, voluntary outsourcing, the Cloud, and backsourcing; organizations utilizing these concepts often reap the benefits of more outstanding quality and cheaper costs (Rouse, 2010).

Crowdsourcing calls to mind similar business patterns with the presence of problem-solving approaches such as transcribing ship's logs, editing Wikipedia, classifying galaxies, holding idea innovation contests, and funding campaigns (Proctor, 2013). The concept of crowdsourcing involves integrating inputs from a diverse group of people, usually facilitated through the internet, as it provides easy access to individuals from anywhere in the world. In the literature, the term has been described from varying perspectives.

According to Howe (2012), crowdsourcing has been defined as organizations taking a function once performed by employees and outsourcing it towards an undefined network of people in the form of an open call. Peng and Zhang (2010) consider crowdsourcing a tool for addressing problems in organizations and businesses. According to Brabham (2008), it has been described as a strategic model for attracting motivated and intrigued individuals capable of providing solutions that are superior in terms of quantity and quality compared to traditional forms of business. According to Kleeman, Vob and Rieder (2008), it has been described as the integration of consumers during the process of creating internal value with the intention of mobilizing and exploiting creative ideas and other forms of consumer labour. According to Grier (2011), crowdsourcing is an industry's attempt to use human beings and machines in large production systems. Doan, Ramakrishnan and Halevy (2011) define crowdsourcing as a general-purpose problem-solving method.

The variety of definitions give different contexts and focuses as to what crowdsourcing can be. According to Estelles-Arolas and De-Guevara (2012), however, who performed a textual analysis of these definitions, three common elements were identified: 1) crowd, 2) initiator, and 3) process. They combined these for a general definition of crowdsourcing as: ″a type of participative online activity in which an individual, institution, or non-profit organization proposes to a group of unidentified individuals of varying knowledge to undertake a task which involves problem-solving, the proposition of ideas, contributory funding and/or experience″. For this study, it is necessary to adopt a definition. Hence, crowdsourcing is defined here as "the use of information technology (IT) in order to outsource any organizational function to a strategically defined population of individuals (human and non-human) actors in the form of an open call" (Kietzmann, 2017). This study's scope focuses on understanding and integrating crowdsourcing activities concerning organizations using individual actors from the concept above.

The utilization of a diverse workforce and knowledge residing outside the boundaries of organizations has been seen to have real benefits in facing challenges like maintaining competitive advantage, increasing return on investment, undergoing research and solving world problems. Continued deriving of these benefits requiring new thinking, resources and capabilities to effectively navigate the unpredictable creative and processes of managing risks and engaging with the crowd (Surowiecki, 2004; Hurni & Wiesmann, 2014; Palacios et al., 2016). Examining the literature on crowdsourcing, crowdsourcing is viewed as a capability, method, model or tool that can make the use of the internal or external crowd allowing the organization to effectively arrive at outcomes that would be of value to customers or the economy in general (Brabham, 2008; Vukovic, 2009; Leimeister et al., 2009; Saxton, Oh & Kishore, 2013).

Today's operating environment can be characterized by the growing importance of knowledge, which is further fuelled by globalized competition and the increasing complexity of technology. Leading firms to shift away from an over-reliance on strictly using internal sources for their research and innovation capabilities (Chesbrough & Crowther, 2006). There are also growing studies of its efficiency, as organizations increasingly rely on crowds to achieve series of task ranging from evaluation of TV programs (Netflix), collection of litter (Litterati), product design (99 Design), raising capital (Kickstarter), problem-solving (InnoCentive) and new product development (Fiat) (Vuculescu & Bergenholtz, 2014). Just to mention a few, organizations such as Starbucks, Adidas, BMW, Foldit, the National Oceanic and Atmospheric Administration (NOAA), and Ducati have also ventured into utilizing this approach to improve their research and innovation performances, thereby empowering their operations. Crowdsourcing has become a potential for advances in value creation, which has attracted the attention of organizations seeking a method to generate ideas and solve existing problems within companies by further enhancing the power and use of human knowledge (Hammon & Hippner, 2012). Palacios et al. (2016) provide an overview of the crowdsourcing research, revealing that most research focused on the end functionality of crowdsourcing in the innovation process, such as end-product development, continuous feedback, and collaborative ventures.

The literature also reveals some theoretical relationship between crowdsourcing and open innovation. Although a general agreement exists proposing that both are based on an open model of innovation, the majority theorize crowdsourcing to be an extension of open innovation—thereby categorizing crowdsourcing as a sub-category of open innovation (Panchal & Fathianathan, 2009; Knudsen & Mortensen, 2011; Erickson, 2013). Other experts view differ concerning the context of innovation and participation (Schenk & Guittard, 2009). Although both enable organizations to benefit from external sources, open innovation focuses on the innovation process and knowledge flows between organizations, while crowdsourcing is more of the linkage of organizations to an unidentified nexus of participants (Schenk & Guittard, 2011).

Crowdsourcing's applications are not only specific to just the innovation process; it is widely used for other business operations, in scientific research, the mapping of buildings, and sensing environments (Boulton et al., 2012; Mooney, Corcoran & Ciepluch, 2013; Martinez & Walton, 2014). It is mostly deployed in situations where there is uncertainty. Examining the applications of crowdsourcing, four key pillars are observed: the crowd, crowdsourcing platform, the crowdsourcer and the task. The next section will give a description of the pillars that permit crowdsourcing to be used by organizations during various activities. This would assist in broadening the knowledge of components that are vital for its successful application.

2.2.1 Crowdsourcing Tasks

This section describes crowdsourcing tasks that can be sourced from the crowd. Although these tasks vary, many do not satisfy companies requirements (Boudreau & Lakhani, 2009). To obtain satisfactory solutions, understanding the types of tasks and their requirements are essential. According to Schenk and Guittard's (2011) study, tasks can be categorized into routine, complex, and creative. According to Schulze et al. (2011), tasks can be categorized into quick profit, information and challenge tasks. Although these studies attempt to categorize emerging tasks, they fall short of critical theoretical criteria (Ye & Kankanhalli, 2013). Ye and Kankanhalli (2013) propose that tasks can be categorized into four main types: 1) simple tasks with low outcome variety,

2) simple tasks with high outcome variety, 3) complex tasks with high outcome variety, and 4) complex tasks with low outcome variety.

According to a study by Estellés-Arolas et al. (2015) comparing a variety of studies, crowdsourcing activities fall into five main types: crowdcasting, crowdcollaboration (crowdstorming and crowdsupport), crowdcontent (crowdproduction, crowdsearching and crowd analyzing), crowdfunding and crowdopinion. Although these types have been proposed, it is suggested they be under constant review, thereby adapting to the reality of the phenomenon. According to Ali and Allam's (2016) comparison study on crowdsourcing initiatives, activities can be broadened into 12 categories which range from fansourcing, crowdnetworking, crowdsharing, crowdvoting, open-source software, crowdfunding, ideation, crowdpedia, open innovation, user innovation, scisourcing (scientific crowdsourcing), and crowd relief. According to Prpic et al. (2015) study, crowdsourcing activities can be categorized into four main categories: crowd voting, idea crowdsourcing, solution crowdsourcing, and micro-tasking. Howcroft and Bergvall-Kareborn's (2019) study was meant to identify the challenges for work and employment, and proposed crowdsourcing activities could be classified into online task crowdwork, playbour crowdwork, asset-based services and profession-based freelance crowdwork. Given the breakdown of tasks, solutions sourced from these tasks have no clear boundaries (Estellés-Arolas et al., 2016). Summarizing previous scholars works, Table 2.1 below proposes the types of tasks sourced from the crowd.

Table 2.1: Sourcing from the Crowd

Forms of Crowdsourcing	**Definition of Tasks**
Fansourcing	Fans that are knowledgeable and passionate about the products.
Crowdnetworking	Occasionally discover interesting new content that is relevant to their intellectual activities.
Crowdsearching	Search for content or micro tasking on the internet.
Crowdvoting	Voting towards predictions; communities' judgment to evaluate, rank, or vote for items such as books, movies, ideas, newspapers, articles, decisions, or opinions through textual comments, numeric scores, or tags.
Open Source Software	Beta testing, co-developing.
Crowdfunding	Funding/financing.
Scisourcing/Citizen science/Crowdscience	Behaviour monitoring, offering computing power, classification, digitization, conflation.
Crowdrelief/Crowdsupport	Offering help towards problems crisis update.
Crowdopinion/Crowdsharing	The buying or selling of shares towards insight; know-how knowledge as in ehow.com, and expert knowledge as in Yahoo Answer, share items such as video clips from YouTube, tagged websites like Delicious, photos as in Flickr, music as in Napster.
Ideation/Crowdcollaboration	Assistance in product enhancement and development.
Crowdpedia	Share and combine information, sentences, paragraphs.
User Innovation	Top-quality ideas for unique product and services.
Crowdanalyzing/Micro-tasking	Search for content in images or videos.
Open Innovation/ Crowdcasting	Creative skill and knowledge, e.g. designing logos or webs.

The next section covers a pillar of the crowdsourcing process to describe and understand what can be defined as "the crowd. "

2.2.2 Crowd

The crowd is defined as the large nexus of people who participate based on motivation (intrinsic vs extrinsic) during the crowdsourcing process. According to Hosseini et al. (2014), features that define the crowd are diversity, mass, being undefined, being unknown, and its suitability. For example, organizations can utilize internal crowds (employees, experts, professional scientists) and external crowds (customers, the public, novice scientists). The next section would examine "the crowdsourcer."

2.2.3 Crowdsourcer

The crowdsourcer can also be called a seeker or sponsor. This is generally considered an individual, organization, institution, or non-profit organization, searching for a way the crowd can complete an outsourced task. According to Hosseini et al. (2014), common features that are related to the seeker in terms of crowdsourcing are the development of an open call, provision for incentives, provisions for ethicality and privacy provisions. According to Randhawa, Wilden and West (2019), other features related to the seeker's relationship with crowdsourcing are the definition of a solution space, engagement of the crowd, managing crowd contributions and integrating contributions into the internal process. The next section will describe another pillar of crowdsourcing—crowdsourcing intermediaries.

2.2.4 Crowdsourcing Intermediaries

Technology plays a major role in extending organizations' ability to connect with individuals in diverse regions. It provides a more cost-effective way to apply crowdsourcing and leverage the crowd's skills. Inexpensive technologies and devices such as apps, software, mobile phone, and hardware empower the crowd to be even more active participants during the process (Chanal & Caron-Fasan, 2008; Doan, Ramakrishnan & Halevy, 2011; Hecker et al., 2018). The use of an intermediary allows for mediation between the crowd, the task and the crowdsourcer.

According to Niu and Qin (2017), crowdsourcing intermediaries can be classified into two categories: web-based and mobile-based. The web-based intermediaries can be divided by their approaches, either volunteer contributory or paid contributory. Examples of volunteer contributory approaches are Wikipedia, Linux, Android and various open-source softwares that grew due to the continuous contribution from volunteers at an international and national scale. On the other hand, a well-known paid crowdsourcing platform such as Amazon's Mechanical Turk facilitates both amateurs and professionals to gain rewards and payment for completing micro-tasks. Existing intermediaries could partly support the PDD process, for example, with concept generation and information collection at the early design stages as well as providing creative solutions, transcriptions, creating a brand, taking pictures or collecting air quality information in a specific location.

These days, mobile-based crowdsourcing platforms mainly exist to improve on the drawbacks of web-based crowdsourcing platforms, as they allow individuals to mix smartphone-based mobile technologies and crowdsourcing. Mobile-based crowdsourcing can be divided into two categories: human sensor and human intelligence (Wang et al., 2015; Niu & Qin, 2017). It allows smartphone users to sense, collect, process and distribute data at any time and place. This crowdsourcing application is utilized comprehensively in environmental monitoring, intelligent transportation, personalized medicine, and many others. Crowdsourcing intermediaries are considered an evolution of technology knowledge brokers, as they have the functions of knowledge processing, knowledge generation, knowledge re-combination and knowledge sharing that should all be executed within the crowdsourcing process (Silva & Ramos, 2012). Intermediaries allow the generation of distinct contributions that surface through contest, challenges, campaigns, tournaments, competitions and programs by well-established organizations and start-ups (Terwiesch & Xu, 2008; Boudreau, Lacetera & Lakhani, 2011).

Generally, crowdsourcing intermediaries can be categorized into (1) Corporate digital crowdsourcing platform licensed and run by corporation’s internal IT department; (2)

Intermediary broker platforms owned by a service provider company and offering fee-based crowdsourcing services to clients (businesses/solution seekers) (Qin et al., 2016).

As new information technologies have empowered companies in solving certain problems faster, better and cheaper compared to in-house attempts, there are potentially profitable opportunities in the use of intermediaries (Owyang, 2015).

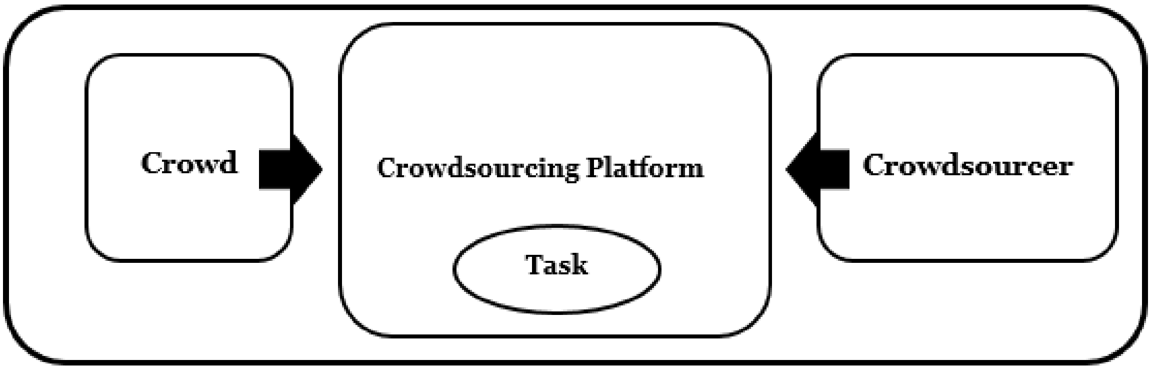

Figure 2.1. Pillars of crowdsourcing (Hosseini et al., 2014; Mtsweni, Ngassam & Burge, 2016)

Figure 2.1 above gives a holistic illustration of the pillars that are needed for the application of crowdsourcing. The next section will propose the benefits of using crowdsourcing.

2.3 Benefits of Crowdsourcing for Science and Innovation Activities

Understanding the potential benefits of crowdsourcing can help in pinpointing its key drivers. Crowdsourcing, as an umbrella term, has multiple overlapping applications within a variety of disciplines, emphasizing its usefulness. The evolving terminology has generated a list of overlapping terms like *user-powered systems, user-generated content, community systems, peer production, social systems, collective intelligence, human computation and mass collaboration* (Von Hippel, 2009; Aitamurto, Leiponen and Tee, 2011; Hossain & Kauranen, 2015). The expectations and drivers vary depending on the context, organization or industry. This section will discuss the use of crowdsourcing and how the literature on the subject provides insights and fresh perspectives on crowdsourcers.

2.3.1 Creative and Problem-Solving

Organizations use of the crowd through intermediaries such as Threadless, 99 designs, CrowdSpring, for example, have allowed for the development of creative designs for logos, photos, brochures, clothing and accessories at a lower cost. Intermediaries such as iStockphoto provide photographs and animated clips created and voluntarily uploaded by the crowd to organizations, which would have been much more expensive if done through employing professionals (Whitla, 2009). Shifting to more technical issues faced by organizations such as research and development problems, InnoCentive and NineSignma are prominent intermediaries that have enabled organizations to solve problems they face. By opening challenges with monetary rewards, organizations such as Dupont, P & G, and GlaxoSmithKline have leveraged solutions for problems by, for example, creating methods to prevent the breakage of snack chips, the proofing of preparatory research, and providing an optimum way to transfer the chemical powder to a container (Erickson, 2013; Lakhani & Panetta, 2007).

2.3.2 Collective Intelligence, Data Collection and Knowledge Sharing

The involvement of the crowd has been beneficial for collective intelligence initiatives that can be traced to the earliest records of the Chinese locust outbreaks (Tian et al., 2011). The use of online networks has followed macro trends such as citizen science, data-intensive science, collective intelligence and open scientific outputs with common examples such as data collection, knowledge sharing with prominent platforms such as Wikipedia, Youtube and open source software (Erickson, 2013; Jane Budge et al., 2015; Szkuta & Osimo, 2016). The phrasing "citizen science" has been used recently to describe crowdsourcing in science as a research technique that utilizes the members of the public to analyze or gather data (Mizuyama et al., 2013; Clarke et al., 2017). The nature of this project tends to range from contributory, collaborative, and co-created while some have also been classified as action, conservation, virtual, educative and investigation (Wiggins & Crowston, 2011; Follet & Strezov, 2015).

Crowdsourcing science can be observed taking varying approaches in many scientific disciplines. Opening up the scientific process is not only done for sharing information, but also for increasing participation and ensuring that new knowledge is co-produced, leading to it making a better impact and societal improvement of user communities (Smart et al., 2019). Scientists that utilize crowdsourcing can choose from two perspectives, either contributing towards a solution and requesting a solution to a problem (Schildhauer & Voss, 2014). Generally, the scientific process comprises basic research and applied research with the intention of scientific discovery (Kline & Rosenberg, 2010). Scientists' use of crowdsourcing towards scientific activities is intended to achieve certain objectives depending on their perspectives. From an academic perspective, they want transparent and accessible knowledge. From a policy perspective, they seek new approaches to design and to develop efficient policy recommendation. From a citizen and business perspective, they are concerned with copyright, knowledge transfer mechanisms, and citizen engagement (Vicente-Sáez & Martínez-Fuentes, 2018).

The collective actions, wisdom and abilities of the crowd have enabled experts to undergo research and successfully achieve outcomes that would have been difficult to accomplish due to the magnitude of the tasks, data and research project. For example, the collaborative annotation efforts of the crowd in regards to texts, pictures, audio recording and videos have aided users in obtaining a deeper understanding of materials compared to analysing digital content without such collaborative efforts (Parent & Eskenazi, 2011; Raddick et al., 2009; Cappa et al., 2016; Evanini & Zechner, 2011; Chen & Tsay, 2017).

Another example is the use of the crowd for research projects such as translational medicine, or the monitoring of birds and invasive plant species by research scientists and institutions such as the National Institutes for Health (NIH), National Centers for Advancing Translational Sciences (NCATS), the Nature Reserve, and so on. Implementing citizen science methods within translational pathways has provided opportunities to seize and drive advances in areas such as medical care. The MyHeartMap challenge is an example that presents citizens with the task of programming dynamic maps indicating defibrillators within communities for emergency use (McGill, 2013). A study by Ranard et al. (2014) reviewed the use of harnessing the input of the masses to advance health revealing task application categories ranging from problem-solving, data processing, monitoring, and surveying—further showing it to be a viable way of increasing computer recognition accuracy, and a low-cost alternative to more traditional behavioural research, engaging with multiple people and producing scientific discoveries.

This study would adopt the term "crowdsourcing science" as a description for the use of crowdsourcing towards activities like scientists connecting with individuals and communities to collate data or run through tasks, and scientists connecting with other scientists or research labs to conduct research into scientific questions (Schildhauer & Voss, 2014).

2.3.3 Value and Production Innovation

The involvement of the crowd (users, customers and stakeholders) through focus groups, questionnaires, surveys, category appraisal, and empathic design has always been utilized as a source of input for organizations (Von Hippel, 1978; Grunert et al., 2011; Estrada-Flores, 2010). The advent of crowdsourcing, however, has provided an additional and easier means for consumer involvement at a very low cost (Hoyer et al., 2010). Both the reduction of innovation failures and the improvement in return on funds invested are mainly determined by the capability of innovations to meet customer's wants and needs (Bretschneider & Zogaj, 2016). The use of crowdsourcing during several stages of new product development for tasks such idea generation, design, prototyping, testing, funding, and others allows organizations to invest heavily in innovative ways to support new idea processes that will help them gain intelligence and discover emerging technologies, and, ideally, make them market winners or early followers of market leaders (Westerski, Dalamagas & Iglesias, 2013).

As crowdsourcing is aimed at a broad network of people, it is considered a good form of delivering innovation (Zhu, Sick & Leker, 2016). Evidence of this can be found in IBM's Innovation Jam (Bjelland & Wood, 2008), Emotionalize Your Light by OSRAM (Hutter et al., 2011) and Muji (Nishikawa, Schreier & Ogawa, 2013). Collecting ideas during idea competitions as a customer integration method during the first stage of the NPD process allows for generating ideas and collaboration based on the qualitative winning ideas (Leimeister et al., 2009; Jeppesen and Lakhani, 2010). Another example is an organization's collaboration with the crowd to arrive at winning ideas using various approaches —consensus, averaging, polls, and collaborative filtering (Fuchs & Schreier, 2011; Poetz & Schreier, 2012).

Regarding the use of the crowd during design approaches, organizations utilize two approaches: human-based genetic algorithms and design competitions (Wu, Corney & Grant, 2014). For example, United States electric utilities held the SERP design competitions to develop and manufacture refrigerators that delivered more energy savings, which led to a disruptive impact on the refrigerator models in the industry. Another example is the US Defense Advanced Research Project Agency (DARPA) competition for driverless vehicles, which enabled the development of usable designs (Lampel, Jha & Bhalla, 2012). The human-based genetic algorithm not only allows the crowd to generate ideas but also evaluate which designs are best, thereby enabling organizations to choose the most creative possibilities (Wu, Corney & Grant, 2014).

As product innovation is not a linear process, crowd involvement has enabled organizations to test and fund concepts to gauge a new product's desirability (Kunz et al., 2017). The funding of innovations supports the development of anything from a new product being launched to entire start-up operations (Golic, 2014; Meyskens & Bird, 2015). Research shows that good collaboration with consumers decreases the number of faulty prototypes until the desired product is achieved, reduces development costs into accomplishing certain innovation, and brings about a higher creative efficiency (Sánchez-González & Herrera, 2014; Vuculescu & Bergenholtz, 2014). Also, the less expensive acquisition of consumer ideas and the outsourcing of the new product development process gives organizations faster time to market, a reduction in the risk of product failure, and post-launch gains by means of continued product development and exploration into further usages (Hoyer et al., 2010).

Crowdsourcing research has also been examined within the context of marketing activities, with pioneering companies such as Threadless, iStockphoto and Apple (Marsden, 2009). With the failure rate of new brands still considered high, experts have suggested this might be due to a failure to understand consumer needs (Nadange, 2014). The general consensus is that firms can integrate the crowd at any stage of the NPD process, with the crowd given different roles and tasks depending on the stages in which they participate (Mladenow, Bauer & Strauss, 2014). Overall, crowds can be utilized for a variety of tasks that can benefit organizations. As this study is within the scope of innovation management, the next section will investigate the relationship between crowdsourcing and innovation management theories in order to better understand its use during phases as well as providing a better understanding of the management of activities during organization processes.

2.4 Innovation and Innovation Management Techniques

This section will clarify and provide an overview of the development of the term innovation, its benefits, and innovation management techniques. This is examined to understand its components and relationships, which may be relevant to the application of crowdsourcing.

A variety of scholars have attempted to define the term "innovation." One writer refers to it as the implementation of changes that are new to any organization (Mohr, 1969). Rogers (2003) defined innovation as an idea, product, technology, or program unique to an individual or organization. Innovation has been regarded as any method, process, policy, structure, product or strategy being novel by its adopters (Choi & Valikangas, 2001). According to Schumpeter (1934), innovation can be defined as the formation of new products, new processes, raw materials and new organizations. The term itself is a broad concept that can be understood in various ways, but a more recent definition is offered by (Trott, 2017).

"is the management of activities and the successful implementation of ideas within an organization."

In practice, innovation implies the exploitation of new processes, systems, services, and initiatives in order to improve the quality of work, thereby adding value to it. Generally, innovation drives the achievement of competitive advantage, response to consumer needs and economic growth as a whole (Sood & Tellis, 2005; Carlin & Soskice, 2006). The possible applicability of innovations has been studied in a variety of disciplines through different lenses of analysis. Innovation types can range from product, process, technology, operational, management, organizational, business model, system infrastructure, collective, collaboration, societal, and inter-organizational, given their diverse applicability (Bessant & Tidd, 2011; Lazzarotti, Dalfovo & Hoffmann, 2011; Boons & Ludeke-Freund, 2013; Trott, 2017). For this study, crowdsourcing is perceived as a technological innovation.

The term “innovation management” alludes to the management of the creative processes of innovation (Igartua, Garrigos & Herva-oliver, 2010). Certain elements such as the environment an innovation surfaces, organizational structure, leadership, and culture have led to little consensus on how the process should be presented (Rothwell, 1994; Eveleens, 2010; Oke, 2007). However, as the process does not occur in a vacuum, most authors propose the process begins with searching for an idea (a necessity) and ends with attaining value based on the organization’s strategy, techniques and capabilities. Over the years, innovation management models have been developed to simplify its representations, with some presenting the process as linear (Daft, 1978) and others viewing it as dynamic and recursive, characterized by feedback and feed-forward loops (Schroeder et al., 1989). Prominent examples include the trial and error approach, industrial scientific curiosity-driven model, coupling model, technology push, market pull theories, interactive models of innovation, and the rest (Rothwell, 1992; Cooper & Kleinschmidt, 1987; Verloop & Wissema, 2004; Hansen & Birkinshaw, 2007).

However, innovation management consists of tools and methodologies that assist organizations in adapting to changing market challenges. It is said that the lens through which innovation management is viewed determines its interpretation (Phaal, Farrukh & Probert, 2006). Overall, as there are no exact correlations between an organization's specific problem and the methodologies used to solve them, there is no generalized closed set of proven innovation management techniques for each specific problem. Instead, the challenges faced are solved as a whole (Hidalgo & Albors, 2008). Table 2.2 below illustrates the clusters of innovation management techniques utilized by organizations.

Table 2.2: Innovation Management Techniques

Innovation Management Techniques	**Methodologies and Tools**
Knowledge management techniques	• Knowledge audits • Knowledge mapping • Document management • Intellectual property rights management
Technology management and market intelligence techniques	• Patent analysis • Business intelligence • Technology watch • Road-mapping • Customer relationship management
Lean techniques	• Lean tools — Just in Time
Continuous improvement	• Process-based management • Six sigma and problem-solving
Cooperative and networking techniques	• Team-building • Networking • Supply chain management • Industrial clustering • Collaborative projects • Outsourcing
Human resources management techniques	• Teleworking • Corporate intranets • e-Learning • Online recruitment
Interface management techniques	• Research and Development Marketing
Creativity development techniques	• Brainstorming • TRIZ • Lateral thinking • Mind mapping • Creativity workshops • Expert panels
Innovation project management techniques	• Project management • Project appraisal • Project portfolio management
Design techniques	• CAD systems • Rapid prototyping • Value analysis
New product and service development techniques	• Benchmarking • Workflow • Concurrent engineering • Lead user-based NPD • Quality function deployment
Entrepreneurship management techniques	• Business simulation

	• Business plan • Spin-off from research to market
Innovation finance techniques	• Investment/financial analysis • Research and development financing
Organizational techniques	• Virtual enterprise

Modified from (Hidalgo & Albors, 2008; Igartua, Garrigos & Herva-oliver, 2010; Skalkos & Bakouros, 2011; Albors-Garrigos, Igartua & Peiro, 2018)

The table above shows that these techniques vary according to the organization's problem, strategy, tools, methodologies, and innovation phases. Nevertheless, studies show the benefits of adopting and implementing innovation management techniques. Studies by Steiner et al. (2009), Retkoceri & Kurteshi (2019), Ning et al., (2006), Lüthje and Herstatt (2004), Darroch and McNaughton (2002), Muller, Valikangas and Merlyn (2005), Blindenbach-Driessen and Van Den Ende's (2010), Jakubavičius and Vilys (2008), Igartua, Garrigos and Herva-Oliver (2010), Schuh, Lenders, and Hieber (2011), Huesig and Endres (2019) are examples, where the utilization and combination of innovation management techniques can enhance firm performance. Investigating specific innovation management techniques during the innovation models can uncover insights on its utilization. The next section will examine the process of innovation management models and their development over the years.

2.5 Innovation Management Models

This section will investigate the models and process of innovation over the years, which have helped organisations maintain an advantage in markets and have also caused a change in management procedures.

The management of innovation involves novelty in organizational change. According to Birkinshaw, Hamel, and Mol (2008), there are four distinct perspectives on the management of innovation: institutional, fashion, cultural, and rational; these perspectives assist in the understanding of innovations. Examining innovation as a process helps one identify the phases and its management activities (Tidd & Bessant, 2018). Over the years, a number of authors have provided guidance for examining innovation management models, including Van De Ven and Poole (1990), Verloop and Wissema (2004), Cormican and Sullivan (2004), Hansen and Birkinshaw (2007), Jacobs and Snijders (2008) and Trott (2017). Each giving guidance on the process as countless innovations have been developed, such as the light bulb, development of medicines, democracy as a form of government, Dyson air multiplier (Eveleens, 2010; Trott, 2017).

The literature reveals that the generational pattern of innovation models has been shifting from linear forms to more interactive models (Berkhout et al., 2006; Bagno, Salerno & Silva, 2017). These models (drive) range from the first generation (technology push), second-generation (market pull), third-generation (the combination of technology push and market pull), fourth-generation (aided by alliance and partnerships), fifth-generation (a network of relationships) and sixth generation (collaboration with internal and external actors). Generally, there are two parallel paths involved in the innovation process: one involves the generation of ideas (idea generation), development of concepts (concept development) and comprehensive engineering; the other involves internal R&D (technology push) or marketing analysis (market pull) and market research (Tran, Hasan and Park, 2012).

Organization's can either follow a closed innovation v open innovation logic (Chesbrough, 2003). Organizations working with closed innovation logic are constrained to generating their own ideas, products and traditional market launch with little or no feedback from stakeholders due to the encouragement of self-reliance, control and lack of confidence in the others' capability (Chesbrough, 2003). While this led to breakthrough discoveries (Evans & Varaiya, 2003; Abrantes-Metz, Admas & Metz, 2004; Castellion & Markham, 2013), the utilization of traditional closed innovation models have increasingly been challenged due to concerns with ex-employee knowledge spill out, and fast time to market for many products and services (Chesbrough, 2003; Lakhani, 2006; Teece, 1998; Livieratos, 2008; Buecheler et al., 2010; Smeilus, 2015). Hence, the shift to a logic of less control and exclusion.

Open innovation models support the leveraging of internal and external ideas as well as internal and external pathways to market, strengthening an advantage in markets and generating insights on future needs (Enkel, Gassmann and Chesbrough, 2009; Leiponen and Helfat, 2010). New products such as the case of the iPhone (Apple) and the Bagless vacuum cleaner (Dyson), were introduced into mature industries dominated by large multinational firms who failed to detect the customers' needs and product technical superiority, paid the penalty (Tzokas, Hultink & Hart, 2004; Spithoven, Vanhaverbeke and Roijakkers, 2013). Products launched by these companies saw a rejuvenation of industries by redefining an already competitive market. This generation of models requires interaction networks with the ease of contacts, effective business models, and trust between stakeholders and natural conditions, to support collaboration and create value. Figure 2.2 below illustrate the open innovation model.

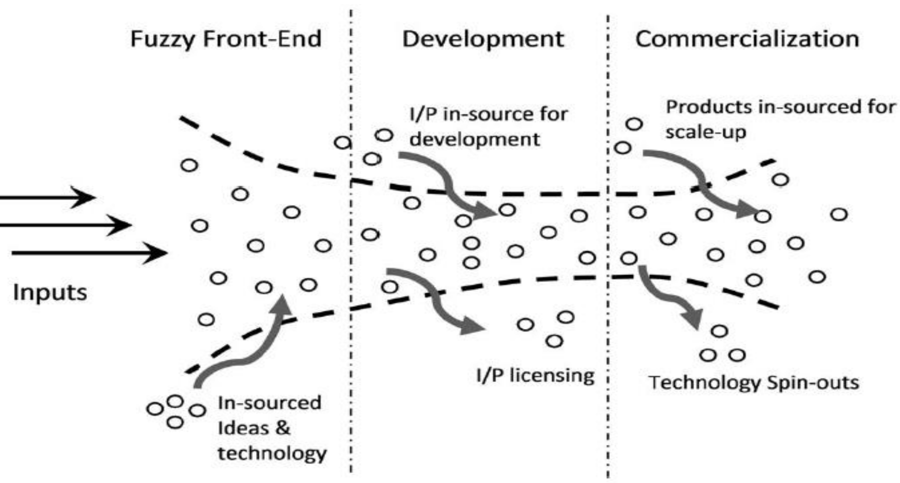

Figure 2.2. Sixth-generation model (Chesbrough, 2003; Bagno, Salerno & Silva, 2017)

In this innovation model, the origination of research and innovation discoveries can emerge inside organisation processes. Although these discoveries can leak out either in the research or development stage through mechanisms such as IP management, external licensing, and start-ups (Chesbrough & Crowther, 2006). The presence or seeking of effective organization's business models enables the capturing of value.

The drive for external sourcing is emphasized by two types of motivations: improved efficiency through economies of scale, and access to innovations (or innovation producing capabilities) not held by the focal firm. Actors involvement and use of external resources during innovation and research activities have been observed by various researchers considering how organisations' absorbed knowledge is essential for any operation's success (Adams, Bessant & Phelps, 2006; Hidalgo & Albors, 2008; Livieratos, 2008). As the abundance of knowledge supports open innovation processes, it enables the opportunity to experiment, weed out false prospects as well as the conversion of abandoned projects into valuable outcomes through managing IP, licensing and research partnerships (Chesborough 2003). Generally, the shift of innovation beyond the boundaries of an organization allows for exploiting of both internal and external pathways. Although terms such as "closed" and "open" have been used to describe innovation management techniques, studies reveal that innovations vary in a continuum between these extreme modes and to deal with these two extremes, organization's should imbibe a degree of openness during practices (Laursen & Salter, 2006; Lazzarotti & Manzini, 2009; Trott & Hartmann, 2009).

This section shows the shift in the development of innovation management models utilized to develop, improve products and create value. This was done to enable the researcher to understand how the innovation process has progressed over the years to assist in the development of a holistic framework utilizing crowdsourcing during the innovation process. The next section will identify the stages of the research process.

2.6 Phases of the Research Process

This section will discuss the process of research activities to identify the main phases. Traditionally, the research process is composed of several stages which are dependent on the type of research discipline, the actors involved and the research method. The research process is observed as a series of methods for carrying out scientific research. Over the years, a variety of models have emerged, such as traditional science, scientific consulting, adaptive co-management, participatory action, and the community engagement research process (Cooper et al., 2007). According to Tripp (2005), the research process is broken down into planning improvements to practice, acting to implement proved improvements, monitoring, and describing the effects of the action and evaluating the action. Bücheler and Sieg (2011) examined the use of crowdsourcing within scientific processes, and proposed that the research process is to define a question, develop a methodology, develop a proposal, obtain funds, identify workers, set up a laboratory/field group, gather information and resources, form a hypothesis, perform experiments, collect data, analyse data, interpret data, draw conclusions, publish results, secure IP and retest. Mertler (2012) proposed that the research process follows phases such as planning, acting, developing and reflecting. Table 2.4 below illustrates the breakdown of the research process uncovered in the literature with Mertler (2012) closely examined for this study.

Table 2.3: Stages of the Research Process

Authors	Crawford & Stucki (1990)	Bücheler & Sieg (2011)	Tripp (2005)	Defrijn et al. (2008)	Mertler (2012)
			Stages		
1	Problem identified	Define the question	Plan an improvement to practice	Planning • Preliminary diagnosis • Data gathering • Feedback on results • Action planning	Planning phase • Identifying and limiting the topic • Gathering information • Reviewing literature • Developing a research plan
2	Research plan developed • Community selected • Funds secured	Develop a methodology	Act to implement planned improvement	Action • Learning process • Action planning • Action steps	Acting phase • Collecting data • Analyzing data
3	Intervention or data collection • Data collection instruments designed • Researcher recruits community subjects	Develop a proposal	Monitor and describe the effects of the action	Results • Changes in behaviour • Data gathering measurement	Developing phase • Developing an action plan
4	Analyze data	Obtain funds	Evaluate the outcomes of action		Reflecting phase • Sharing and communicating results • Reflecting the process
5	Interpret data and disseminate results to peers and academic community	Identify a team of co-workers			
6		Set up a laboratory/field group			
7		Gather information and resources			
8		Form hypothesis			
9		Perform experiments and collect data			
10		Analyze data			
11		Interpret data			
12		Draw conclusions			
13		Publish results/ Secure IP			
14		Retest			

Many authors have utilized the research process to uncover major findings in scientific fields (Crawford & Stucki, 1990). According to Bücheler & Sieg (2011), the scientific research process starts with the inception of an idea, the formulation of a problem statement or hypothesis, development of a methodology, development of a proposal, obtainment of funding, identification of a research team, setting up a laboratory and/or field group, testing of the hypothesis, collection of data, analysis of data to make inferences, and reporting the results through peer review. Although it is revealed that science as a process can also be subject to iterations as different fields have different approaches, it should be emphasized that the research processes have certain shared features, like experiments, and hypotheses (Buecheler et al., 2010). Hence, certain phases are similar in the majority of existing processes.

In recent times, we have also witnessed a shift in the research process to accommodate external stakeholders' involvement and collaboration, which has led to research processes such as action research or participatory action research. The action research process is a collective and self-reflective inquiry in which scientists and participants are influenced by an understanding of history, embedded social relationships, and culture, with results leading to empowerment and increased action, as well as then participant having better control over their lives (Baum, Macdougall & Smitt, 2006). The action research process tends to differ from traditional scientific process concerning the deliberate sharing power between the researcher and participants as well as its primary purpose of enabling action through a reflective cycle. (Baum, Macdougall, & Smitt, 2006).

According to Tripp (2005), the research process follows four phases: planning improvements to practice, acting to implement the planned improvement, monitoring/examining the effects of the planned activities and evaluating the outcomes of the action. Defrijn et al. (2008) proposed that the process follows planning (identifying, informing), acting (collecting data, questioning), observing (analysing, reporting), and reflecting (evaluating, implementing). According to Mertler (2012), however, the research process follows four phases (planning, acting, developing and reflecting). This study adopts this model to build the crowdsourcing science process, illustrated in Figure 2.3 below.

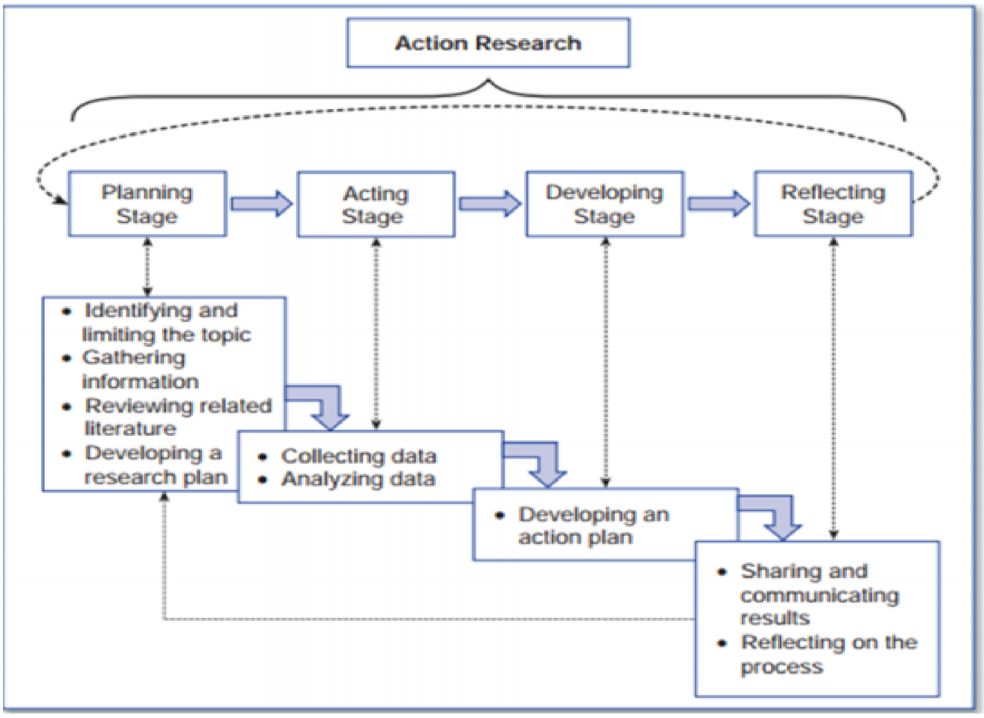

Figure 2.3. Research process (Mertler, 2012)

The first phase, planning, involves identifying a problem for investigation and the setting of objectives. This involves gathering information on the context and problem identified with the goal of developing a research plan. The second phase, acting, involves collecting past information from studies, articles, and scientific journals to enrich the knowledge on the current problem. This would enable the setting of research questions to address the problem of the study. The third phase is the development phase, which entails the methodology, as well as the collection and interpretation of data. The participants, and the instruments utilized for the study support this phase. The fourth phase involves the sharing of findings with the community and the reflective analysis of the process. The process's findings allow for the implementation of decisions and the improvement of the process as a whole (Defrijn et al., 2008; Mertler, 2012).

To sum up this section, the research process has been examined to identify the main phases. This study adopts Mertler's model with contributions from previous scholars to propose that the research process follows the main phases of planning, acting, development and reflecting. The next section will identify the stages of the innovation process.

2.7 Phases of the Innovation Management Process

This section will examine the process of innovation in order to illustrate and identify the main phases of the innovation process. As the innovation process is composed of several stages previously shown by its generational development over the years, it has been observed that there is no globally accepted number of stages. The academic literature relating to the innovation management process has chronicled the departing of models from the notion that the innovation process is linear and sequential (Berkhout et al., 2006). Table 2.3 below illustrates the innovation processes uncovered thus far. For this study, studies such as Koen et al. (2001), Verworn and Herstatt (2002) are closely examined to illustrate the stages of the innovation management process.

Table 2.4: Stages of the Innovation Management Process

Stages						
Authors	1	2	3	4	5	6
Rothwell (1994)	Basic science	Design	Innovation	Marketing	Sales	
Rothwell (1994)	Need	Research	Development	Commercialisation	Diffusion	Consequence
Galanakis (2006)	Idea generation	Research design and development	Prototype production	Manufacturing	Marketing and sales	Marketplace
Rothwell (1993)	Marketing	Research and development	Product development	Product engineering	Parts manufacturing	Manufacture and launch
Berkhout et al. (2006)	Scientific research	Technological change	Product development	Market transitions		
Cooper (2008)	Discovery stage	Scoping	Build a business case	Development	Testing and validation	Launch
Chesbrough (2003);Bagno, Salerno & Silva (2017)	Fuzzy front end Input In-sourced ideas and technology	Development of I/P source for development; I/P licensing	Commercialisation Products in sourced for scale-up Technology spinoffs			
Koen et al. (2001), Verworn & Herstatt (2002), Chesbrough (2003), Bagno, Salerno & Silva (2017)	Fuzzy front end: Idea generation and assessment	Fuzzy front end: Concept development, product planning	Design: Development	Design: Prototypes and pilot tests	Commercialization: Production, market introduction and penetration	

The existing literature on the innovation process simply describes the process as consisting of management activities and actions performed, as there is no one universal and smooth sequence of steps to move from the initial vision, to idea generation, to development, and finally, implementation (Glynn, 1996; Rogers, 2003). A variety of authors have described the innovation process as a combination of stages and subdivisions (Ram & Pattinson, 2009). According to Glynn (1996), the process of innovation is a two-stage model: 1) the initiation stage, which consists of all activities related to the problem, information gathering, attitude formation, resource allocation, and making the decision to adopt; and 2) an implementation stage which relates to modification activities, initial utilization and continued use within an organization.

According to Cooper (1980), the stages of the innovation process involve decisions and behaviours leading towards the arrival of a certain product or result. Wheelwright and Clark (1992) propose the innovation process as following three phases: idea generation, detailed project/product bound, and the rapid development of projects. Hansen and Birkinshaw (2007) proposed that the process consists of idea generation, selection, conversion and diffusion. O'Connor et al. (2008) proposed that the innovation process of new business platforms consists of three phases: discovery, incubation and acceleration. According to Rogers (2003), the stages of the innovation process follow five stages (knowledge, persuasion, decision, implementation and confirmation), while Birkinshaw, Hamel and Mol (2008) believe that innovation entails: 1) motivation, which is concerned with factors and circumstances driving the development; 2) invention, which is the initial act of experimentation, resulting in new ways of management practices; 3) implementation, which deals with the process of establishing value in a real setting; and 4) theorizing and labelling, which deals with the social process of the external and internal individuals of an organization making sense and validating the innovation.

In contrast with the smaller number of stages proposed by other scholars, Kim, Park and Sawng (2016) felt that the innovation process can be classified into 13 different stages: brain-storming, early-stage idea screening, preliminary market evaluation, preliminary technology evaluation, preliminary production evaluation, preliminary financial evaluation, market survey and research, product development, in-house product evaluation, customer focus group testing, market testing, financial evaluation and market launch. Koen et al. (2001), however, classifies the innovation process into just three main phases: the front end of innovation, development and the commercialization phase. As innovation as a process encompasses multiple stages and activities, these stages converge with a continuous emphasis on reducing risks defined by the organizations' existing technology. Koen et al.'s (2001) model is adopted in this study, as it provides a concise view of the innovation process by depicting the main phases identified below in Figure 2.4.

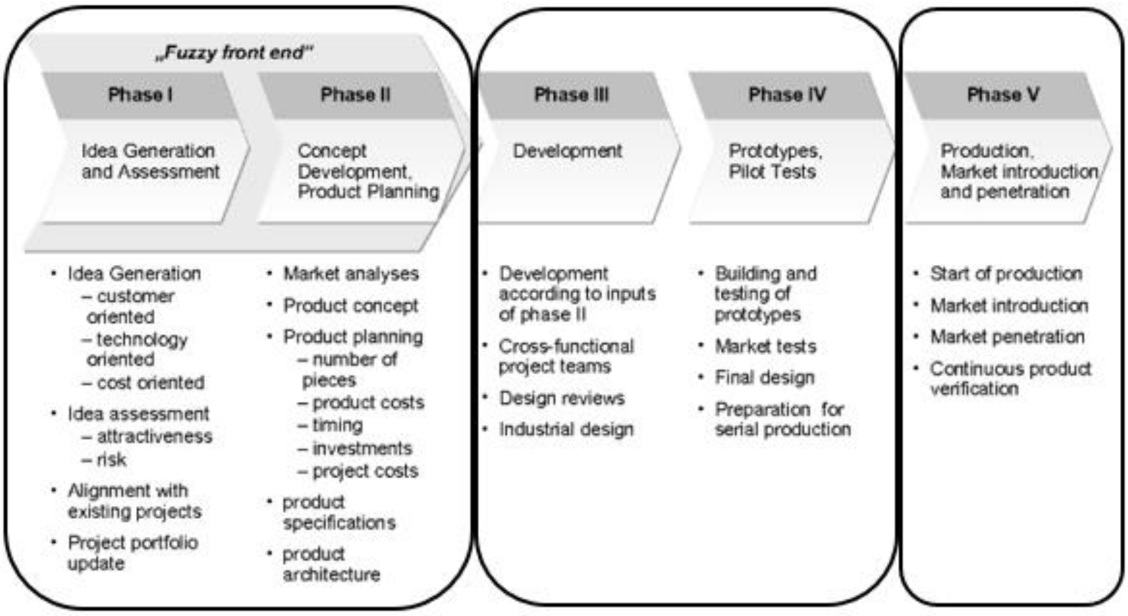

Figure 2.4. Innovation process modified from (Koen et al., 2001; Verworn & Herstatt, 2002)

The first phase—the fuzzy front end—involves activities related to opportunity identification, awareness, idea genesis, idea selection, and concept development (Koen et al., 2001). This phase is considered the most crucial phase during the innovation process, as it allows for experimentation with ideas to strengthen concepts, rather than to achieve a planned milestone (Koen et al., 2001). The second phase is considered the development phase, which involves product development, in-house product evaluation, customer focus group testing, and market testing. The third phase is considered the commercialization phase, including market testing, financial evaluation, and market launch (Kim, Park & Sawng, 2016).

To sum up this section, the innovation process has been examined to identify the main phases. This study adopts the model proposed by Koen et al. (2001), with contributions from previous scholars, to propose that the innovation process follows three main phases: fuzzy front-end, development and commercialization. The next section will examine the related theories and models of this study.

2.8 Related Theories and Models

This section will cover the theories utilized in achieving the research aim and objectives of this study. The objective of the study is to understand the integrated process of crowdsourcing, as well as the relevant factors that are vital for its integration during organizational processes. Hence, it is important to utilize theories that would enable the researcher to achieve this. The literature directs the researcher to adopt the idea that crowdsourcing can be viewed as not just an innovation but also an IT-mediated technology. Because of this, the theories and models that would be examined would be closely related to these perspectives. As innovation varies due to its type and context, it is accepted that a unifying theory can be applied to all types of innovations (Wolfe, 1994; Fichman, 2000; Hameed, 2012).

Experts have been utilizing several theories and models, however, to explain individual acceptance, adoption attitudes, behaviour and various determinants in different contexts of innovation and technology adoption as well as process theories to support project success. These theories vary in terms of the individual or organizational level of examination within the literature. The most commonly used models of acceptance are the technology acceptance model (Davis, 1989), the technology acceptance model 2 (Venkatesh & Davis, 2000), the diffusion of innovation theory (Rogers, 2003), and technology, organization and environment (Tornatzky & Fleischer, 1990). This section will justify the choice of certain theories, which would be used to examine and assist in achieving the studies' aims and objectives. Regarding this study, a perspective that reveals the process and unifies the factors (positive and/or negative) is observed. This study would therefore utilize 1) the input-process-output model 2) technology-organization-environment model.

2.8.1 Input-Process-Output (IPO) Model

The Input-process-output Model (IPO) model has been utilized in a variety of disciplines such as information systems, education, corporate business and management (Scheerens, 1990). According to Gregor (2006), the IPO model is a form of theory for analyzing the components or features found in discrete observations when nothing (or little) is known about a phenomenon. The model can be used to examine and distinguish concepts that exhibit variations in labelling, definition, and measurements (Simsek, 2009).

The input component of this framework relates to the factors and variables that relate to a task such as question type, problem, users skills and context (infrastructure) (Shachaf, 2010; Geiger & Schader, 2014). The process component involves activities that relate to the task as well as the supporting group maintenance (Shachaf, 2010). The task processes include activities such as planning, categorizing questions, and evaluating questions, which are considered valuable predictors of the system's output.

On the other hand, the group processes relate to areas such as management, trust-building, coordination, communication and cohesiveness according to the system's norms of behaviours (Shachaf, 2010). The output relates to the assessment and performance of the system's inputs (task, user and context). This study takes a process view of the management of creative processes such as crowdsourcing as an innovation management techniques during the innovation process. Figure 2.5 below gives a holistic view of the I-P-O model.

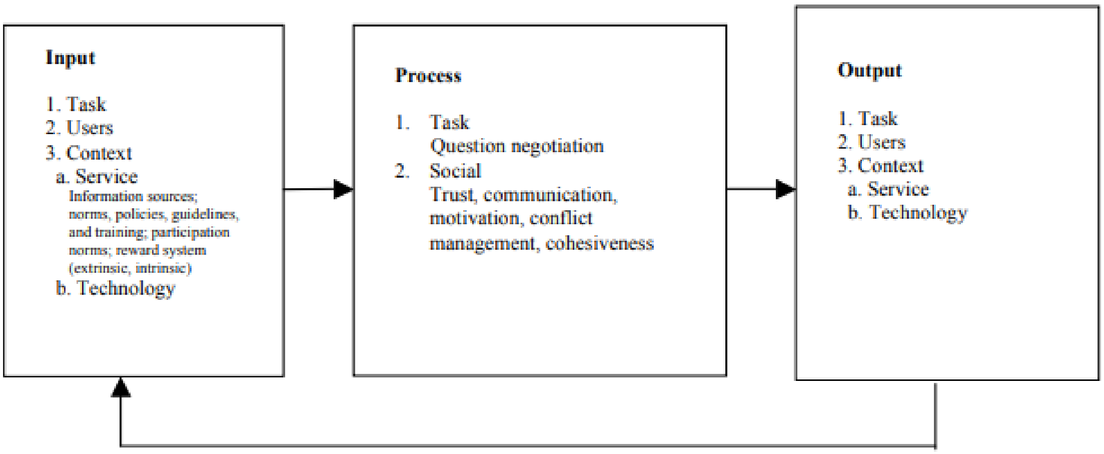

Figure 2.5. Input-process-output model (Shachaf, 2010)

2.8.2 Technology, Organization and Environment (TOE) Framework

This section will justify using the selected framework for this study as an aspect of this research to investigate the factors that either enable or inhibit the utilization of crowdsourcing. Innovation adoption has also been explored at an organizational level, which is said to be influenced by factors from several dimensions (Rogers, 2003; Tornatzky & Fleischer, 1990). As innovation theories do not completely explain innovation adoption at an organizational level, information systems experts have combined individual-level adoption models—such as TRA, TAM and DOI—with contexts within the organization to provide a more illustrative model to describe and predict innovation adoption in organizations (Oliveira & Martins, 2011).

The TOE model is described as the process of technology innovation (Tornatzky & Fleischer, 1990) that explains the three different contextual attributes of an organization that influence adoption decisions: technological, organizational and environmental contexts. (1) The technology context describes technologies that are currently used within the organizations, as well as technologies available in the market that are relevant to the organization; (2) The organizational context relates to the characteristics and resources at play, such as the size of the organization and volume of slack resources; (3) The external task environment context describes the structure of the industry and the conditions surrounding the organization in which it resides and executes its business. In this study, technology factors are related to the benefits and complexity of technologies. The organizational factors (strategy, culture, etc.) are considered internal and can be managed by the administrations of organizations and institutions. The environmental factors are considered to not be internally related and managed similarly to laws, partners, etc. (Oliveira & Martins, 2011). Figure 2.6 below illustrates the linkages between each of the variables.

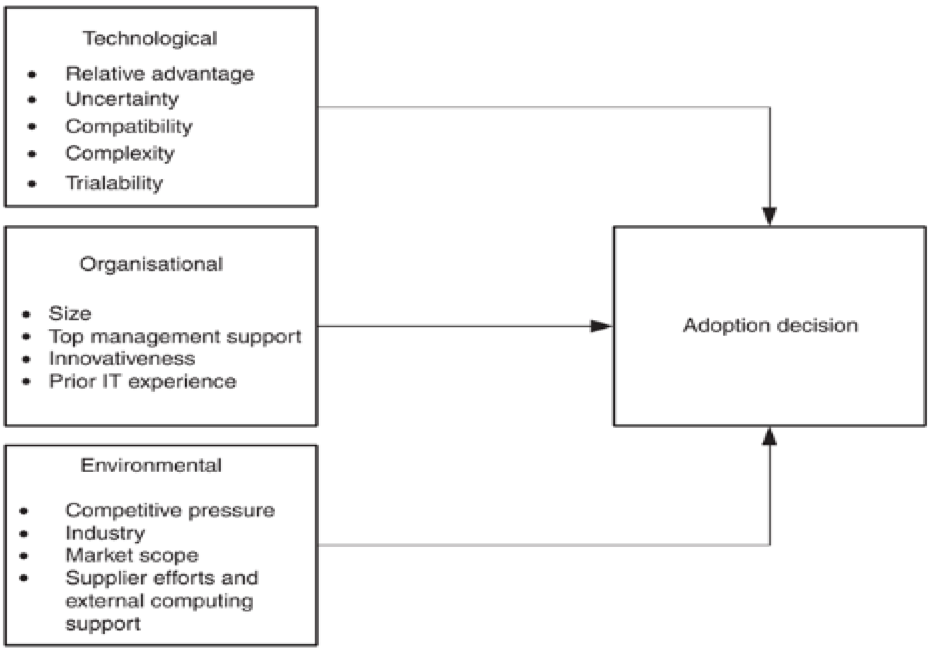

Figure 2.6. TOE model (Tornatzky & Fleischer, 1990)

2.9 Justification of Background Theories

Considering the IPO and TOE models selected for this study, this section sets out to justify their suitability. This study takes a process and factorial angle to understand crowdsourcing and the factors that influence its application. From a process perspective and understanding the different elements that makeup such a phenomenon, it is most suitable to utilize a theory that aids the researcher to classify and appropriately group activities during the entire process. Many theories such as the Delone and McLean IS success model (D&M) and the resource-based view (RBV) were considered, but these theories tend to elaborate either the output/success of a phenomenon or the organization's capabilities to utilize an innovation. The D&M model focuses more on the utilization and services of a system, while RBV focuses on the internal resources that enable an organization to achieve a competitive advantage. Compared to IPO, D&M lacks the focus on explaining the input dimension that IPO provides (Subiyakto & Ahlan, 2014). The IPO model describes systems in a manner that are easily understood by stakeholders who are technically inexpert. The IPO model's processional and causal flow is considered more comprehensive than the D & M model in terms of implementation success (Davis, 1998). I-P-O is chosen for this study because it can assist in identifying, evaluating and refining the components of a system and its implementation flaws. The researcher proposes that the understanding of crowdsourcing components can generate better insight into the needs, skills, and results during the entire process. Secondly, this study takes a factorial angle that influences the application of crowdsourcing from an organizational perspective.

Many authors propose theories and adoption models—such as diffusion of innovation (DOI), the technology acceptance model (TAM), and the theory of reasoned action (TRA)—to examine the acceptance, diffusion and factors of a technological innovation. Due to these models techno-centric predictions, however, they are perceived as offering an illusion of accumulated utilitarianism and technological determinism (Eze et al., 2013; Vankatesh, Davis & Morris, 2007), which means that technology, not individuals, determine implementation (Awa, Ojiabo & Emecheta, 2015). Thus, a model that allows for emphasizing the individual factors involved and consists of more comprehensive generic constructs is considered best for this study. Crowdsourcing is perceived as a technological innovation, and, as this study examines its use by organizations, it can elaborate and unify identified factors under their deterministic constructs. Hence, the TOE framework is chosen as a lens for this study due to its broad applicability in previous studies (Eze et al., 2013; Ven & Verelst, 2012). Comparing the frameworks—TAM, DOI, and TOE—one can see that similarities exist. Examining the TAM and TOE frameworks, it is clear that technology adoption at an organizational level can be achieved, but TAM neglects social and psychological factors. In the same notion, examining the DOI and TOE frameworks, one sees that organizational factors exist, but DOI neglects environmental and technological contexts (Awa, Ukoha & Emecheta, 2016). The TOE framework is chosen for this study as it is flexible, unifies widespread contexts, and provides insights for theoretical implementation beyond attitudinal lenses provided by the TAM and DOI models.

In this study, the researcher draws on the work of Tornatzky and Fleischer (1990) and Oliveira and Martins (2011) to make the argument that certain factors that are inhibiting and enabling the integration of an innovation need to be contextualized. Studies such as those carried out by Gonçalves, Sousa Mendes and Oliveira (2017), Van Belle and Reed (2012), and Troshani, Rampersad and Plewa (2011) examined the proposed TOE theory with an emphasis on the enablers and inhibitors of the adoption of an innovation, an emphasis which is vital to the study's analysis, as this allows the researcher to follow a train of thought in uncovering the influential factors.

As most theories have been criticized due to being fragmented, there is clearly a lack of a cohesive model that can accommodate the various factors that influence an innovation's implementation and success. Nevertheless, these chosen models (IPO and TOE) have attempted to improve, better explain and predict the general organizational crowdsourcing process, as well as the individual and wider factors for crowdsourcing integration. Table 2.5 below clarifies the related theories and models that would help the researcher structure and provide some focus for the study.

Table 2.5: Related Theories and Implementation

No	Theories and Models	Implementation	Contribution
1	Innovation and Research Models	This study would investigate the process of crowdsourcing as well as its detailed application during the phases of innovation models to uncover and understand the relationship between the various stages and phases that lead to the benefit of seekers.	The contribution is to examine the different steps and illustrate if the process differs or follows a similar process. This would enhance our understanding and integration during organizational processes.
2	Input-Process- Output Framework	Considering the key stages of this model, crowdsourcing implementation within the innovation and research process would be examined and investigated based on the input, process and output stages. This study would investigate the general system of crowdsourcing by utilizing this framework and uncovering the key components.	This study would contribute to understanding the framework by either revealing a similar process or enhancing the framework.
3	Adoption and Integration	Considering the technology, organization, and environment (TOE) contextual determinant theory, this study would examine and unify the key enablers and barriers under their contexts for crowdsourcing utilization.	Examining the key factors that either enable or hinder the utilization of an innovation. This study would enhance our understanding of what factors negatively or positively affect the use of crowdsourcing.

2.10 Summary of the Background Chapter

As crowdsourcing is a relatively new concept that encompasses many benefits, its multidisciplinary nature makes it difficult to categorize (Estellés-Arolas & González, 2012; Palacios et al., 2016; Ghezzi et al., 2018). For this reason, a review of the literature is necessary to gain in-depth insights into the field.

The background chapter provided an overview of the pillars of crowdsourcing, the benefits, innovation management techniques and process. Many experts have contributed to the field, exploring the growth and beneficial use of crowdsourcing as a practice. However, some questions remain: *How is crowdsourcing utilized by organizations to achieve results?* and *What process is followed?* and *How can the challenges encountered provide more insight? Could the challenges be due to their business models, culture, and lack of knowledge on crowdsourcing capabilities?* As many crowdsourcing applications emerge and vary from one another, this study seeks to examine specific types of crowdsourcing and to identify key elements of its use for organizations' tasks. Figure 2.7 below illustrates the direction of the research study.

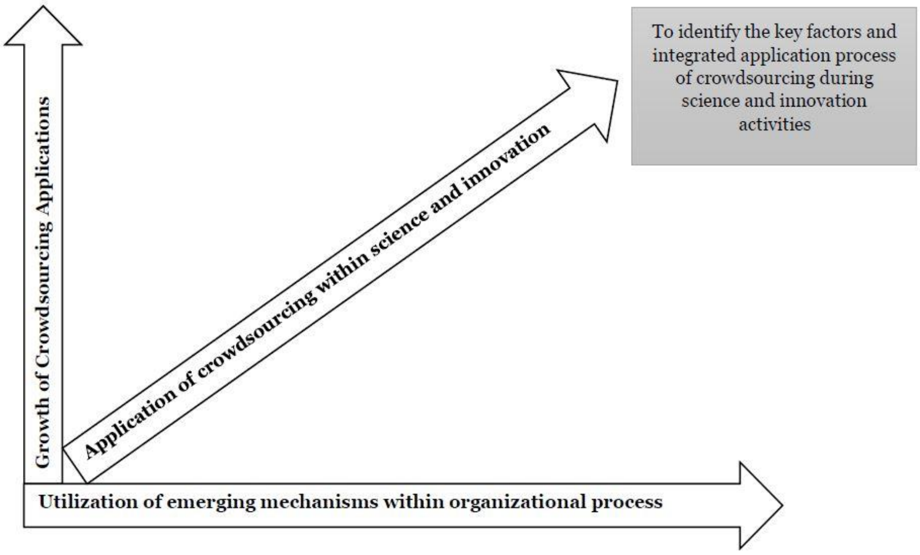

Figure 2.7. Pictorial view and direction of the research study

The following chapter will provide an overview of the literature streams on crowdsourcing activities (science and innovation). The key models and conceptual studies will be described and critically analysed, thereby leading to the limitation of the current understanding of the growth, application and integration of crowdsourcing activities.

Chapter 3: Literature Review

3.1 Introduction

Following the background section, this study covers a review of crowdsourcing literature with focus and scope within innovation and science activities. This study applied a systematic literature analysis that describes the literature collection method, as well as the narrative and systematic review methods. The literature collection method includes the criteria for including/excluding the described literature in order to enable the review process. As this study focuses on understanding the use of crowdsourcing for organizational and institutional benefits, the researcher examines the literature to uncover a guide as to how crowdsourcing is applied from a crowdsourcer's perspective.

To fit the research scope, this study scanned various e-journal databases and key journals by means of a group of keywords. Given the previous section's examination of elements on crowdsourcing, innovation management and science research activities, this chapter focuses on crowdsourcing within innovation and science-related literature. This section examines the literature on crowdsourcing during the innovation and science processes, focusing on crowdsourcing's organizational use to achieve outcomes rather than the crowd's perspective. Although the organizational perspective is the main focus for this research, it does not mean crowd related factors are avoided as some of these factors are also crucial for crowdsourcing to occur. To identify the relevant literature for this research, keywords such as "crowdsourcing" and "crowd related practices" were used with other clusters of keywords such as "innovation" "innovation process" "scientific process" and "research process." These were used to assist with the Boolean search terms in the topic or advanced search section of databases. In the first phase of the publication selection process, the possible literature was identified by using key terms and relevant sources using terms, as shown below:

Innovation related studies: crowdsourc* OR crowd-sourc* OR “crowd sourc*” OR ((macrotask* OR "macro task*" OR "micro task*" OR microtask*) AND crowd) AND ((product OR innovation) AND process) AND (idea* AND (integrat* OR evaluat*)) AND (success AND (metric* OR factor*))

Scientific Research related studies: “crowd scienc*” OR citizenscienc* OR “citizen scienc*” OR “participatory scienc*” OR ((macrotask* OR “macro task*” OR “micro task*” OR microtask*) AND crowd) AND “research project*” OR “scientific process*” OR “research process” OR “scientific project*” OR “action research process” OR “action research” AND (data AND (validation OR evaluation OR quality)) AND (success AND (metric* OR factor*))

In the second phase, the relevant studies were organized according to the publication date, ranging from older to recently published. In the third phase, the selected publications were evaluated by the number of citations. Google Scholar was also used to identify different literature types and sources separate from the previously mentioned journal databases. After reviewing all the collected literature on the use of crowdsourcing during innovation and science activities, this study presents existing studies to understand how crowdsourcing is utilized. The next section covers the literature on the findings thus far.

3.2 Crowdsourcing Process: Innovation

The proliferation of crowdsourcing initiatives can be aligned with different phases of the innovation process, which are fuzzy front end, development and commercialization. This section will cover the crowdsourcing process to enable the researcher to understand and build a holistic representation during innovation activities.

Ebner, Leimeister & Krcmar (2009) investigated the “SAPien” idea competition process of the ERP software company, and proposed the virtual community uses are probably strongest within the first two stages of the innovation management process. In Fig 3.1, the study reveals that the process of implementing idea competitions follows a five-stage process as illustrated below:

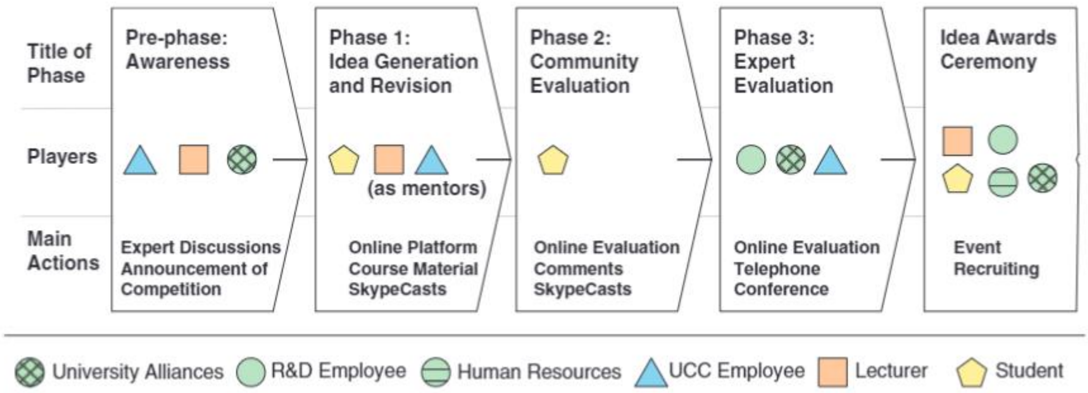

Figure 3.1. Idea competitions (Ebner, Leimeister & Krcmar, 2009)

The researchers observed that the features of ideas competitions vary between organizers, timelines, evaluation, incentives, contexts, problems attempting to be solved, target groups, the composition of the groups, reviewing committees, natures of the competitions, elaborateness, and reviews of ideas. Although this study provides an understanding of the use of crowd wisdom, further work illustrating what mechanisms support and harvest the wisdom of the crowd in selecting ideas is lacking, a conceptual gap was revealed between the generation, selection and transformation of ideas into innovations. Although the integration of idea competitions is a promising approach during innovation activities, factors like easy communications instruments, motivational structures and trust supporting elements can play an essential role in success.

Lauto et al. (2013) examined the idea market as a promising crowdsourcing tool by illustrating a hybrid approach to the idea generation model. The effectiveness of these new tools tends to lead to information overload, as companies often lack the managerial attention needed to evaluate inputs due to the high amounts of suggestions making it difficult for managers to identify the best ideas (Soukhoroukova, Spann & Skiera, 2012). Nevertheless, Lauto et al. (2013) examined the design of the 2011 Growbets campaign by Novozymes, and revealed the campaign was structured in five stages. The two stages in the idea generation stage are the preliminary and conception stages, and those in the selection stage are the screening, maturation and selection phases. The preconditions of success were the support of the R & D team, the allowance of employees (the crowd) to spend time on not just the idea generation platform, but also on maturation activities. The key element of success was the presence of clear communication throughout the campaign, accompanied by openness, clarity, and accessibility, which increased trust amongst participants. Figure 3.2 below gives an illustration of the crowdsourcing process.

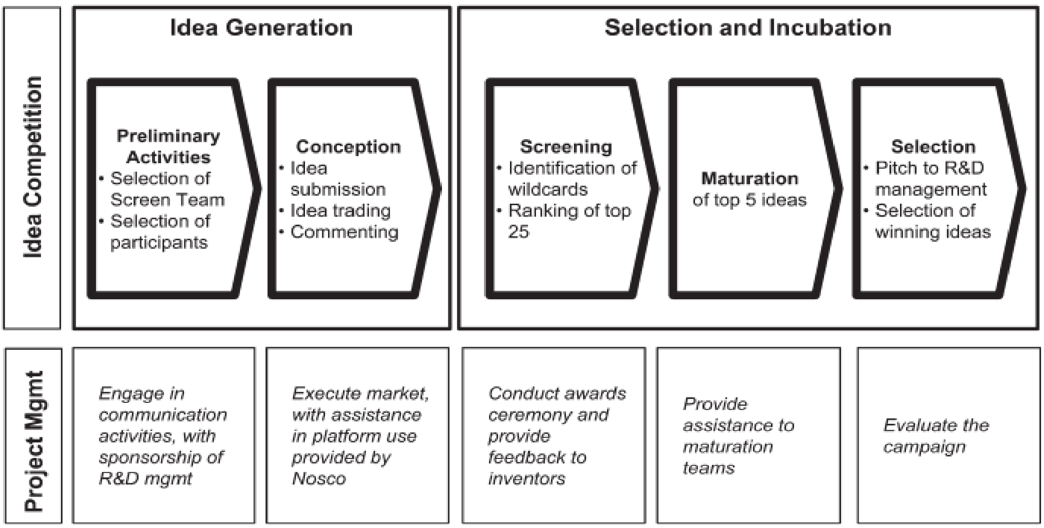

Figure 3.2. Crowdsourcing idea competition (Lauto et al., 2013)

Huang, Singh, and Srinivasan's (2014) study examined the declining number of ideas generated from crowdsourcing initiatives. Although the initiatives have become popular in a variety of industries, critics have raised a few concerns regarding this discovery. Firstly, consumers' contributions during contests are sometimes less feasible and have low potential due to the customers being unaware of the organizations' internal cost structures. Secondly, an organization being slow or having no response to contributed ideas was witnessed, limiting or stopping ideas' contribution. Technology does not necessarily have intrinsic value by itself, however, it contributes to the use of the innovations to obtain competitive advantage and to transform contributions into profits, though this requires the application of competencies and, capabilities, or the ability to select and apply the right resources appropriately (Cautela, Pisano & Pironti, 2014).

Chiu, Liang, and Turban's (2014) study looked into the use of crowdsourcing from a managerial perspective for the purpose of supporting decision making. Their study proposed a crowdsourcing framework, which was divided into four basic components: the task, the crowd, the process and evaluation. It was proposed that the process used in crowdsourcing depended on the type of supportive technology, the use of an intermediary, and the nature of the solutions. The authors' proposed solutions can range from writing content, idea generation, co-creation of products, and rendering feedback, and are actually derived by small groups or by a few experts. The process involves the flow of information, collaboration, interaction and control. Figure 3.3 below illustrates the process proposed by the authors.

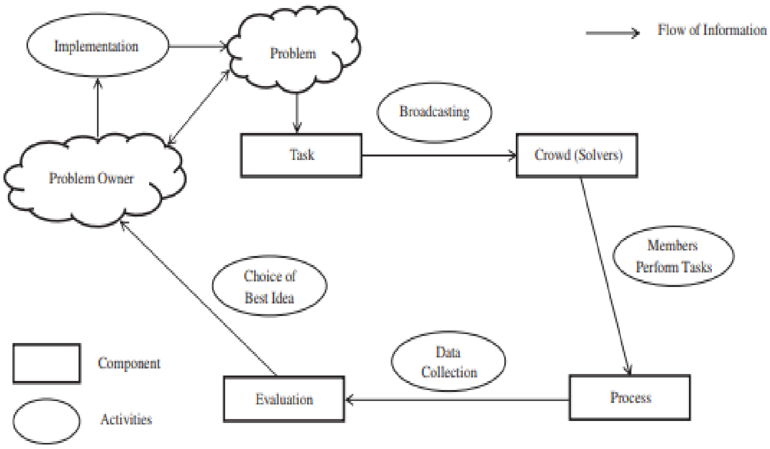

Figure 3.3. Proposed breakdown of the crowdsourcing process (Chiu, Liang, & Turban, 2014)

An example of the use of crowdsourcing can be found within multiple stages of the Fiat Mio's development into a car prototype that encompasses a map of customers' wishes and not a final product (Saldanha et al., 2014). Saldanha et al. (2014) proposed an accordion model, which is different from a classical stage-gate model in terms of the number of iterations that occur due to an idea generation mind-set during the crowdsourcing projects. The use of crowdsourcing has benefits in connecting with consumers, with the stages following a six-step approach. The study provided valuable lessons, but its focus on just one company leads to less generalizability. A similar study can be conducted on a variety of successful cases investigating the process of how to quantify the "legacy" of a crowdsourcing project in terms of the amount of the consumer data collected for the future development of products or services, or in terms of how organizational structure changes before or after crowdsourcing projects. Figure 3.4 below illustrates the steps revealed from the study.

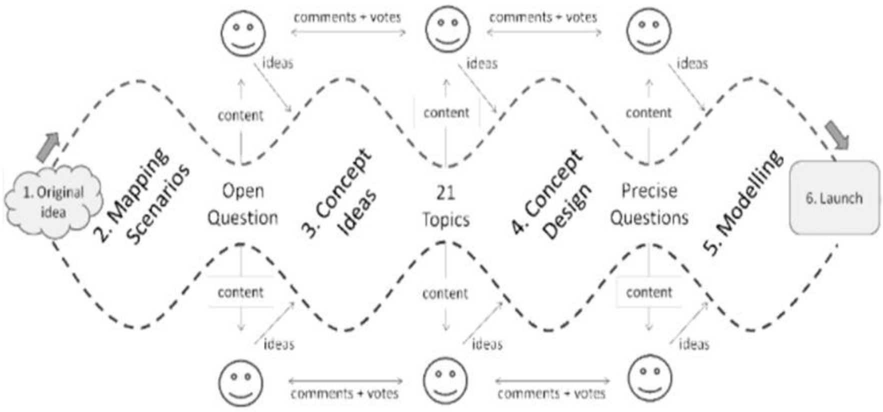

Figure 3.4. Proposed crowdsourcing process for the Fiat Mio (Saldanha et al., 2014)

The increasing popularity of crowdsourcing's benefits for both ideas and funding needs understanding, and it is even less understood in a business-to-business (B2B) context (Edgeman et al., 2015). It has been proposed that managers can draw inspiration from other successful crowdsourcing projects (Boudreau & Lakhani, 2013). Nevertheless, the crowdsourcing process proposed by Edgeman et al. (2015) happens in six stages involving the task, crowd selection, creation of the environment for crowdsourcing (broker or platform), crowd motivation, reaching the crowd, and lastly, the managing of inputs and communication of value. Although this study was more focused on the business-to-business (B2B) context, as there are differences in relation to business-to-consumer (B2C) context regarding incentives and ethical issues, the study provides some understanding of the crowdsourcing process. Figure 3.5 below illustrates the process proposed by the authors.

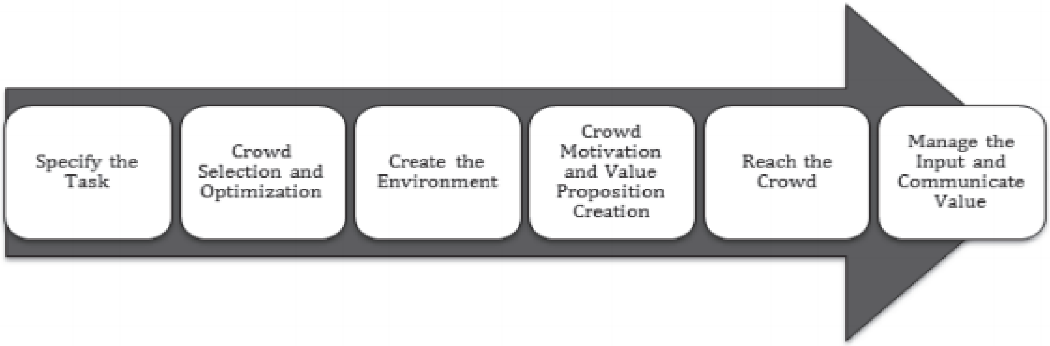

Figure 3.5. Proposed steps for crowdsourcing (Edgeman et al., 2015)

According to Cullina, Conboy, and Morgan (2015), the measurement of crowdsourcing can be viewed from four different metrics/perspectives: crowd membership, crowd platform, crowd incentivization and crowd interaction outcomes. As the integration of external resources (like the expertise, skills, and creativity of individuals) during the innovation process has increased, so has the need to pay attention to aspects at an individual level (West & Bogers, 2014). Mack and Landau (2015) examined the nature of individual engagement in innovation contests. Although this study is more crowd-related research, the authors propose a creative process that can assist with the understanding of the phenomenon. Figure 3.6 below illustrates a proposed model derived from the study.

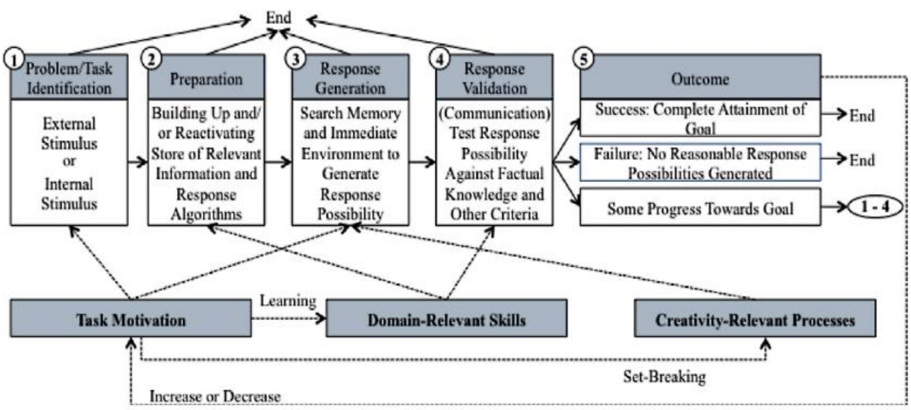

Figure 3.6. Proposed steps and factors for crowdsourcing (Mack & Landau, 2015)

The model proposes a five-stage process spanning three components task motivation, the need for domain-relevant skills, and the creativity relevant outcome process.

Palacios et al.'s (2016) overview of the crowdsourcing research revealed that most research focused on the end functionality of crowdsourcing in the innovation process, such as end-product development, continuous feedback, and collaborative ventures. This overview further suggested future research themes within crowdsourcing to assist in better understanding the field through research streams such as problem-solving, learning paradigms, open collaboration, organizational innovation, collaborative tools, and new product development. Specifically, on new product development, the authors analyzed crowdsourcing as a method for generating and gathering ideas for the new product development process to complement traditional NPD perspectives (Poetz & Schreier, 2012). The authors' examination of work in organizational theory supports the claim for including organizational-level factors in the process of crowdsourcing such as identifying the antecedents or factors that form the basis for meso and micro-level interactions; this can facilitate the development of more successful organizational crowdsourcing engagement with the crowd. According to the overview by Palacios et al. (2016) and the model built based on organizational forms, there are three levels of institutional logic with regards to crowdsourcing application. These levels range from micro (opportunity recognition) to meso (design and mechanics of organizational form) to macro (governance practices and ethical issues) levels. Figure 3.7 below illustrates the components of the crowdsourcing process with regards to the institutional logic levels.

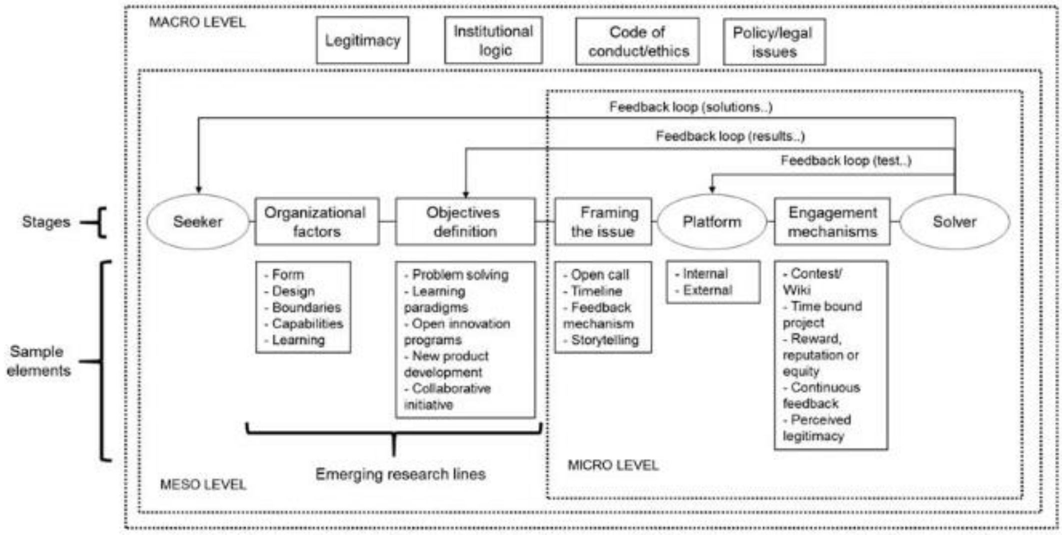

Figure 3.7. Proposed breakdown of the crowdsourcing process (Palacios et al., 2016)

Lauto and Valentin (2016) examined the use of online innovation contests as a tool during new product development in order to uncover the extent to which crowds use different criteria to evaluate new ideas. By analyzing the strategies, crowds, and committees of Danish company Novozymes, different aspects of the proposal of quality were realized, as the crowds tend to focus on the characteristics of ideas, whilst committees focused more on the characteristics of the inventors. Although crowdsourcing initiatives—like innovation contests —enhance the innovation process, emphasis is placed on the need for the appropriate infrastructure to support knowledge management with the reliance on multiple evaluation mechanisms for the assessment of discontinuous innovations. The authors find that crowds are less effective in gauging ideas that depart from the current technological competence of an organization compared to committees. Furthermore, crowds have the tendency to overlook ideas with lengthy textual descriptions.

Valuing user opinions is important in the world today, with people wanting to be heard, to customize products according to their needs and so on. Companies can, therefore, expand their horizons through the implementation of crowdsourcing.

Mehtala et al. (2016) examined the implementation of crowdsourcing within the fashion industry and observed that mass customization is a growing trend amongst brands such as Adidas and Nike, but the evidence still prevails: there is a negative attitude towards the adoption of crowdsourcing. Nevertheless, Mehtala et al. (2016) propose the crowdsourcing model for idea development in the fashion industry, which includes the platform, maintenance of contributor engagement, and working with data generated through the assistance of evaluation experts. Figure 3.8 illustrates the use of the crowd within the fashion industry.

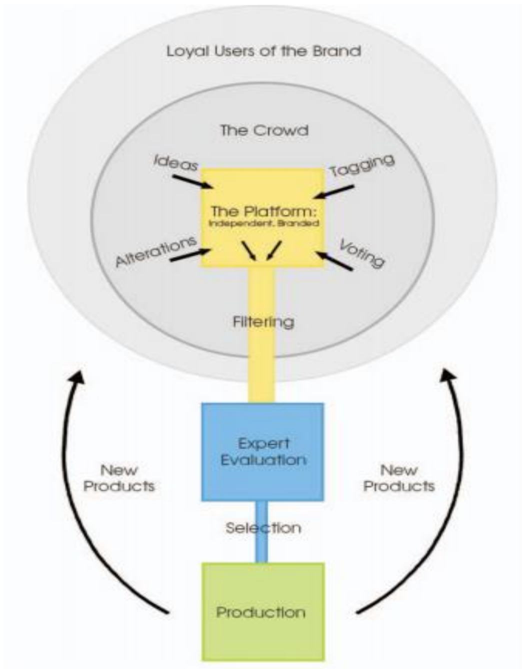

Figure 3.8. Proposed breakdown of the crowdsourcing process (Mehtala et al., 2016)

Organizations' increasing use of the crowd has been beneficial (Lehner, 2013), however, for most, it is still regarded as unfamiliar territory since it requires new thinking, capabilities, and resources to ensure creativity and an impulsive engagement process with the crowd in order to arrive at results and outcomes. The balance between the mixture of quantity and quality has an influence on the success in achieving results when using crowdsourcing approaches. For example, Belleflamme, Lambert, and

Schwienbacher (2010) revealed that organizations that are not driven by profit tend to be more successful in achieving fundraising targets compared to those who are driven by profit, which signifies that organizational forms may be a driver for some crowdsourcing approaches.

According to Zhu, Sick, and Leker (2016), the process of crowdsourcing has five general phases requiring several organizational decisions and challenges. These phases are deliberation, preparation, execution, assessment, and implementation. The authors examined the use of internal and external crowds within the chemical industry, and performed a cross-case analysis. It was revealed that a phase common to both processes was the evaluation phases. Figure 3.9 below illustrates the process revealed.

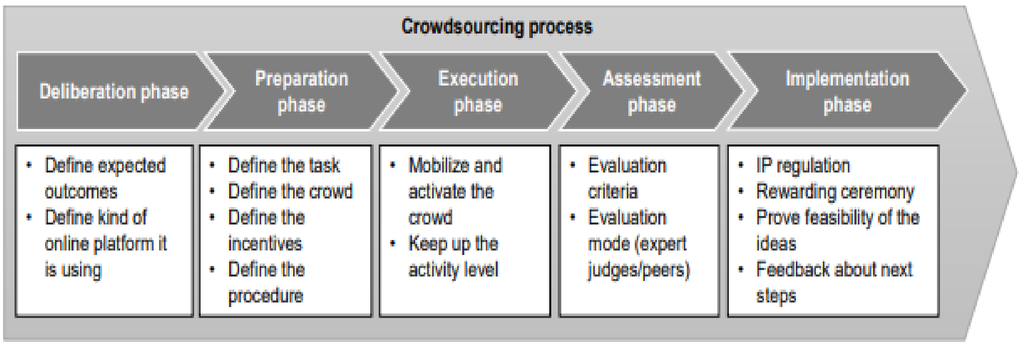

Figure 3.9. Proposed breakdown of the crowdsourcing process (Zhu, Sick & Leker, 2016)

Risks involved in using this approach include investment risk, development risk, coordination risk, motivation risk, control risk, security risk, governance risk, culture risk and intellectual property risk. Due to companies and researchers reaching outside of their boundaries in searching for solutions, ideas, and technologies, they may also incur many more risks such as the disclosure of innovation strategy, weakened control of intellectual property rights, lack of motivation from the crowd, low quality of ideas, poor quality of data, and loss of core competencies, amongst others. Although these risks exist, what is evident here is the knowledge held by 'the crowd' and its capability to solve problems in diverse ways that are better than an individual or experts; the real challenge is to find ways to use networks to produce new ideas that are less costly for organizations a whole (Silva & Ramos, 2012).

De Mattos, Kissimoto and Laurindo (2018) attempted to examine the key variables related to internal crowdsourcing settings that lead to adoption by companies. The study's focus was on the role technology plays. The findings were in line with the categorization that crowdsourcing follows either an internal or external approach, while the technical architecture can be of two configurations: innovation tools or co-creation and customization tools. The key variables identified were senior management and professionals' involvement in managing interface, the coordination of activities, and the development of technological tools for building a virtual environment. Analyzing other crowdsourcing activities would help to understand and operationalize the process further. Wilson, Bhakoo and Samson (2018) examined the link between crowdsourcing, operation management and project management to understand how crowdsourcing as operation management improves key outcomes. The crowdsourcing process proposed was broken down into workflows, which range between three variables—firm, crowd, and client—follows an eleven-step process. Figure 3.10 below illustrates the workflow process proposed.

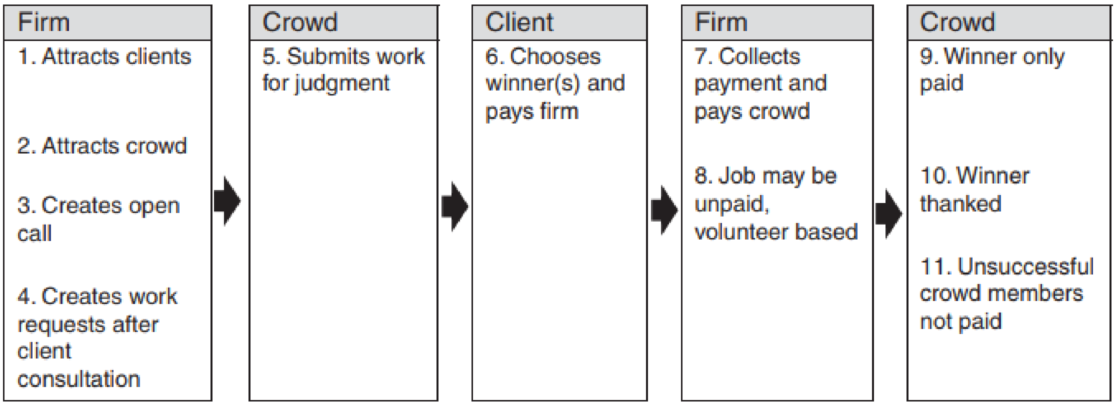

Figure 3.10. Proposed breakdown of the crowdsourcing process (Wilson, Bhakoo & Samson, 2018)

According to a 2018 study by Ghezzi et al., which performed a systematic review of the literature on crowdsourcing from process and management perspectives between 2006 and 2015 propose an input-process-output (IPO) framework to map the components of the crowdsourcing process. The input consists of tasks or problems (micro-task and innovation-oriented); the process involves session management, people management, knowledge management, and technologies for crowdsourcing; and, the output sees the micro-task combined with other micro-tasks to solve a complex problem, then the solution is evaluated and selected by the seeker, so both the solver and seeker benefit. The authors' proposal of an IPO framework suggests a linear or one-directional relationship, which might not be the case, as human actions can lead to feedback effects, thereby changing the social structure. Furthermore, a study that examines and integrates other forms of crowdsourcing (such as crowdfunding, citizen science, and so on) can add to this study. Figure 3.11 illustrates the process proposed by the authors.

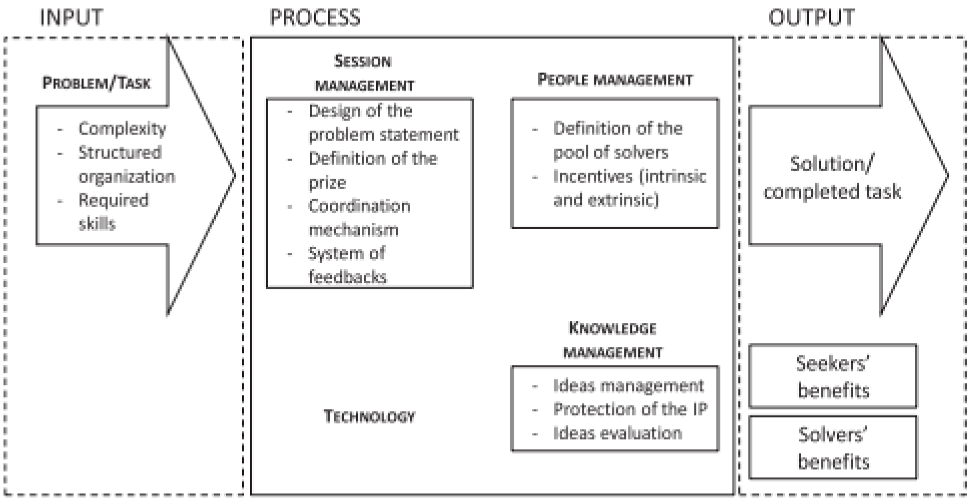

Figure 3.11. Proposed breakdown of the crowdsourcing process (Ghezzi et al., 2018)

This section of this study gives an overview of the stages involved during the crowdsourcing process for innovation. An in-depth examination of the phases will be covered in the next section of this study.

3.2.1 Leveraging Crowd During the Fuzzy Front Phase

According to Leimeister et al. (2009), organizations aim to integrate customers during the early phases of an innovation process, and they utilize idea competitions as a method for expanding the sources of potential ideas. To utilize this method, technical components directed towards activation, participation, competence, and supporting incentives play a vital role in the creation of ideas and in the maintenance of trust between organizers and the crowd. Generally, an idea competition includes features like task specificity, degree of idea elaboration, organizational appearance, timeline, incentives, and target group. A major question that presents varied discussion for research has always been centered on how to find and leverage the potential of the crowd intelligence. Ideas are said to be useless on their own, and it is only in their implementation that their true value can be realized.

Organizations are faced with the difficulty of adopting the right ideas for further development, as novel ideas are usually accompanied by high risk and uncertainty (Baer, 2012). Understanding organizations' decision making and evaluation of ideas then becomes critical in linking the generation and transformation of ideas into promising products to increase the likelihood of innovation success. The literature related to the mechanisms for filtering novel consumer ideas and firms' boundary conditions still seems to be lacking, leading to reluctance in adopting ideas. As firms utilize simplified filtering cues such as idea feasibility whilst facing challenging ideas that are incompatible with their structures and capabilities (Chan, Li and Zhu 2018).

Schweitzer et al. (2012) performed a comparative study between idea competitions and focus groups for idea generation, and discovered that idea generation approaches provide more and better ideas at a lower cost, but that focus groups tend to yield richer interactions with the consumers involved. This study was done on Cisco, who were able to collect 2,500 ideas from contributors in over 104 countries. A large amount of data generated in big data pools has been considered a key issue during crowdsourcing approaches. Some studies propose modules (such as co-occurrence analysis) to assist with online brainstorming to better understand how key concepts are linked together (Malhotra & Majchrzak 2014). It was discovered that satisfactory results were arrived at using both approaches, however, the ideas submitted through idea competitions were witnessed to be less representative of consumer's personal needs for new products than those from focus groups, as these ideas were more representative.

Some researchers have questioned the success of crowdsourcing practices, as the acquisition of input is relatively low compared to the number of ideas submitted, such as in the case of idea competitions. As little is known about winning ideas, Mortara Ford and Jaeger (2013) examined the process after idea competitions have concluded.

It was highlighted that a process of knowledge-seeking, the enabling, filtering, and acquiring of innovation is done in a feedback loop. Although their study highlighted the methodological process after idea competitions have closed, the definition of what constitutes success remains problematic as little is still known on how valuable ideas are obtained.

Another issue realized was the lack of justification for large firms to run such exercises considering their need to show some return on their investments; therefore, more studies concentrating on defining metrics for crowdsourcing processes were proposed. Bayus's (2013) study examined the contribution from ideators to the Dell IdeaStorm community, and highlighted that, although valuable ideas are realized and implemented on the platform, the continuous contribution of exciting ideas by ideators tends to diminish as they propose ideas similar to ones that were already implemented, thereby generating less diverse ideas. Although the accumulation of ideas has its benefits, it can also become overwhelming, with the proliferation of ideas making it difficult to identify the best ideas due to the lack of managerial attention to evaluating inputs (Soukhoroukova, Spann & Skiera, 2012). This stock of dormant ideas further discourages employees from participating in such approaches.

Chan, Li, and Zhu (2018) performed a quantitative study exploring the role of idea novelty on the feasibility of idea adoption and revealed that novel ideas from the crowd are not always adopted by organizations as said organizations tend to take on ideas with a path of least resistance. Exploring the idea evaluation process across different crowdsourcing approaches can be useful for further understanding idea selection. As social media technologies have enabled interactive feedback between large organizations and internal crowds, the impact of these technologies on idea quality is still being questioned. Zhu et al. (2019) analyzes feedback characteristics such as the diversity of commentators, feedback constructiveness, and the degree of facilitators' interaction during online idea generation sessions revealed that all the above features are independent of each other. The findings show that feedback generally had a positive effect on the diversity of commentators, thereby emphasizing online feedback as an important knowledge-exchange process that must be completed through facilitators in order to make a profit.

Value co-innovation platforms stand as an important strategy due to the opening of innovation activities, and involving users and customers more actively in the NPD process has been found to generate new products ideas which are quite novel, to propose a lot of customer benefits, and to be more valued by consumers in terms of product quality when compared to the ideas of professionals; thereby, this increases the likelihood of new product success and competitive advantage (Hoyer et al., 2010; Poetz & Schreier, 2012).

Tapping into the collective intelligence of the crowd has been praised in various studies, but with the shift in audience from small groups to an unstructured environment, there are still implementation challenges with organizations admitting to a number of the ideas being submitted during contests as being relatively immature needing much filtering and improvement (Guido, 2009). This might either be related to the type of crowd involved or the organisations' capabilities in question. Another issue pointed out in the literature is "crowdslapping", which refers to when the responses of the crowd go against the pre-existing intention of the crowdsourcer. As idea generation and design processes prove to be the ultimate successes of any firm in terms of the generation of new product ideas, the process still remains an issue in organizations who usually designate their marketers, engineers, and designers to take on creative tasks. The fundamental assumption behind this notion is that professionals have the experience and expertise required to identify, create, and solve relevant consumer problems by inventing creative solutions that lead to successful new products (Ulrich & Eppinger, 2008). In many innovation scenarios, the use of design contests and innovation tournaments have been used to generate ideas and engage with idea generators; feedback has proven to play a vital role in influencing individual behaviour. The use of feedback varies, however, as directed feedback does not appear to benefit the best ideas, thereby resulting in more entries associated with higher-than-average quality ideas (Wooten & Ulrich, 2017).

The circumstance for an organization to crowdsource depends on the characteristics of the problem, the knowledge required for the solution, the crowd involved, and the evaluation of the solution (Afuah & Tucci, 2012). Iacobucci and Hoeffler (2016) support the use of crowdsourcing in their study by proposing ways companies can leverage social networks to develop radically new products that form new product categories, thereby staying ahead of consumer's emerging needs and preferences. They propose observing and interacting with lead users to identify frequently encountered questions, and then to experiment with trusting customers.

Building on the growing recognition that an innovation culture requires, the move beyond the constraints to out-of-the-box thinking and the creativity which can exist outside of an organization, crowdsourcing can be seen as possessing the potential to increase innovation productivity and harness creativity from a distributed network of contributors (Marjanovic, Fry, & Chataway, 2012). Although it is necessary to use technology infrastructure to arrive at these potentials, research is needed to look into variables that influence the success of crowdsourcing efforts, such as the strengths and weaknesses of models, information on the nature and size of "wise crowds", and the capabilities needed to effectively evaluate external solutions (Surowiecki, 2004;

Marjanovic, Fry, & Chataway, 2012). When organizations can harness interaction with customers, this enhances consumers' trust in a company's capabilities, which also leads to unique value.

The ability of organizations to arrive at outcomes relies on their capacity and capabilities to utilize knowledge, which is dependent on the contributions of the crowd. The benefits of crowdsourcing are evident, however, managers are increasingly interested in using crowdsourcing as a strategy to improve innovation capabilities. Maiolini and Naggi (2011) noticed that the use of crowdsourcing has been relatively low among SMEs and organizations, and, thus, investigated the benefits and challenges of crowdsourcing by organizations. They identified the main reasons firms use crowdsourcing—the size and diversity of crowds, cost reduction in performing certain activities, and the multiplicity of competences, ideas and resources—which are more significant than what can be found internally. They found that major challenges faced by SMEs arise in how they integrate knowledge developed externally in with the internal knowledge of organizations, which involves the motivation and sustenance of both internal and external actors. They also revealed that it would be useful for organizations to have the ability to have resources that identify needs through a defined plan of development or a business model; furthermore, the capability to manage crowdsourcing practices is essential. Figure 3.12 illustrates the proposed process with some factors needed for the crowdsourcing.

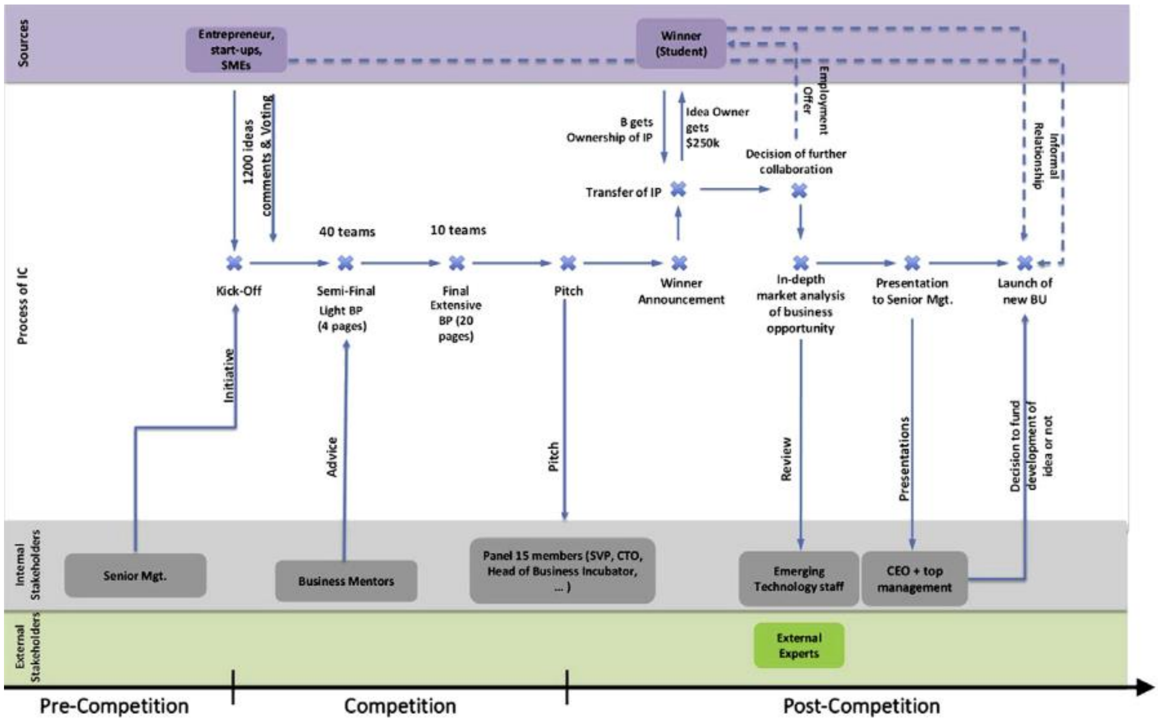

Figure 3.12. Proposed breakdown of the crowdsourcing process (Maiolini & Naggi, 2011)

Malhotra and Majchrzak (2014) illustrated the difficulty of not only managing crowds, but also the encouragement of the knowledge integration process of innovation challenges, which is comprised of sharing, highlighting, and combining ideas to create solutions. As this contributed to the literature, it was more of a crowd-specific study. The originality of ideas is said to result from the creative synthesis of similarities from different perspectives. However, the process of generating knowledge during the process is still under-researched (Kosonen et al., 2012). According to Steils and Hanine (2016), the clear framing of the brief providing organizations' requirements and expectations plays a central role in helping to guide crowd idea generation in the right direction. By providing the brief and playing a passive role, valuable information can be acquired with the provision of feedback after ideas are submitted.

Studies show that successfully engaging with the crowd and acquiring the necessary desired contributions cannot generate crowd capital alone (Prpic et al., 2015). The need for a separation between value creation and value capture enables organizations to achieve successful strategy implementation (Lepak, Smith, & Taylor, 2007). Therefore, it is important for organizations to have internal processes, such as a team or individual tasked with engaging the crowd, organizing, and ensuring that desired outcomes are produced from incoming knowledge (Prpic et al., 2015).

3.2.2 Leveraging the Crowd During the Design and Development Phase

The group of studies in this section provides an overview of the process of crowdsourcing during the design and testing phase of innovation activities; this is done to better understand how crowdsourcing is integrated and utilized. De Couvreur and Goossens conducted a 2011 study examining how design-thinking approaches, such as crowdsourcing, user-generated content, and peer production, can provide more feasible, universally designed objects within healthcare rehabilitation. According to the study, a certain amount of trial and error is needed in untangling the physical, cognitive, and emotional needs of specific patients. The study utilized a co-design approach, an iterative process that follows the gathering of data and analysis of data, as well as formulating and implementing solutions.

Research on the use of crowdsourcing for design initiatives has also been witnessed. Xu, Qin, and Xiao (2012) examined SME's application of crowdsourcing for design activities keeping in mind the difficulties of cost, and the challenges of leveraging a scalable workforce and selecting the most suitable intermediaries for their design process. Through this study, it was realized that enterprises can spend less and benefit more from engaging plenty of witkeys (crowd), with the potential of organizations making some form of income whilst arriving at product designs. Gabelloni, Montelisciani and Fantoni's (2013) study on the new product development process focused on design problems and how design crowdsourcing approaches are useful for new product design. A collaborative crowdsourcing platform was developed to drive the user's creativity and participation with the complemented tracking of intellectual property rights. Three problem-solving sessions with small team size and themes of incremental innovation (six members), a new architecture for new product generation (eight members), and next-generation of needs (thirteen members) were studied to examine the benefit of crowdsourcing such tasks. The application of design crowdsourcing efficiently provided solutions, but could be furthermore improved through the integration of a set of tools—like CAD drawings—to enhance the collaborative design experience. The findings of this study revealed that the variation of user team size and compositions according to product typologies enables problem-solving.

Aitamurto, Holland and Hussain (2013) examined crowdsourcing use during the participatory and co-design approaches as a form of openness. Through an autonomous design process and consumer-company collaboration, three layers of actions can be utilized by organizations for design phases: listening to, interacting and creating with, and sharing with co-designers and the crowd. Although these services are also rendered by online platforms, the impact of openness on the innovation process is relatively under-researched; furthermore, how to apply these online practices poses a question to be studied. According to Nishikawa, Schreier and Ogawa's (2013) study on the comparison between user-generated and designer/professional generated products in Japan, user-generated products contain higher levels of novelty, and outperformed their designer-generated counterparts in terms of market performance metrics such as sales revenue, which favour market research and support managers in considering the integration of user ideas into the process of new product development. Although this is just initial evidence that supports the potential of user-generated products, their study only revealed that most users were just providers of ideas and did not participate in the decisive in-house efforts to convert ideas into successful new products. They point out the importance of involving users during the later stages and also the difficulty of managers in handling and implementing crowdsourcing initiatives on a larger scale.

Although we are witnessing the increased use of crowdsourcing for design-related activities, difficulty exists in terms of designing crowdsourcing initiatives that would maximize both participation as well as the quality of outcomes within cost constraints. Due to the lack of frameworks for designing activities, Panchal (2015) proposed a holistic framework to assist engineers, which is comprised of three phases: 1) select the class of crowdsourcing initiatives; 2) make structural, problem-related and evaluation decisions; and 3) designing the appropriate reward structures. The types of crowdsourcing initiatives range from crowdsourcing contests, open calls with rewards, open calls with indirect benefits and microtasks. Structural decisions include the number of stages, duration, entry restriction, and team formation. Problem-related decisions are either system decomposition or the amount of information shared with the crowd. Evaluation decisions relate to the assessment of quality, choosing winners and distributing awards. Appropriate incentives are to be decided based on metrics such as the quality of solutions, the number of contributors, the overall cost of running contests, the amount of effort invested, etc. Figure 3.13 below illustrates the proposed process for design activities.

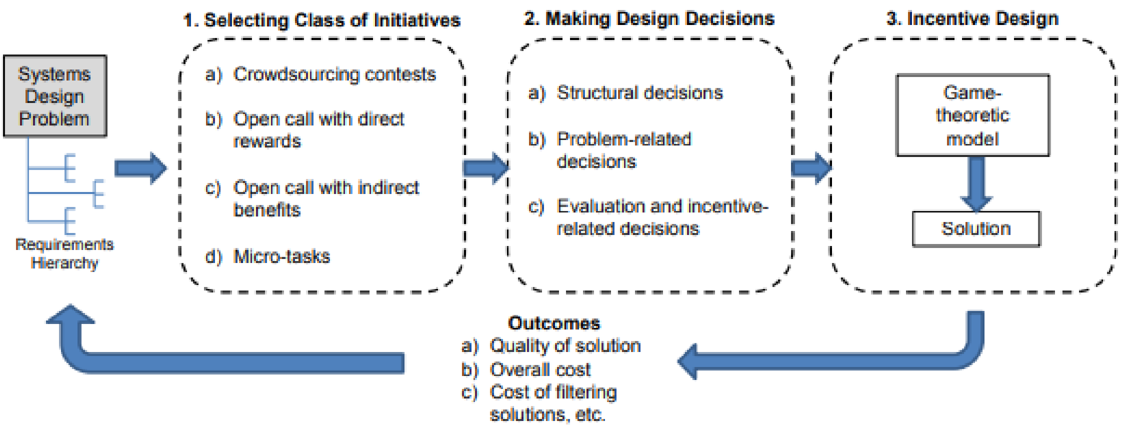

Figure 3.13. Proposed breakdown of the crowdsourcing process (Panchal, 2015)

3.2.3 Leveraging Crowd During the Commercialisation Phase

Whitla's (2009) study on crowdsourcing examined how firms utilize crowdsourcing for marketing-related tasks, concentrating on areas such as advertising, promotion and product development. It was found that crowdsourcing does have benefits when utilized by companies with respect to locating a large number of individuals willing to complete large menial tasks for limited financial compensation.

When considering crowdsourcing during marketing, three common issues faced by organizations were legal, ethical, and privacy issues. Studies have also proposed that, for organizations to avoid the noise returned by the crowd, it is essential to acquire procedures for the effective filtering and consideration of ideas supplied (Whitla, 2009; Gatautis & Vitkauskaite, 2014). Crowdsourcing can be seen to devalue creative talent within the crowd, as only the best ideas are paid for and, even then, the ideas paid for are usually below average (Gatautis & Vitkauskaite, 2014). Gatautis and Vitkauskaite (2014) examined success factors for crowdsourcing marketing activities, and proposed that factors can vary from contributor characteristics (breadth and quality), reputation measures (public reputation and internal reputation), and project management (capabilities, tools, and quality control).

A review of studies shows that the crowdsourcing process for innovation can have varying benefits. Many researchers have focused on uncovering the process via systematic literature review (Marjanovic, Fry & Chataway, 2012; Palacios et al., 2016; Ghezzi et al., 2018) and case study approaches (Ebner, Leimeister, & Krcmar, 2009; Saldanha, Cohendet & Pozzebon, 2014; Lauto & Valentin, 2016). Few studies have focused on examining the crowdsourcing process by comparing two or more activities (Schweitzer et al., 2012; Zhu, Sick & Leker, 2016). Schweitzer et al. (2012) discovered that ideas submitted through idea competitions were witnessed to be less representative of consumer's personal needs for new products when compared to ideas from focus groups (Lauto & Valentin, 2016). The literature review highlights extensive research on crowdsourcing but within specific phases, as researchers have mostly focused on crowdsourcing in project and business management (Wilson, Bhakoo, & Samson, 2018; Ghezzi et al., 2018). As a result, these findings may not be generalized to the crowdsourcing process as a whole. Hence, more research is needed in comparing crowdsourcing activities to uncover a holistic crowdsourcing process.

3.2.4 Evaluation Mechanisms of Crowd Contributions

The group of studies in this section are comprised of mechanisms utilized to arrive at quality ideas that can be integrated into the innovation process.

Leimeister et al. (2009) study examined idea competitions as a mode of integrating customers, and how active participation is supported by software functionalities, design measures, and incentives. The active participation of customers was witnessed to stem from motives such as the ability to learn, direct compensation, and social incentives. The competitive feature of idea competitions encourages participants to produce winning ideas, but the evaluation of winning ideas is carried out by review committees of organizers (Ebner, Leimeister, & Krcmar, 2009).

Jouret (2009) examined the process of finding an idea that would spawn into success at Cisco by fitting into the company's strategy. This study's findings revealed that the process followed a three-step approach whereby the organization invited innovators to submit ideas. Then followed the winnowing of ideas based on criteria such as the idea having a big appeal to the market, ideas addressing the organization's real pain points, the organizational capability to pursue an idea, etc. Last comes the refinement of ideas. It was revealed that the entire process was not so easy, as the organization underestimated the amount of labour and complexity involved. Benefits were still derived, however, as Cisco was able to map ideas from a vast range of countries to gain perspective on relevant solutions, putting a high value on ideas that combine interesting technologies with smart, innovative business models.

For organizations to get optimal solutions from using crowdsourcing, they need to improve task designs and motivate the crowd during the process. According to Zheng, Li, and Hou's (2011) study on solvers in China, task attributes—autonomy, variety, and analysability, for example—are positively associated with the motivation of solvers. Poetz and Schreier's (2012) research on the value of crowdsourcing in generating ideas for new products discovered that users can be recognized as an alternative source for new product ideas. This study shows a divide within industries, whereby some companies had attributed great potential to outsourcing idea generation to a crowd of users, others remained quite sceptical; the domain (new products) in particular used to be exclusive to marketers, engineers and professionals.

It is understood that users generated highly novel products that are customer beneficial, but less feasible, which could complement professionals at NPD firms. Past research has argued that relying on professionals rather than users in describing future products is more likely to lead to valuable products. On the other hand, a growing number of studies also show that consumers might have propositions for new product ideas, and can further innovate for themselves with products having commercially high attractiveness (Jeppesen & Frederiksen, 2006; Stodden, 2010).

Stieger et al. (2012) examined the application of crowdsourcing methods by sketching out the technical implementation process, followed by the process of creating the platform, the introduction of the platform in a top management meeting, and the launch and evaluation of the project based on five crowdsourcing objectives (energizing, listening, talking, supporting and embracing). They discovered that crowdsourcing approaches are scarcely applied in companies, and shared important components for embedding a platform during strategy processes, proposing the creation of suitable processes for the encouragement and guidance of the crowd's participation and collective knowledge creation. According to Aitamurto, Holland, and Hussain's (2013) study on crowdsourcing ideas for design challenges, specific criteria are utilized for the shortlisting, refining, iteration of the platform or the sponsor to select a winning concept. Wu, Corney, and Grant (2014) examined the quality of the provided designs utilizing a quantitative study, and revealed that expert panels are utilized to judge the quality of submitted work. By examining the quality assessment methods and the reward models of Chinese platforms that utilize either public design or multi-stage competitions, it was revealed crowds utilized a marking system ranging from 0 to 100, with less influence on the different levels of payment for their crowd creations. The use of *in momento* methods is proposed to yield better reliability and efficiency of results for QoE testing approaches (Gardlo et al., 2014).

Crowdsourcing still poses a challenge during product design (Chang & Chen, 2014). Chang and Chen (2014) proposed a method to improve the efficiency of evaluating results by using web-mining techniques to extract textual information into world tags, which was followed by calculating the similarity in estimation between design requirements and crowdsourced concepts. The similarity is based on three situations: repetition, synonymity, and design knowledge hierarchy. As the innovation process continuously relies on generating, evaluating, and refining ideas, organizations are regularly searching for a way to develop innovative ideas. The literature reveals, however, that organizations who use crowdsourcing platforms for ideas tend to source for ideas and develop them internally, which leads to less creative ideas when compared to collaborating with the crowd (Yu & Nickerson, 2011). Link et al. (2015) proposed a method for the selection and evaluation of ideas called anchored discussion approach, which leads to more structured discussions amongst the crowd. The evaluation of submissions was performed by four independent judges who rated outcomes based on eight dimensions: 1) originality, 2) paradigm relatedness, 3) acceptability, 4) completeness, 5) implementability, 6) applicability, 7) effectiveness, and 8) implicational explicitness.

According to Blohm et al.'s (2016) study comparing 120 participants' decision-making patterns based on a rating scale and preference market, they proposed that rating-based tasks tend to influence the perception of the crowd when compared to preference market-based tasks; a perception that affects the quality of ideas evaluated. In general, the evaluation approaches utilized were idea evaluation by mechanism accuracy, idea evaluation by preference markets, and idea evaluation by a rating scale. Although the true quality of ideas can not be known until it is implemented, mechanisms utilized during crowdsourcing approaches are meant to reduce the ideas submitted to a subset (Girotra, Terwiesch and Ulrich, 2010). According to Zhu, Sick, and Leker's (2016) study, four key dimensions for evaluating creative ideas are thoroughness, feasibility, novelty, and value addition.

The crowd's exposure to examples of original ideas can be helpful, as it increases originality during idea generation, but not so much effectiveness. The inclusion of voting mechanisms can enable the surfacing of highly original ideas (Wang, Nickerson & Sakamoto, 2018). Although previous scholars have proposed dimensions for evaluating ideas, organizations still seek satisfactory mechanisms for evaluating contributions (Chen et al., 2009). Still lacking are studies that explore the evaluation processes combining the crowd and organization mechanisms to arrive at quality ideas. It is proposed that many firms lack a coherent or formal process for selecting ideas further leading to the fading away of the best ideas (Barczak et al, 2009).

Based on the extensive literature review, the majority of studies utilize experimental (Chan, Li, & Zhu, 2018) and quantitative approaches (Wu, Corney, & Grant, 2015; Chang & Chen, 2014; Link et al., 2015) with focus on participant perspective or idea features. These findings may not be considered generalizable in terms of understanding how and with what combined mechanisms seekers use to evaluate and arrive at ideas.

3.2.5 Success Factors for the Use of Crowdsourcing for Innovation

This section will cover the literature in order to identify the factors that determine the success of using crowdsourcing for innovation activities. As studies have determined the success from various perspectives, it is important to understand what is required to effectively integrate crowdsourcing during the innovation-related process and manage its use.

According to Shao et al. (2012), an empirical study on creative contests in China revealed that the success of crowdsourcing is strongly related to the quantity and quality of solvers. The authors proposed that certain attributes of contests—such as higher rewards, increased ease of tasks, and lower competition—lead to an increase in the number of solvers. Årdal and Rottingen (2012) examined the use of crowdsourcing for pharmaceutical innovation, and revealed that success factors are related to clearly defined entry points, funding to cover material costs, transparency, and access to results. Lauto et al. (2013) examined the use of idea competitions by R & D management during the front end of the innovation process, revealing that the active involvement of the management team enabled its success. Segev et al. (2014) proposed that the active participation of staff during crowdsourcing was pivotal in arriving at outcomes such as improved knowledge sharing, working relationships, and response to customer needs, promoting innovation processes at Volpe. Ruggieri et al. (2016) examined cloud workers on platforms such as oDesk, Freelancer and Elance to understand how communities influence recruitment strategies. The authors explain that the encouragement of trust and ethical behaviour through investment in reputations, providing feedback, and increasing validation are all key. Zhu, Sick, and Leker (2016) performed a comparative analysis on internal and external idea sourcing in the chemical industry, and proposed findings. The conditions for achieving success are having internal buy-in and, the commitment of internal resources, as well as by ensuring tasks and outcomes are analyzed from a practical perspective. Generally, low level of adoption is perceived due to the unawareness of models by SME's, and few managers lack the knowledge of utilizing tools and platforms suitable for tasks (Diederik et al., 2014).

The literature review highlights the critical factors for adopting crowdsourcing (Shao et al., 2012; Sharma, 2010). Shao et al. (2012) found that attributes of contests linked to management—attributes such as higher rewards, ease of tasks, and lower competitions—can lead to an increase in the number of solvers. Sharma (2010) found that vision, strategy, human capital, infrastructure, external environment, linkages and trust are critical for the success of collective intelligence. What is missing in the literature are success factors in terms of the skills and capabilities that enable seekers to readily manage and utilize crowdsourcing for innovation activities (Maiolini & Naggi, 2011; Lüttgens et al., 2014; Ghezzi et al., 2018). Podmentina et al. (2018) propose the required skillsets for managing open innovation range from interpersonal, technical engineering, content management, project management, to crowd management skills. Examining the internal success factors in terms of skills and capabilities for managing crowdsourcing can provide more insight. Table 3.1 below gives a summary of the factors uncovered thus far in the literature.

Table 3.1: Overview of Success Factors for Crowdsourcing Innovation

Success factors	**Authors**
Quantity and quality of solvers	Shao et al. (2012)
Clearly defined entry points Funding to cover material costs Transparency and access to results	Årdal & Rottingen (2012), Zhu, Sick, & Leker (2016)
Active involvement of the management team	Lauto et al. (2013), Segev et al. (2014)
Encouraging trust and ethical behaviour	Ruggieri et al. (2016)
Internal buy-in Commitment of resources Practical analysis of outcomes	Zhu, Sick, & Leker (2016)
Adequate human resources Training programmes Capital investment to support schemes	Kavaliova et al. (2016)

3.2.6 Enablers and Barriers for Crowdsourcing Innovation

This section examines the literature concerning the enablers and barriers of crowdsourcing use for innovation which has followed a few variations due to the different areas that crowdsourcing has been applied. Crowdsourcing innovation barriers are factors that have a negative influence on the use and likelihood of it being beneficial. Enablers, on the other hand, are factors that have a positive influence on its utilization.

Existing studies using different approaches show similar factors for crowdsourcing innovation activities. These studies approach range from surveys, case study, and qualitative methods focusing on related mechanisms such as open innovation, co-innovation as well as specific stages of the NPD process such as fuzzy front end, product design and development process (Mergel, 2018; Qin et al., 2016; Niu et al., 2019; Albors-Garrigos, 2015; Evans et al., 2015; Simula, 2013). The literature on crowdsourcing innovation identifies a wide range of barriers and enablers, such as organizational resistance, labour exploitation, retention of the crowd and so on. Table 3.2 below gives a breakdown of uncovered barriers thus far.

Table 3.2: Breakdown of Barriers during Innovation Activities

Barriers	**Authors**
Selection and retention of the crowd	McGonigal (2008); Antikainen, Makipaa & Ahonen, (2010); Kavaliova et al., (2016); Maiolini & Naggi, (2011); Poetz & Schreier, (2012); Girotra, Terwiesch & Ulrich, (2010); Afuah & Tucci, (2012); Cooper & Edgett, (2008); Simula, (2013); Djelassi & Decoopman, (2013)
Crowd perception and labour exploitation concerns	Cooper & Edgett, (2008); Poetz & Schreier, (2012); Simula, (2013); Djelassi & Decoopman, (2013)
Lack of support for product innovation and integrating knowledge	Diederik et al., (2014); Qin et al., (2016); Maiolini & Naggi, (2011)
Alignment of firm budgets with crowdsourcing project time-line	Zahay, Hajli, & Sihi (2018)
Awareness of crowdsourcing initiatives	Simula, (2013)
Organizational resistance (no invented-here syndrome)	Cooper & Edgett, (2008); Poetz & Schreier, (2012); Qin et al., (2016); Djelassi & Decoopman, (2013); Albors-Garrigos, (2015); Evans et al., (2015); Maiolini & Naggi, (2011); Simula, (2013)
Restrictive culture	Qin et al. (2016); Evans et al. (2015); Albors-Garrigos (2015); Chao, Reid & Mavondo (2012); Simula (2013)
Vote tweaking	Cooper & Edgett (2008); Poetz & Schreier (2012)
Lack of data quality validation	Cooper & Edgett (2008); Poetz & Schreier (2012); Evans et al. (2015); Niu et al. (2019)
Legal issues and loss of corporate data	Cooper & Edgett (2008); Poetz & Schreier (2012); Evans et al. (2015)
Lacking the know-how and unclear responsibility managing crowdsourcing systems	Diederik et al. (2014); Qin et al. (2016); Zahay, Hajli, & Sihi (2018)
Lack of flexible and appropriate platforms	Qin et al. (2016); Niu et al. (2019); Ebner, Leimeister & Krcmar (2009); Zahay, Hajli, & Sihi (2018)
The difficulty of maintaining trust and confidentiality	Djelassi & Decoopman (2013); Qin et al. (2016); Evans et al. (2015)
Use of gamification strategies	Boulet, (2012); Kavaliova et al., (2016)

Crowd lacking adequate knowledge	Chao, Reid & Mavondo (2012)
Restrictions intertwined with the design of traditional methods	Zahay, Hajli & Sihi (2018); Evans et al. (2015)
Organizations lack of resources for innovations	Oliveira, Ramos & Santos (2010); Maiolini & Naggi (2011)

Only recently have a few studies started attempting to identify the factors based on a theoretical lens (Bigliardi & Galati, 2016; Zahay, Hajli, & Sihi, 2018; Mergel, 2018).

Bigliardi and Galati (2016) examined the behaviours of 157 Italian SME's and inhibiting factors through the lens of resource-based view and transaction cost theory. Bigliardi and Galati identified main barriers ranged from knowledge', 'collaboration', 'organisational', 'financial and strategic'. Mergel (2018) observed the adoption barriers of open innovation platforms (challenge.gov) within the public sector to increase government innovations. The authors' quantitative analysis of the platform and qualitative interview with 36 public managers identified that system inherent drivers and barriers affecting public sector organizations' adoption of technological innovation. The barriers range from inter-organizational—legal barriers, technological barriers in designing crowdsourcing processes, cultural factors, and the uncertainty over how the process works and how outcomes were delaying the process—to institutionalization—integration into standard operating procedures—to inter-organizational and extra societal organizational barriers.

Zahay, Hajli, and Sihi's (2018) exploratory qualitative study with four managers in the United States examine the internal perspective on crowdsourcing use in the fuzzy front end of the NPD process. Using the lens of a resource-based view, the authors identified the use of both internal and external crowdsourcing, but with more reliance on internal crowdsourcing in the FFE by B2B managers. The authors identified restrictions intertwined with the design of traditional methods; such restrictions do not complement crowdsourcing, including managers' lack of trust, lack of data quality validation, and lack of proper measures to evaluate results from innovation based on consumer feedback. The study conducted provided general insights on just B2B organizations, however, B2C organizations can offer more insights, as B2C organization usually develops products more closely related to consumer preferences (Fuchs & Schreier, 2011). The study also only focuses on organizations in the United States, with only four participants, so a qualitative study that examines other countries can provide patterns on cultural practices or regulations that influence the development of new products.

Studies on barriers and enablers have framed research using the lenses of a resource-based view and transaction cost theory (Bigliardi & Galati, 2016; Zahay, Hajli, & Sihi, 2018), as well as extensive literature reviews in specific industries (Evans et al., 2015; Niu et al., 2019). Based on previous studies, it can be seen that no single study focuses on the factors that enable or inhibit the use of crowdsourcing while using a unifying lens that allows for the examination of broad constructs. Furthermore, no study has compared crowdsourcing activities to arrive at more generalized findings. Accordingly, this study will address these gaps in the literature. The next section would examine another type of crowdsourcing activity, crowdsourcing science.

3.3 Crowdsourcing Process: Science

This section will cover the literature on the use of crowdsourcing within scientific research fields carried out to broaden the understanding of the crowdsourcing process, a topic that various authors have discussed. A plethora of concepts and terms related to crowdsourcing science exist in the literature, such as "participatory science," "citizen science," "open science," "crowd science," "networked science," "massively collaborative science," or "public participation," (Young, 2010; Wiggins & Crowston, 2011; Groom, Weatherdon & Geijzendorffer, 2017). These approaches have been proposed to be classified into “top-down” or “bottom-up” management approaches based on the extent of volunteer involvement (Conrad & Hichley, 2010). As crowdsourcing science is a growing practice that has become a powerful addition to ongoing scientific research with the aim of increasing participants knowledge and changing attitudes towards the scientific process and the environment (Brossard, Lewenstein & Bonney, 2005; Boyle & Sigel, 2015; Wiggins & Crowston, 2011). This has led to the creation of experimental procedures for which this section seeks to examine and identify the main phases.

According to Smith and Lazarow's (2006) study, the development of an adaptive management framework was an attempt to broaden the understanding of citizen science research theme by focusing ongoing learning between both the communities and institutions involved. The study’s purpose was to facilitate more effective community participation in coastal management. Cooper et al. (2007) examined the potential of human activities in contributing to the conservation of biodiversity and developed an adaptive framework for citizen science. To achieve the implementation of this approach to research, the researchers identified the need for a unique combination of scientific, educational, recruitment, and management objectives. The process can be tailored to various purposes, however, with key features such as the procedure for establishing goals, identifying and reaching target communities, training participants, retention of participants, data collection, feedback mechanisms, and management recommendations. Figure 3.14 illustrates the process proposed by the authors.

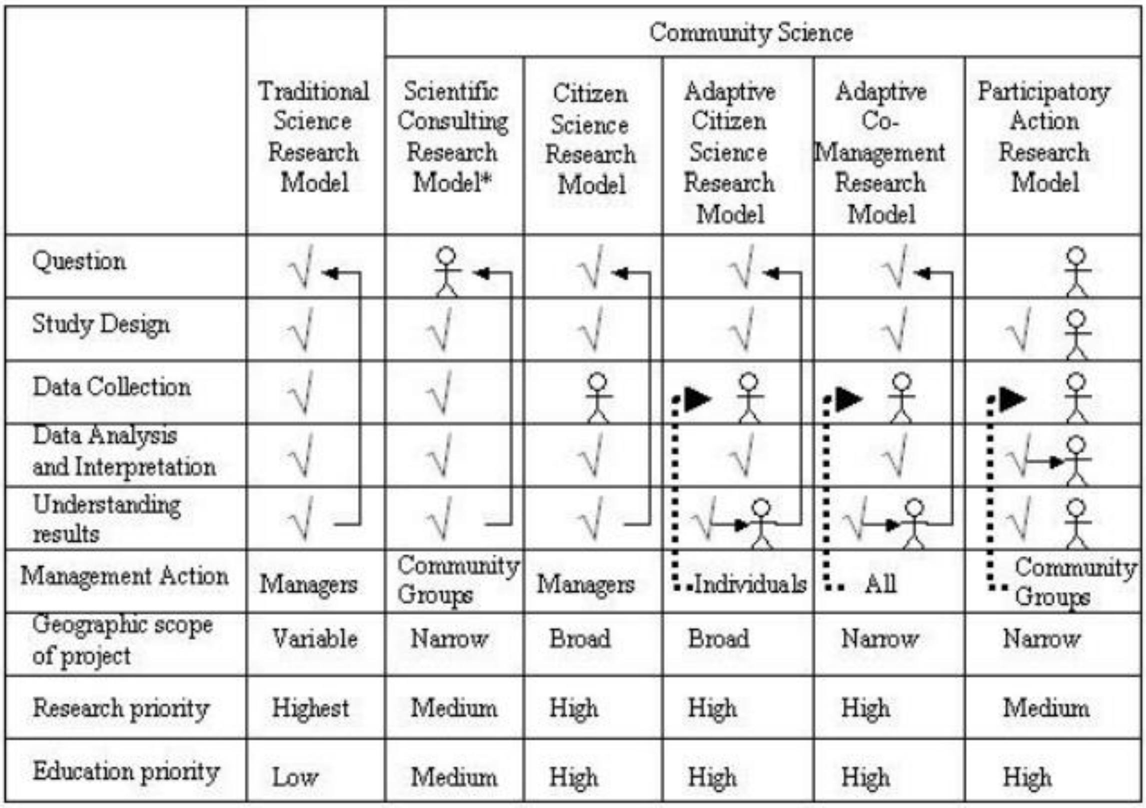

Figure 3.14. Proposed breakdown of the crowdsourcing process (Cooper et al., 2007)

The contribution of this study was proposing that the operation of citizen science requires large scales of dispersed participants. Although the study proposes a framework to utilize citizen science for research, it was limited in addressing the issue related to motivating and coordinating the participation of non-professionals in advancing conservation goals and in increasing the likelihood of culturally transmitted changes and improvements in environmental quality. Devictor, Whittaker and Beltrame (2010) examined how citizen science can be utilized to improve biogeographical studies and large scale conservation. The authors proposed a general framework which can be broken into phases: question, protocol, data, results, and education. They further proposed that the five success factors key to ensuring the framework is functioning vary in terms of simplicity, scheme, feedback, communication and sustainability. Figure 3.15 illustrates a general framework with essential key factors for using crowdsourcing for scientific activities.

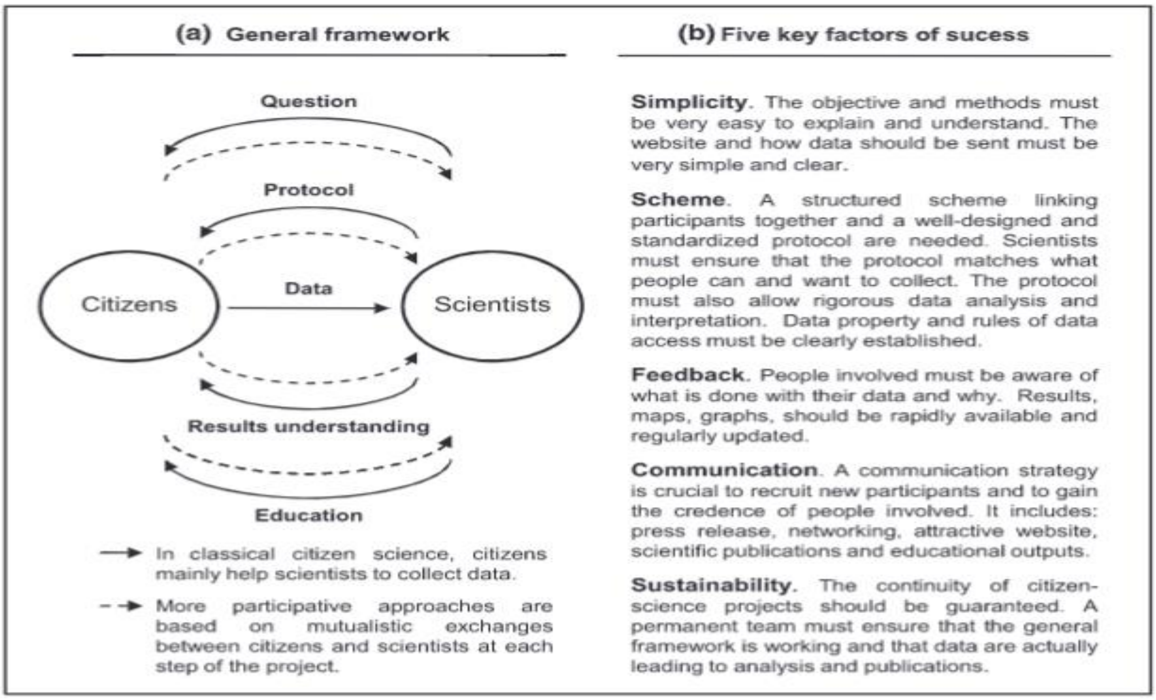

Figure 3.15. Proposed breakdown of the crowdsourcing process (Devictor, Whittaker & Beltrame, 2010)

The main contribution of this study was emphasizing that the strength of programmes lies in the curiosity and pleasure of the volunteers to learn and observe things. Crowdsourcing science is increasingly recognized as a better option compared to other top-down conservation approaches. The practical means to implement conservation strategies, however, is missing in the literature. Arvanitidis et al.'s (2011) study on the engagement of the broader community for biodiversity research proposed a design concept for divers and snorkelers and the implementation of citizen science. The key characteristics of the project varied from the development of a website, presence of a well-defined scientific hypothesis to be tested with the collection of data, species in focus, a suite of tools, collaboration with external agencies, and the exploration of new service tools to enhance the scuba diving services, mainly targeting the tourism industry. Figure 3.16 below illustrates the process and components of the project, which enable a better understanding of the process.

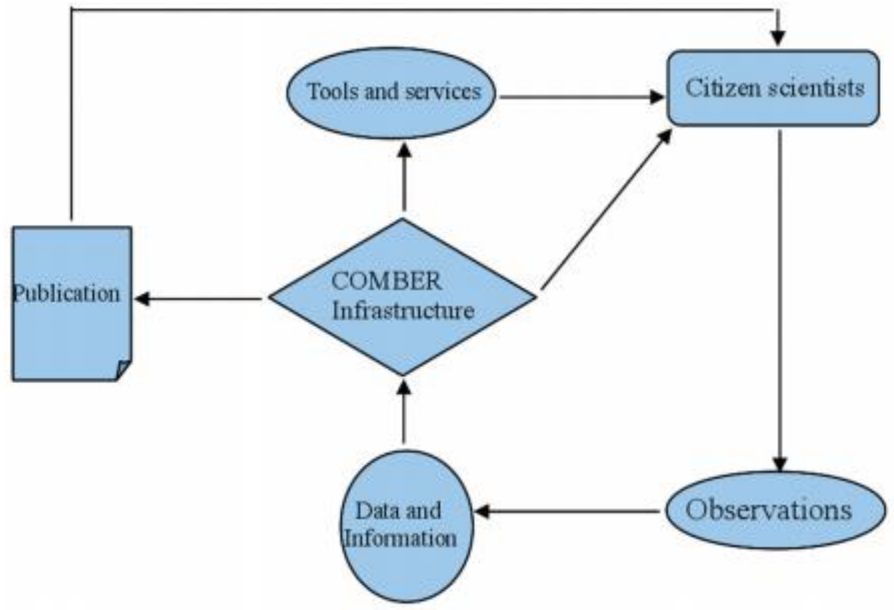

Figure 3.16. Proposed breakdown of the crowdsourcing process (Arvanitidis et al., 2011)

The last century has witnessed the emergence of projects that appear to drift away from traditional science approaches involving large members of the public to address real-world problems (Cohn, 2008). The interaction between these individuals and groups can be viewed as examples of the collective intelligence of decision-making and mass communication (Bücheler & Sieg, 2011). Opening of processes to not just experts, professionals and academics but also interested non-academics who are considered as citizen scientists has allowed for increased understanding of science in solving problems (Newman et al., 2012). Figure 3.17 below gives a simplified illustration of the scientific research process.

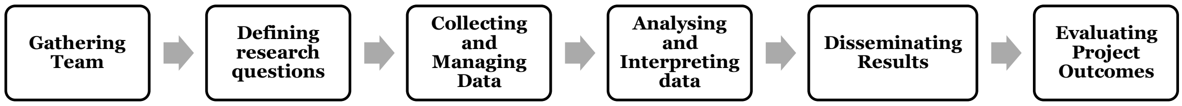

Figure 3.17. Proposed breakdown of the crowdsourcing process (Newman et al., 2012)

Haywood and Besley's (2014) study on the utility of science in society suggests it is mostly influenced by the structure, legitimacy and efficacy of the scientific research process. They reveal that, for scientists to primarily develop citizen science approach, they mostly should be guided by initiative goals and objectives with two major philosophies that separate projects, the public understanding philosophy that strives to increase public scientific knowledge, acceptance, and learning, as well as the public engaging in science to enhance the responsiveness, transparency and social legitimacy of science. According to Shirk et al.'s (2012) review on public participation and the case study approach, a design framework was developed with the aim towards outcomes such as scientific findings, participants acquiring new knowledge, and building community capacity for decision making and influencing policies. The authors proposed a framework which was based on the quality of participation and the management of interests from the crowd during the project. The degree of participation in terms of public participation varied from contractual, contributory, collaborative, co-created, to collegial projects. The authors proposed that the crowdsourcing process follows five key phases: inputs, activities, outputs, outcomes and impacts. This is illustrated in Figure 3.18 below.

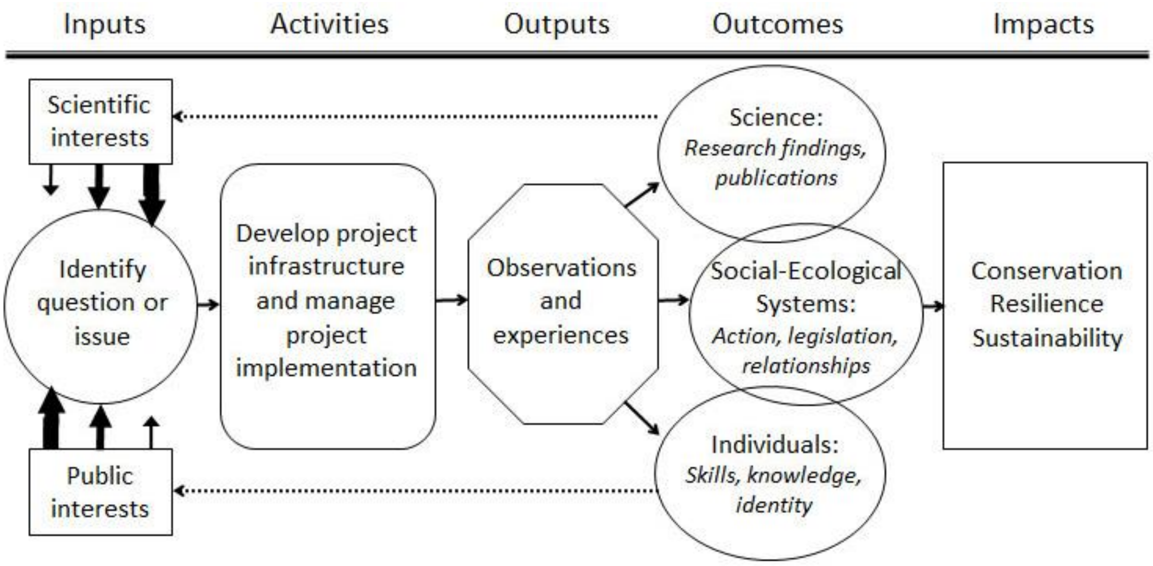

Figure 3.18. Proposed breakdown of the crowdsourcing process (Shirk et al., 2012)

Shirk et al. (2012) emphasizes project design to yield specific and measurable project outcomes requiring designers to keep the end of a project in mind. Although the proposed framework enables the understanding of the crowdsourcing science process, ensuring and maintaining participation levels during projects was not fully illustrated even though it was emphasized that certain degrees of participation are necessary to achieve desired outcomes. The framework also did not approach the aspect of ensuring data validity and reliability. Ferreira, Soares and Andrade's (2012) implementation of the citizen science approach towards beach profiling proposed the approach followed by four stages: 1) classroom explanation, 2) construction of profiling apparatus, 3) beach profiling, and 4) data processing and graphing.

Liu et al. (2014) proposed that to effectively and efficiently harness environmental data and knowledge to manage environmental issues, there is the need for a shift from a traditional one-way communication paradigm to a two-way communication model in which citizens become active in information capturing, evaluation and communication. The authors proposed a top-down and bottom-up approach which allows for a two-way data connection between researchers and citizen scientists, creating a medium for the exchange of information in two directions. It was also understood that these approaches should not be run individually, but rather in parallel with the necessity for technical capacity for facilitating an environment for citizen observation, collecting of data, communication, and visualization of the results to the broader community. Challenges still remain, however, with suggested considerations towards data quality, involving and maintaining broad participation, data interpretation, data privacy, security, and understanding citizen demographics to develop platforms that meet citizen needs. Kobori et al.'s (2016) examination of the citizen science approach within disciplines such as ecology, education, and conservation proposes an adaptive management approach which follows five key stages: situation (program context), inputs (resources needed), outputs (activities, events during projects), outcomes (changes expected, learning, impacts and benefits) and assumptions (guiding principles).

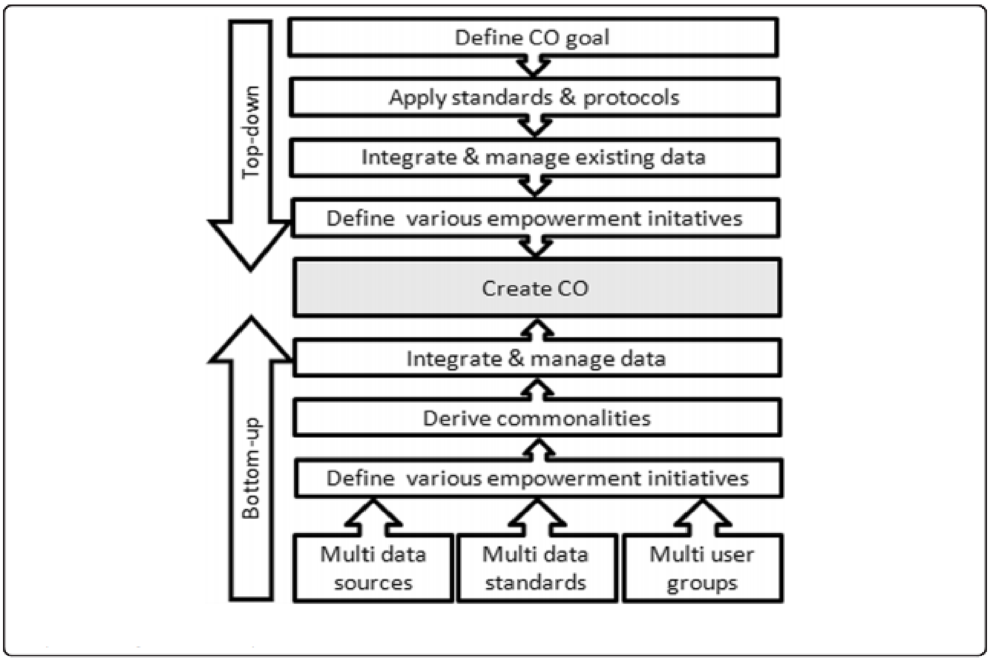

Figure 3.19. Proposed breakdown of the crowdsourcing process (Liu et al., 2014)

Another contribution to developing a citizen science framework was conducted by Ahern, Cilliers and Niemela (2014) by proposing an adaptive urban design planning framework. Similar to previous frameworks provided by previous authors, the contribution of this framework was the need to identify indicators and metrics to measure goals such as baseline conditions, and standard metrics for learning. Although this study was more focused on discipline examined (landscape and ecosystem), the need for standardized indicators and metrics which are understandable and transferable would allow for the exchange of knowledge and the efficient utilization of citizen science within various disciplines.

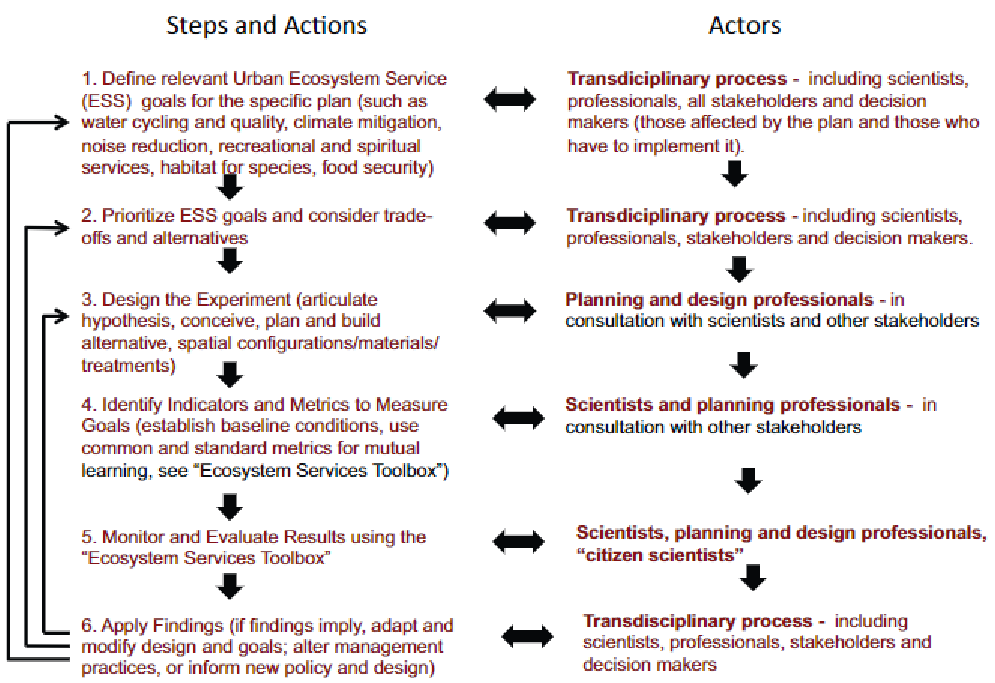

Figure 3.20. Proposed breakdown of the crowdsourcing process (Ahern, Cilliers, & Niemela, 2014)

Many professionals still demonstrate biases against the use of citizen science as a research tool due to issues pertaining to engagement, and measures of quality assurance, and quality control (Parrish et al., 2018). Parish et al. (2018) proposed that high-quality science can be achieved through the use of simple data collection procedures and quality control, which include algorithm voting, computational modelling, and statistical pruning. Through their framework illustrated in Figure 3.21 below, the authors emphasized that the citizen science approach follows a six-step process: design, development, delivery, data ingestion, post-processing, and publication.

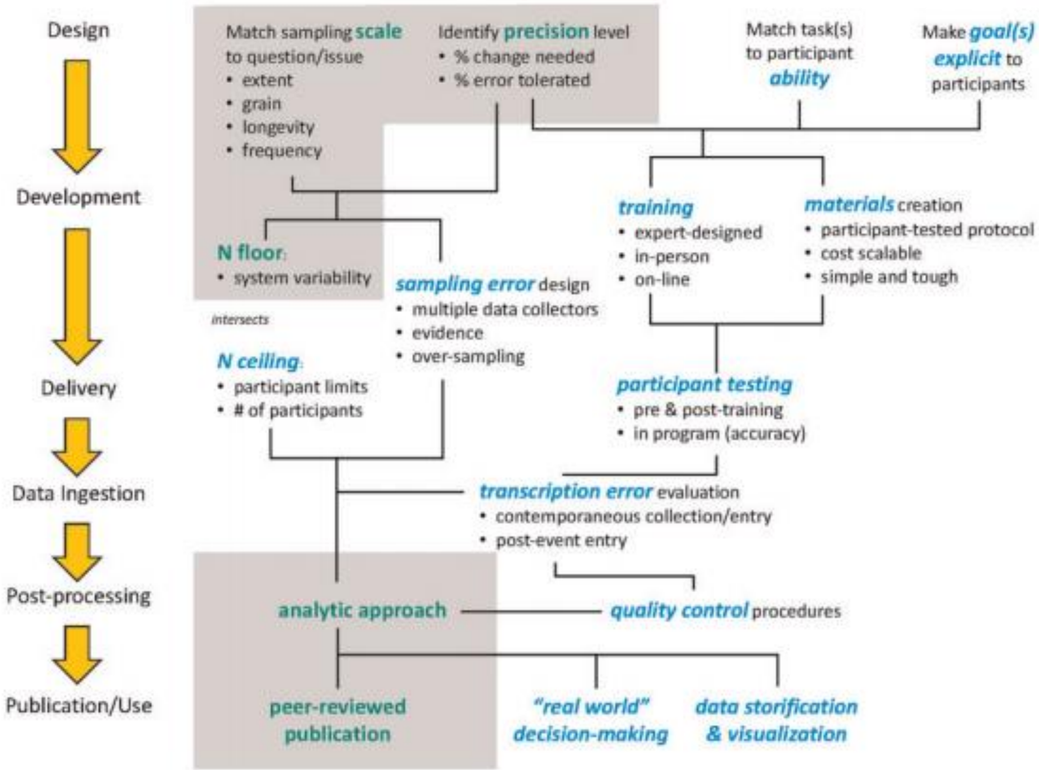

Figure 3.21. Proposed breakdown of the crowdsourcing process (Parrish et al., 2018)

The study provides insight into the application process of citizen science projects, but some limitations still prevail. Issues pertaining to participation and ensuring data quality are prevalent in the literature. The previously reviewed frameworks present attempts to provide approaches to apply citizen science to ensure suitability and convenience, however, there is still a need for developing frameworks that illustrate factors enabling or inhibiting tasks and citizen science components.

Although the use of citizen science as a scientific approach is accepted as being capable of offering substantial and noteworthy contributions, there is still a shortage of scholarly research that presents some challenges to the adoption in the scientific community. Flower et al. (2016) examined the application of citizen science in monitoring koalas and developed guidelines for a national citizen science data collection project which follows progressive stages, such as volunteer recruitment, implementation of standardized methods, and ensuring data quality and validation.

Recently, crowdsourcing science projects have been initiated within social science disciplines due to new technologies such as smartphones which have changed the practices of the nexus of people and made contributions more feasible in situations like uncovering new methods of data collection (Schneidewind et al., 2016; Heiss & Matthes, 2017). For example, in the citizen science project Young Adults' Political Experience Sampling (YAPES), school students were engaged in independent data collection using their smartphones (comments and pictures sent via e-mail or WhatsApp) (Heiss & Matthes, 2017). Based on their own daily experience, they followed the predefined research question concerning how young people get in touch with political issues in their everyday lives. The key objects of interest were the places (school, on the street, on social media, etc.), the channels (advertisement, media, political talk, etc.) and the content (the issues) of political youth communication in Austria. Whereas researchers hardly have access to this information and usually have to rely on either memory-based survey data or a small number of qualitative interviews, the citizen science approach allows for collecting large-scale, real experience data. Even though YAPES was designed as just a small pilot project, the participating 254 students collected a total of 1,768 observations. In this participatory research context, the young participants have evolved from a mere subject role to an active scientific role, as they actively screened and reported information about their political environment. Selected results were published on the project blog in order to provide the participating students with an outcome of their effort. YAPES, like other similar projects currently evolving in the social sciences, shows that there are spaces where citizens can add value to SSR by engaging in tasks that have traditionally been implemented by scientists. There are also, however, a number of practical challenges.

Citizen science approaches have been used to address some negative effects of human impact through projects focusing on river restoration and rubbish dumps of non-biodegradable polystyrene, which have enabled improvements in communication amongst groups, increased social networking, and archived large sets of data to make more informed decisions (Smith, Clifford & Mant, 2014; Korpela, 2012). The goal of most crowd science projects falls into one of these outcomes: research (findings), individual participants (acquiring new skills), and social-ecological systems (policy). The philosophy of engaging the crowd in scientific discourse and policy-making has witnessed the demand for a careful, voluntary and transparent recruitments mechanism to achieve targeted outcomes and reveal structured relationships (Shirk et al., 2012). Hinckson et al. (2017) described categories that can be considered when designing a citizen science project in relation to public health issues, and proposed four-levels of constructs, which are the individual level (demographic, advocacy skills, empowerment and civic engagement, personal efficacy, health behaviour), the interpersonal level (social norms and neighbourhood cohesion), the environmental level (urban, poverty, safety, weather and air quality, public transport), and policy level (process evaluation). The next section will cover crowdsourcing science literature as a tool that leverages the crowd to achieve outputs.

3.3.1 Leveraging the Crowd for Science

This section will cover the use of crowdsourcing as a tool with scientists realizing the benefits of utilizing this approach with science. The use of crowdsourcing across a broad range of research domains is considered relevant to today's conservation issues (Theobald et al., 2015; Shirk & Bonney, 2018). It has been applied to many heterogeneous projects, which are largely characterized by two main features, such as the open-wide base volunteers and problem-solving algorithms that are made openly available (Franzoni & Sauermann, 2014).

"Top-down citizen science instructs volunteers in standard scientific data collection techniques, thereby ensuring that the information is useful for research projects and government monitoring. These models are of use when looking to implement large-scale monitoring for the early detection of potential environmental issues, and are effective at generating long-term data sets which can then be assessed by scientific researchers while bottom-up approaches involve the volunteers in not just data collection, but also in providing feedback on the results of the project."

(Flower et al., 2016)

Evans et al.'s (2005) research project on the application of citizen science towards Neighborhood Nestwatch was primarily to improve the knowledge on avian ecology, collect data that can help researchers, and teach people living in the surrounding area about bird biology. Mckinley, Briggs, and Bartuska (2012) observed that citizen science can be of assistance in informing government policy and industry when the generation of scientific knowledge through peer-reviewed publications does not always satisfy the needs of managers and the public. Dickinson et al. (2010) examined the use of citizen science as a tool within ecological studies and emphasized not just the benefits of engaging with participants, but also its benefit to scientists. The authors proposed it offers observational monitoring over broad regions, which can be used for ground-truth remote sensing and spatial coverage, and can provide critical sampling for parameters such as weather, water table depth, herbivory, and soil moisture (Kueppers et al., 2007). Some of the highlighted reasons for implementing crowd science within biodiversity research were the high cost of professional monitoring, leading to unsustainable monitoring programs, and difficulty in monitoring due to logistics and technicality (Danielsen, Burgess & Balmford, 2005).

Through thoughtful study design and under the right circumstances, this approach to science has generated high-quality data that has led to trustworthy insights, innovations and valid scientific outcomes (Trumbull et al., 2000). Crowd science projects found on platforms such as Foldit and Zooniverse, amongst others, have taken advantage of the ease and the increasing number of virtual modes of contributions to advance scientific research (Silvertown, 2009). Citizen science relies on the cooperation between a range of experts and non-experts, which, in many cases, are interdisciplinary and involve some public engagement, education, and data collection, etc. A study by Paul et al. (2014) on the use of CS approaches has helped to reduce the underreporting of wildlife vehicle collisions along roads and to prioritize road sections where mitigation measures might be required.

A study by Theobald et al. (2015) on the authenticity of data collected using the citizen science approach within biodiversity research revealed a sense of value in utilizing this approach, but also mentioned the scientific impact could be much greater if it were embraced and better integrated into established modes of scientific research procedures. For it to be integrated and adopted, however, authors have proposed that it is essential to have the acknowledgement from the scientific world as a source of information with increasing awareness of and accessibility to data generated. Nevertheless, citizen science's usefulness has also been observed in making a contribution to marine legislation by providing a cost-effective way of obtaining and processing large amounts of data that are supportive in evidence-based policy-making (Hyder et al., 2015). Citizen science projects have been proposed to be divided into either sample collection or deriving the wisdom of the crowd (Predavec et al., 2016). Fauzi et al. (2016) examined the use of citizen science (with indigenous people) to examine tropical forest survival and growth by breaking down research into three main tasks whereby participants were expected to copy tree data from a tree inventory worksheet which led to participants tagging trees and recording tagged information. The purpose of breaking up tasks was to assess the ability of indigenous people to accurately insert data into mobile data collectors, and, furthermore, to assess the accuracy of the data collected.

The literature review shows the development of frameworks that elaborate on the process of crowdsourcing science activities. A few studies examine crowdsourcing science through case studies and theories (Shirk et al., 2012) or through comparing varying scientific disciplines (Kobori et al., 2016), with other studies focused on either specific science disciplines, technology, or participant perspectives (Liu et al., 2014; Evans et al., 2005; Fauzi et al., 2016), providing less generalizable knowledge. Furthermore, no study compares crowdsourcing activities (such as crowdsourcing science and innovation) to derive a general process of crowdsourcing. This study will attempt to examine crowdsourcing from two activities and across varying science disciplines based on a theory to elaborate on the components and activities, providing additional insights.

3.3.2 Evaluation Mechanisms of Crowd Data Collection

This section covers a group of studies on the methods and mechanisms utilized by scientists to understand how to ensure data quality is valid and reliable during science activities. Though there are many benefits to the use of crowdsourcing for science, issues in providing the quality of data collected can stem from insufficient guidelines during projects, lack of training, and from volunteer experience (Wiersma, 2010). Some authors have suggested ensuring user-supplied data is of a high standard, taking an individual expert verification approach, and using trust reputation models for screening volunteers (Hamel et al., 2009; Bishr & Mantelas, 2008). These mechanisms are said to have their limitations, due to the ever-increasing data sets produced during projects. According to Lukyanenko, Parsons, and Wiersma (2011), the proposed approach to combat data quality and validity issues is to implement attributed-based design data collection, not just involving the user's classification of observed species, but rather the attributes associated with observations. Hochachka et al.'s (2012) study examining the use of crowdsourcing within ecology proposed maintaining high standards by requiring the appropriate design of data input and management procedures, such as projects having customized quality control filters for data entry. Although the evaluation of data collected is usually conducted by professional scientists, the use of advanced statistical tools can complement the process (Bird et al., 2014).

Thiel et al. (2014) examined marine research and proposed steps such as providing training and support materials, ensuring the simplicity of tasks, and an abundance of assessment based procedures. According to Bordogna et al. (2016), the examination of evaluation procedures for volunteer geographic information projects revealed that procedures could fall under either ex-ante or ex-post strategies. Ex-ante strategies are applied prior to the start of projects to reduce the level of inaccuracy in data collected, whilst ex-post strategies are applied after data has been collected to cleanse and improve quality. Examples of ex-ante strategies are providing training and checklist games, the use of external knowledge, automatic error checking, usage of sensors, volunteer reputation, checks, and filtering by local moderators. Examples of ex-post strategies range from the ranking of volunteer contributions, use of data mining methods to identify outliers, enrichment and cross-referencing with administrative and trusted sources. Continuous data collection in large quantities requires the need for not just the presence of data collection protocols, but also protocols that are not complicated (Bonney et al., 2009). Rewards have also been suggested, such as monetary payments, but there has also been the integration of non-altruistic rewards in projects like Ebird, where the motivation for participants was the satisfaction of the data derived being used in scientific research. Maximizing the data process and information obtained, there needs to be a balance in protocol between data quality and data quantity (Hochachka et al., 2012).

The literature review generally reveals that lack of trust in data collected can hinder crowdsourcing science acceptance. Studies have focused on specific scientific disciplines such as marine research (Thiel et al., 2014), validation of water quality (Jollymore et al., 2017) and design approaches (Lukyanenko, Parsons & Wiersma, 2011). Overall, suggestions of accurate project designs that balance the needs of scientists and citizen can produce reliable and rich data (Shirk et al., 2012). Few studies exist on the evaluation procedures for ensuring crowdsourcing science data quality and examining a variety of science disciplines to derive a general approach. Clearly, Bordogna et al. (2016) propose evaluation approaches focused on volunteer geographic information, which is a type of crowdsourcing science activity. This proves less generalizable to crowdsourcing science as a whole. This study will, therefore, examine the steps and combination of evaluation mechanisms for crowdsourcing science data.

3.3.3 Success Factors for Crowdsourcing Science Activities

This section covers studies on the success factors that guide the use of crowdsourcing science. Success factors consist of varying elements ranging from performance indicators, public engagement, the capabilities and skills of professional scientists (Cox et al., 2015).

Gollan et al. (2010) utilized citizen science to monitor habitat restoration of spiders and assess biodiversity. Due to factors such as its cost-effective and easy-to-use nature, the progress of environmental assessment was achieved. In order for a citizen science project to be considered successful, it must be captivating to users, and keep them interested in the project. According to Chandler et al. (2012), there are four spheres of activities that lead to successful outcomes in citizen science programs which are said to be mutually reinforcing. These activities are generating and sharing of scientific knowledge, informing environmental policies and management plans, inspiring individuals and engaging key stakeholders. Morais, Santos and Raddick (2014) proposed that understanding the behaviour of citizen scientists and their interactions may assist in increasing involvement, providing better design interfaces, and allowing better planning. According to Tobin et al.'s (2014) study utilizing citizen scientists in monitoring the eradication of unwanted non-native organisms compiled of data from 672 eradication programs between 1890 and 2010. The authors proposed that metrics to determine the success included the detection method used, relative detectability of target species, and the infested area's size.

Using the lens of self-determination theory, the authors proposed that success factors for water quality and mobile crowdsensing for water management can be observed from three phases of projects—project formulation, the project's start, and during the project. The factors that composed the project formulation phase: define goals, define a time span, define measuring methods, define validation methods, and have insight in motivation. The start phase factors are offering training, defining a clear task, recruiting and establishing a community. During the project factors include providing feedback, retaining volunteers, and involvement during both data analysis and data collected (Minkman, Overloop, & Sanden, 2015; Rutten et al., 2017). Cox et al.'s (2015) literature review and quantitative examination of online citizen science projects on the Zooniverse platform proposed that projects can be considered successful based on two criteria: their high scientific impact and crowd engagement. Four key elements can be used as metrics, however, to score projects; these are the opportunity for learning, data value and dissemination, project design and resource allocation, participation and feedback. The authors called for more studies, however, considering the knowledge and training of scientists running projects like this can potentially influence project outcomes. Gharesifard and Wehn (2016) suggest that the success of citizen science approaches lies in not just the continuous involvement of volunteers but in strong relation to the sharing of data.

Cunha et al.'s (2017) investigation of citizen science's uses for environmental sciences in Brazil identified components essential for a project's success as being project proponents, funding resources, volunteer profiles, citizen scientist responsibilities, volunteer commitment, scientific methods, communication and engagement. It seems that determining the success of citizen science projects is multifactorial. Therefore, projects should be evaluated according to a project's specific criteria, such as the project's purpose, data produced, the knowledge required, and volunteers' engagement (Freitag & Pfeffer, 2013; Pocock et al., 2017). Pecl et al. (2019) performed a large scale citizen science project for ecological monitoring, and revealed the easy involvement of participants irrespective of training, quality feedback, the presence of high efficient workflows, or access to wireless technologies was influential for the successful implementation. Table 3.3 below gives an overview of the uncovered success factors for utilizing crowdsourcing science.

Based on the overview of studies, common factors such as participation, volunteers' engagement, and production of data are essential. However, there is no single study focused on the success factors in terms of the skills and capabilities required by the teams implementing crowdsourcing science. Researchers have examined success using theoretical and methodological approaches, including self-determination theory (Minkman, Overloop, & Sanden, 2015; Rutten et al., 2017), quantitative study (Cox et al., 2015), bibliographic and comparative analysis of projects in Brazil (Cunha et al., 2017). Furthermore, studies fail to either examine crowdsourcing science from a variety of scientific disciplines or to compare crowdsourcing activities to uncover the seekers' required skills and capabilities for crowdsourcing success. Accordingly, this study aims to identify the success factors in terms of the skills and capabilities of management teams (Cox et al., 2015).

Table 3.3: Overview of Success Factors for Crowdsourcing Science Activities

Success Factors	Authors
• Cost-effective nature • Easy-to-use nature	Gollan et al. (2010)
• High scientific impact of the project • Crowd engagement	Cox et al. (2015)
Project formulation phase: • define goals • define time span • define measuring methods • define validation methods • motivation insights Start phase: • offer training • define a clear task • recruiting and establishing a community Factors during the project: • providing feedback • retaining volunteers	Minkman, Overloop & Sanden (2015), Rutten et al. (2017)

• volunteer involvement during data collection and analysis	
• Involvement of volunteers • Sharing of data	Gharesifard & Wehn (2016)
• Alignment of the goals of projects with local priorities, participants, and researchers • Engagement and commitment of participants • Availability of quality control scientific methods • Investment in training and continuous learning	Cunha et al. (2017)
• Easy involvement of participants irrespective of training • Quality feedback • Presence of highly efficient workflows • Access to wireless technologies	Pecl et al. (2019)

3.3.4 Enablers and Barriers for Crowdsourcing Science

This section will discuss the group of studies in relation to the uncovered barriers and enablers for the effective use of crowdsourcing science. With emphasis from a scientific perspective to integrate such practices, the following literature is examined below. Crowdsourcing science barriers are factors that have a negative influence on the use and likelihood of it being beneficial. Enablers, on the other hand, are factors that have a positive influence on its utilization. Studies have examined related mechanisms with varying perspectives and degrees of focus, such as developing informal learning, deriving benefits, and developing participant capabilities (Schnoebelen & Kuperman, 2010; Arts, Wal & Adams, 2015; Garbarino & Mason, 2016; Shuker et al., 2017; Wechsler, 2014; Hesley et al, 2017).

These approaches range from surveys, case study, qualitative, quantitative, comparative study focusing on related mechanisms such as citizen science, crowdsourced geographic information, collective intelligence as well as specific scientific disciplines such as conventional river management, animal and plant phenology projects, advancing toponym practices, monitoring and appraisal of habitat changes in rivers, biodiversity research, marine research projects, improving elderly involvement, quantifying pollination in gardens, conserving seasonal wetlands, wildlife monitoring, health and environmental studies, digitization of natural history collections and the transcription of biological records and so on (Sendzimir et al., 2008; Feldman, Zemaite & Rushing, 2018; Alexander et al., 2019; Shuker et al., 2017; Perdana & Ostermann, 2018; Hoover, 2016; Burgess et al., 2017; Schläppy et al., 2017; Jansujwicz, Calhoun & Lilieholm, 2013; Kopeć et al., 2017; Birkin & Goulson, 2015; Hobbs & White, 2012; Arts, Wal & Adams, 2015). Only recently have studies started attempting to identify and unify the factors based on a theoretical lens or managerial perspective (Tiago et al., 2017; Turrini et al., 2018; Perdana & Ostermann, 2018; Pocock et al., 2019).

Tiago et al. (2017) performed a study using the self-determination theory, looking into motivational factors that influenced participation and arrived at seven motivational categories: interest/enjoyment, perceived competence, perceived choice, value/usefulness, project relatedness, group relatedness and effort/importance. The incorporation of project design experiences of positive feedback and capacity building would also foster long-term participation. The philosophy for public understanding strives to increase public science knowledge, acceptance, and learning, whereas the focus on public engagement in science is to enhance the responsiveness, transparency, and social legitimacy of science. Turrini et al.'s (2018) study examined the aims of managers of projects and revealed three specific drives are generating new knowledge, enabling civic participation, enhancing awareness and facilitating in-depth learning. Through the use of a quantitative web-based survey with 143 experts from environmental and educational sectors in Germany, Austria and Switzerland, they were further able to find out that enabling civic participation was of least importance when compared to other drivers. The authors revealed that the sample size had a positive view on the approach. Challenges are evident, such as the lack of long term funding, insufficient access to scientific publications, lack of staff capacity, lack of time, insufficient skill sets to produce scientific papers, low recognition by the professional science community and unawareness of tools.

Perdana and Ostermann (2018) addressed the issues in advancing toponym practices present in emerging approaches such as crowdsourced geographic information and citizen science. By examining such practices, a framework was proposed. It cannot be said these issues are either specific or are faced in general by all professional scientists, but the category of problems range from legal aspects, organizational issues, funding, procedures, personnel, accessibility and data output. Figure 3.22 below illustrates these problems. The case study in Indonesia broke down the application of citizen science towards toponymic survey projects into five steps: preparation (planning, preliminary survey, data preparation), fieldwork (recording toponyms, interviews with local people), office treatment (data entry and data compilation), verification (review of place names and approval), and data publication (create gazetteer and publish). Figure 3.22 illustrates the proposed categories identified but with no theoretical base.

Category	Main Problems and Open Issues
Legal aspect	• Licensing, data ownership, and copyright • Data privacy and liability issues
Organizational issues	• The absence of a national naming authority • Coordination between public agencies • Collaboration with non-government sectors • Conflict resolution (potential for conflicts)
Funding	• No dedicated funding • Limited budgeting at local government
Procedures	• Inadequate regulatory procedures for the systematic approval and recording of place names • Insufficient training materials and guidelines on toponym collection • Long procedure, from collection until dissemination, of gazetteers
Personnel	• Limited human resources • Lack of trained staff • Language problems in interviews
Accessibility	• Insufficient transport infrastructure • Limited broadband and Internet services • Poor or bad weather conditions
Data Availability (Output)	• Incomplete place name database • Data uniformity issues (database structure and format file) • Duplicate places • Incorrect type of feature classes • Syntactic (data) integration (history of toponym records) • Semantic integration (meaning of places) • Spatial footprints (point-based location, bounding box (extent of features), and representation of vague places)

Figure 3.22. Proposed category of factors influencing the crowdsourcing science process (Perdana & Ostermann, 2018)

According to Pocock et al.'s (2019) study examining the use of citizen science in East Africa, the list of existing barriers to its use varies from categories such as institutional, participants and structural challenges. The barriers faced include unawareness of opportunities, limited organizational capacity, leadership and planning, lack of interest of participants, lack of skill participants, inadequate funding, limited incentives, lack of appreciation of citizen science from decision-makers, data and information not fitting the purpose, inaccessibility to sites, and limited collaboration.

The literature on crowdsourcing science identifies a wide range of barriers, such as unawareness of tools, lack of funding, lack of skilled and interested participants, inappropriate technologies, etc. Table 3.4 gives a breakdown of the identified barriers thus far.

Table 3.4: Breakdown of Barriers during Science Activities

Barriers	**Authors**
Low recognition and perception from the scientific community	Sendzimir et al. (2008); Pocock et al. (2019); Turrini et al. (2018); Tulloch et al. (2013); Shuker et al. (2017); Jansujwicz, Calhoun, & Lilieholm (2013); Ottinger, (2010)
Lack of leadership	Sendzimir et al. (2008); Pocock et al. (2019)
Unwillingness to change	Sendzimir et al. (2008); Buckland, Castleden & Conrad (2016)
Lack of training and expertise of non-professionals	Feldman, Zemaite & Rushing (2018); Wiersma, (2010); Weathers et al. (2016); Pocock et al. (2019); Lewandowski & Specht (2015); Cohn (2008); Dickinson et al., (2010); Conrad & Hilchey, (2011); Bonter & Cooper (2012); Resnik, Elliot & Miller (2015); Garbarino & Mason, (2016); Hoover (2016), Worthington et al. (2012); Krasny & Bonney, (2005); Dickinson et al., (2012); Bates et al. (2015) Nicosia et al. (2014); Williams et al., (2015)
The awareness of professional scientists	Pocock et al. (2019); Burgess et al. (2017); Alexander et al.(2019); Hobbs & White (2012); Santangeli et al. (2016)
Inaccessibility to sites and information	Pocock et al. (2019); Sendzimir et al. (2008); Weathers et al. (2016); Perdana & Ostermann (2018); Conrad & Hilchey (2011); Turrini et al. (2018); Jansujwicz, Calhoun, & Lilieholm (2013); Nicosia et al. (2014); Hobbs & White (2012)
Limited organizational capacity and incentives	Pocock et al. (2019); Buckland, Castleden, & Conrad (2016)
High costs and inadequate funding	Pocock et al. (2019); Alexander et al. (2019); Perdana & Ostermann (2018); Turrini et al.'s (2018); Weathers et al. (2016); Conrad & Hilchey (2011); Schläppy et al. (2017); Hoover, 2016); Minkman, Overloop & Sanden (2015); Higgins & Shackleton (2015); Hobbs & White (2012)
Presence of language barriers	Alexander et al. (2019)
Legal issues	Perdana & Ostermann (2018)
Organizational issues	Perdana & Ostermann (2018); Conrad & Hilchey (2011)
Communication of results	Perdana & Ostermann (2018); Hoover (2016); Resnik, Elliot & Miller (2015)
Procedures and transition problems	Perdana & Ostermann (2018), Sendzimir et al. (2008); Worthington et al. (2012); Krasny & Bonney, (2005); Dickinson et al., (2012)
Distrust in data quality	Armstrong et al. (2012); Wiersma, (2010); Pocock et al. (2019); Hoover (2016); Schläppy et al. (2017); Conrad & Hilchey (2011); Burgess et al. (2017); Garbarino & Mason, (2016); Hoover (2016); Bird et al. (2014); Hobbs & White (2012)
Inappropriate quality control measures	Buckland, Castleden & Conrad (2016); Conrad & Hilchey (2011); Armstrong et al. (2012); Rose et

	al. (2016); Hoover (2016); Schläppy et al. (2017); Lewandowski & Specht (2015); Cohn, (2008); Dickinson et al., (2010); Bonter & Cooper, (2012); Burgess et al. (2017); Resnik, Elliot & Miller (2015); Worthington et al. (2012); Krasny & Bonney, (2005); Dickinson et al., (2012); Goodchild et al. (2012)
Inappropriate technologies	Fauzi et al. (2016); Minkman, Overloop & Sanden (2015); Heiss and Matthes (2017); Kopeć et al. (2017) Newman et al. (2012); Arts, Wal & Adams (2015)
Lack of time to complete projects	Turrini et al. (2018); Alexander et al. (2019); Hoover (2016)
Lack of staff capacity	Perdana & Ostermann (2018); Turrini et al. (2018); Higgins & Shackleton (2015); Goodchild et al. (2012)
Level of participation and engagement	Pocock et al. (2019); Conrad & Hilchey (2011); Hoover (2016); Schläppy et al. (2017); Wiersma, (2010); Birkin & Goulson (2015); Lewandowski & Specht (2015); Cox et al., (2015); Cohn (2008); Dickinson et al., (2010); Conrad & Hilchey (2011); Bonter & Cooper (2012); Johnson et al. (2014); Heiss and Matthes (2017); Danielsen et al. (2014); Wechsler (2014); Worthington et al. (2012); Krasny & Bonney, (2005); Hobbs & White (2012)

Based on previous studies, extensive research on the factors that influence utilizing crowdsourcing approaches prevail with the use of theoretical approaches such as self-determination theory (Tiago et al., 2017), as well as studies focusing on specific scientific disciplines, such as conventional river management (Sendzimir et al., 2008), toponym practices (Perdana & Ostermann, 2018), monitoring wild species (Worthington et al., 2012), local degraded watershed (Nicosia et al., 2014), garden pollination (Birkin & Goulson, 2015), ecology (Weathers et al., 2016) and biodiversity (Burgess et al., 2017). Many studies exist examining the barriers for a participant, as well as for specific science disciplines, using quantitative approaches, but few studies focus on the organization perspective (Hoover, 2016; Turrini et al., 2018; Pocock et al., 2019). Hoover (2016) examined the effect of the large-scale environmental community collaboration project, and found the amount of time assumed for each task by each party, the giving up control of data by scientists with the communication of results to participants, and distrust in the use of the data.

Turrini et al.'s (2018) quantitative, web-based survey with 143 experts revealed that extrinsic barriers were higher than other barriers with the main ones being the shortage of financial/staff resources, time constraints, insecurity finding collaborators, doubt about target group skills, and the lack of personal autonomy. Pocock et al.'s (2019) collaborative prioritisation approach and workshop with 22 experts revealed that the barriers faced can vary from accessibility to sites, limited organizational capacity, issues with leadership and planning, lack of interest or skilled participants, inadequate funding, limited incentives, lack of appreciation of citizen science by decision-makers, collection of data not fit for the purpose, limited collaboration and unawareness of opportunities. Furthermore, only one study was found to have utilized a theory to uncover the contextual determinants, enablers, and barriers but from a crowd perspective (Tiago et al., 2017).

With a majority of studies attempting to do so by focusing on a particular scientific discipline, these findings may not be generalizable to crowdsourcing science as a whole. Given the rise in investments in crowdsourcing science, this study would integrate a qualitative approach based on a unifying theory to examine organizations' use from a variety of scientific disciplines. The next section will examine the integration of crowdsourcing activities (science and innovation) to arrive at fruitful outcomes during the innovation process.

3.4 Integration of Crowdsourcing Activities during the Innovation Process

This section provides an overview of studies that examine the integration of crowdsourcing science by proposing that knowledge discovery can be utilized in the development, and application of democratic knowledge for improvement in policy, thereby leading to the commercialization of innovations.

Transformation driven by the development of information communication and game-changing production technologies (IT) has contributed to the patterns of openness and has decentralized types of value creation (Schildhauer & Voss, 2014). The concept of openness can be envisioned in the form of open knowledge (García-Peñalvo, De Figuerola & Merlo, 2010) with a framework that encompasses components such as open resources (accessible resources), open processes (participatory processes) and opening effects (democratizing effects) (Schlagwein et al., 2017). Openness is embedded in IT. This transparency of action encourages the inclusiveness of participation, as well as the permeability of organizational structures to utilize open resources that have opening effects—such as open science or open business (Schlagwein et al., 2017). The use of open processes has not effectively transformed science for innovative outcomes; hence, it is not yet considered a straightforward endeavour (Chesbrough, 2015).

According to Redlich et al. (2015), the shift from traditional industrial production towards bottom-up economics will lead to new business models and thinking beyond the boundaries of organizations. The authors argue that openness as a way of thinking enables firms to stay viable and efficient for their customers. Examining studies on crowdsourcing, however, there is a possibility that crowdsourcing science outcomes can have a wider impact than just knowledge discovery; it also impacts the development of commercial innovation, as well as serving as a means of encouraging dialogue, and shaping the formulation of policies (Chesbrough, 2015; Ballard et al., 2017; Nascimento et al., 2018; Hecker et al., 2018). There also seems to be a growing interest in scientists wanting to see their research outcomes making a change in the world (Parcak, 2015). However, this would depend on the shift from a science-centric perception clouding the view of crowdsourcing science (Vann-Sander, Clifton & Harvey, 2016). There is a relative lack of integration of outputs, such as creative designs and scientific data (Lakhani & Panetta, 2007; Flückiger & Seth, 2016). According to Kieslinger et al.'s (2018) study evaluating crowdsourcing as a concept in science, the outcome of projects should be societal, ecological, and of a wider innovative potential. The expectations of crowdsourcing science follow various aims such as promoting scientific education, reaching out to groups, producing higher scientific outputs and so on (DITOS & WeObserve, 2019). The wider innovative potential should be towards achieving sustainability goals, as well as fostering new technologies and societal transformation. The literature shows the promise of innovations that have emerged from implementing crowdsourcing science (Hochachka et al., 2012; Tinati et al., 2015; Shirk & Bonney, 2018).

Outcomes in research projects do not always lead to commercial value, or, if they do, they tend to take a long period of time due to difficulties faced (Chesbrough, 2015; Bartumeus, Oltra & Palmer, 2018). The lack of science commercialization might be due to the research disciplines (Blackwell et al., 2009). The success of these inventions would be dependent on their adoption by stakeholders such as governments, citizens, academia and industries as active subjects of the innovation process (Bartumeus, Oltra & Palmer, 2018). According to a study by Williams et al. (2018), the reuse of data from crowdsourcing science projects can be ensured through open data, open standards, and the contextualization of data with metadata. Contextualization could include a description of the method of dataset creation, which would allow users to evaluate possible reuse. Questions still remain about how meaningful it is to engage the crowd in abstract ideas which could bring emerging technologies to life (Smallman, 2016), due to the need for more improved evidence, participation, and knowledge as a legitimate base for making decisions.

According to Bücheler and Sieg's (2011) study on the applicability of crowdsourcing science suggests it may lead to significant changes to how research tasks are conducted. They propose that basic science has become a collective intelligence effort but question how science can foster the sharing of ideas and data, which still remain unclear. The authors suggest publishing results and securing IP or patents, which could both aid in acquiring value from science whilst maintaining the necessary quality levels. Science, in one part, is stored knowledge about a phenomenon (basic science), and the shift from basic science knowledge to R & D application requires the technical application of knowledge to achieve innovation (Lim, 2004; Trott, 2017). Innovation opportunities have historically only been available to a minority. Integrating science and innovation within crowdsourcing can open the process to participants, fostering democratized innovation, making the process more inclusive, as well as, providing learning opportunities, enhanced scientific capital and progressing societies (Hecker et al., 2018).

By integrating crowdsourcing science data into big data solutions, inventions can become full-scale innovations that add value (Bartumeus, Oltra & Palmer, 2018). These forms of doing science do not mean abandoning the strict procedures that scientists perform in ensuring research is high quality (Shirk & Bonney, 2018). To ensure the wider impact of outcomes, a focus on evaluation methods should be emphasized (ECSA, 2015). Another avenue for success would be to develop competencies that enable the use of the crowd during open activities (Du Chatenier, 2009; Podmetina et al., 2018). Studies on user-led innovation tend to reveal substantial new product innovations (Stodden, 2010). The involvement of users can play a critical role in long-term planning and in ensuring successful business and national development, as this would enable anybody to experiment and exploit their creative potential developing novel solutions that maximize both social and personal use value (Von Hippel, 2009). According to Saritas (2016), the inclusion and participation of various stakeholders in science, technology, and innovation activities can provide value for collective learning and visioning.

The literature review highlights that the majority of studies separately investigate crowdsourcing science (Evans et al., 2005; Weckel et al., 2010; Mckinley, Briggs & Bartuska, 2012; Ferreira, Soares & Andrade, 2012; Mackenzie & Cox, 2013) and innovation activities (Ebner, Leimeister & Krcmar, 2009; Mack & Landau, 2015; Palacios et al., 2016). Studies exist that integrate emerging mechanisms such as open-source software or more broadly when opening the innovation process (open innovation) (Chesbrough, 2015; Stodden, 2010; Athey & Ellison, 2014; Årdal & Røttingen, 2012), but there are no studies that integrate more than one crowdsourcing activity during the innovation process or how organizations can manage this integration. The integration of crowdsourcing science and innovation during the innovation process can provide a promising avenue for research (Smart et al., 2019). Smart et al. (2019) propose that the success of open-source software usage can provide clues on how the coupling of both crowdsourcing science and innovation can be linked. Although removing traditional constraints to advance the agenda of openness in a post-truth age may have both positive and negative effects (Nerlich et al., 2018). Due to the possibility of both effects, commercialization mechanisms (such as research partnerships, technology transfer, managed patenting, and intellectual property can enable the linking of science to innovation (Bücheler & Sieg, 2011; Perkmann & West, 2014; Fini et al., 2018). Clearly, science's commercialization can be transformed into innovations, but the management of such a process is not entirely clear, as many do not lead to commercial value, or, if they do, they tend to take a long period of time due to the difficulties faced (Chesbrough, 2015; Bartumeus, Oltra & Palmer, 2018). Thus, with the gap in the literature, this study examines the integration of crowdsourcing activities (science and innovation) within the innovation process in transforming science to innovation. This is important to organizations with the drive towards inclusivity and open boundaries.

3.5 Assessing the Crowdsourcing Field

The review of previous literature presents some gaps which this study is intended to fill. Although there is an abundance of studies on the field which have provided major contributions to understanding the phenomenon better, gaps still exist.

3.5.1 Analysis of Crowdsourcing Literature

Firstly, the diversity in crowdsourcing literature requires careful investigation, as there is a need to better understand the boundaries of crowdsourcing research as well as examine, quantify, identify trends, visualize the main domains and sub-domains. Although valuable knowledge has been contributed to the field by past research, additional analysis of the literature using objective metric tools and network analysis can provide insights that are not understood. The lack of a literature review based on word metrics makes it difficult for scholars to accurately assess the state-of-the-art crowdsourcing research due to its multidisciplinary nature.

The merits and most significant reason for using this approach are to fathom the features of a scientific discipline. The most common methods and techniques used are bibliometrics, scientometrics and informetrics. The earliest metric field used for the statistical and mathematical analysis of books and topical areas is bibliometrics (Ertz & Leblanc-Proulx, 2018). Recently Malik, Aftab and Ali (2019) examined the crowdsourcing field using bibliometric analysis on publications to uncover findings related to the varying document types, prolific journals, leading countries and leading authors. Scientometric analysis, on the other hand, is the second most used metric method for the analysis of past, present and future scientific developments of a field. This form of analysis is a quantitative method of science mapping utilized to analyse existing intellectual core and landscape of a research field (Darko et al., 2019).

Relevant studies in innovation literature propose interesting scientometric analysis. Authors have examined fields such as Su and Lee (2012) (global open innovation), Chatterjee and Sahasranamam (2014) (Innovation management in India), Appio et al. (2016) (social media innovation), Kullenberg and Kasperowski (2016) (citizen science), Kovács et al. (2015) (open innovation) to cluster respective fields, reveal trends and identify real-time hot topics in a pictorial format. Due to the limitations of previous crowdsourcing reviews, which do not consider an inclusive picture of the crowdsourcing research field and understand the trends, this study attempts to address and provide a scientometric analysis of the crowdsourcing field. The use of scientometric analysis in this study will provide a systematic and comprehensive picture of the crowdsourcing field by mapping the field into its domains, sub-domains and application areas. Focusing on the linkages, mechanisms and the degree of specialization in sectors, countries and subject groups, this examination provides a base for further research on the broader development of the crowdsourcing concept. This focus would fill a gap in the literature by addressing the following research objectives: identify crowdsourcing's main clusters and visualize the network of research; examine the link between research domains and sub-domains; examine crowdsourcing tasks within clusters; and build a framework that illustrates the emerging domains and sub-domains within the crowdsourcing field. Figure 3.23 below illustrates the process followed to assist in achieving the objectives of this thesis.

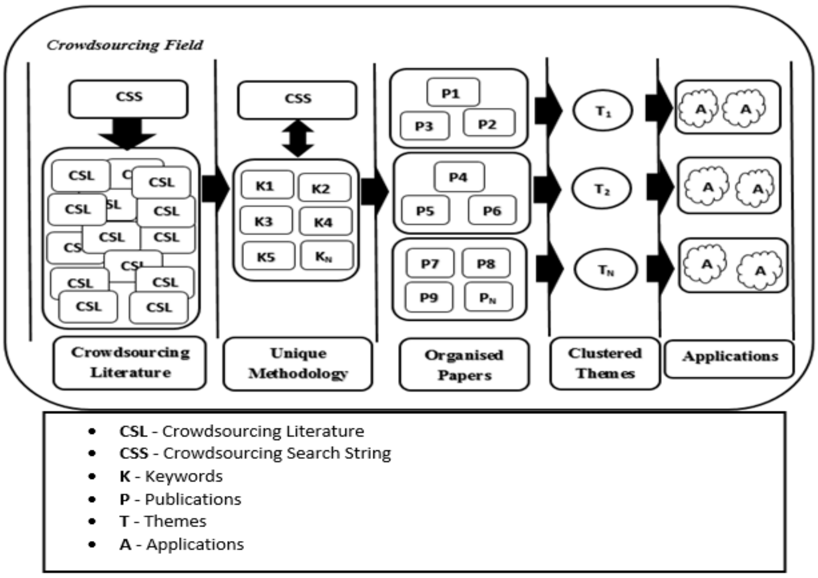

Figure 3.23. The conceptual framework for deriving themes and crowdsourcing applications (Kovács et al., 2015; Ozcan & Islam, 2017)

3.5.2 Context of Enabling and Inhibiting Factors

Secondly, the adoption and integration of innovation are said to occur when organizations invest in and use said innovation. For this to be achieved, certain factors can either hinder or support this process. The importance of this study is due to the fact that crowdsourcing is viewed by organizations as an innovation just for experimental purposes (Zhao & Zhu, 2014). The literature reveals that, in the coming years, crowdsourcing will be a more active and dynamic area of research. Although a variety of articles have proposed benefits of its use, the key factors that facilitate and hinder the organization utilization of crowdsourcing, in general, are still lacking.

Crowdsourcing is considered an IT-mediated technology and innovation; hence, this study examines similar literature to uncover suggestive factors that are expected to influence the use of crowdsourcing. According to Wolfe (1994), “the determinants of the adoption of innovations differ as the features of the innovation differ.” It is said that fostering the use and integration of an innovation can be an extremely frustrating process with a wide variety of factors—such as organizational issues, social, cultural, technical, and economical characteristics of the innovation— that can support or inhibit the integration of said innovation (Surry et al., 2010). Different researchers have conducted some related studies in fields such as open-source software, open-source systems, and information communication technology. There are limited studies, however, on the use and integration of crowdsourcing. Since open innovation and open-source software can be considered related to crowdsourcing (Schenk & Guittard, 2009), these studies may also be relevant to examine the adoption and integration of crowdsourcing by organizations.

According to Macredie and Mijinyawa's (2011) study on the adoption of open source by SME's, certain factorial constructs emerge. Constructs such as relative advantage (license cost savings), complexity (lack of drivers), compatibility (functionality), peer influences (supporting community), superior influences (web media), self-efficacy (innovativeness), resource facilitating conditions (capital investment) and technology facilitating conditions (internet infrastructure) were said to have an influence on the intention and actual use of open-source software (OSS). Van Belle and Reed (2012) examined the adoption of the OSS platform in South Africa using the TOE framework, and revealed that technology factors such as access to source code, cost, compatibility, triability, reliability, and maturity had an influence on its adoption. For an organizational context, such as a firm, the centrality of IT, open-source attitudes, standard attitudes, and boundary spanners were related factors. The environmental context included factors such as vendor support, OSS support, firm size, and technology skills, playing a role in its adoption. Tome et al. (2014) examined the barriers of OSS ERP adoption using a TOE framework, and proposed that major technology-related barriers are sunk costs, reliability, compatibility in terms of employee skills, and lack of technical knowledge. In terms of an organizational context, IT staff time, innovativeness of the organization, and work experience with new platforms were all related to potential barriers. In terms of an environmental context, the infrastructure was a barrier with the availability of IT workers and the availability of external support services also appearing to be potential barriers. Louis (2013) observed the implementation of crowdsourcing platforms in government, and revealed influential factors in categories ranging from individual, to project, to organization. The organization-level included an organization's commitment, alignment with the mission and goals of the organization, bureaucracy, and red tape. The project level is composed of the type of task, and the usefulness of intermediaries. The individual level is related to employee attitudes, and employees' perception of benefits. Sharma (2010) conducted a study on the critical success factors to harnessing collective intelligence; this study revealed factors such as vision, strategy, human capital, infrastructure, linkages, trust, external environment, and motive alignment of the crowd—all critical factors of success. Yang and Lee (2019) investigated the factors that inhibit or enable start-ups from adopting crowdfunding in China using a two-factor theory. The key enabling factors are related to relative advantage, compatibility, and visibility, results in demonstrability, whilst inhibitors are related to operational cost, complexity, reputational risk, and information disclosure. To assist with having a deeper understanding of what enables and restricts an organization's use. Table 3.5 below reveals similar studies related to this study.

Table 3.5: Similar Studies on Enabling and Inhibiting Factors

Authors	**Topic**	**Determinants and Factors**
Gonçalves, Mendes, & Oliveira (2017)	Enablers and inhibitors of servitization: a case study in the Brazilian road transport	Technology: mitigation of accident risks due to on-time monitoring (enabler), high development costs (inhibitor). Organization: workforce focused on core actions (enabler), lack of servitization skills (inhibitor) and Environment (pioneer in the offer of the business model), low market demand for servitization (inhibitor)
Ali (2018)	The Barriers and Enablers of the Educational Cloud: A Doctoral Student Perspective	Enablers (relative advantage, cost efficiency, compatibility, collaboration, scalability, flexibility and mobility). Barriers (complexity, security, cultural resistance)
Carmel (2003)	The new software exporting nations: success factors	1) Government vision and policies 2) Human capital 3) Wages 4) Quality of life 5) Linkages 6) Technological infrastructure 7) Capital 8) Industry characteristics
Chauhan et al. (2018)	Determinants of adoption for open-source office applications: A plural investigation	Technological context (software cost, reliability, strategic flexibility, the usefulness of open code, availability, complexity, triability, compatibility), Organizational context (technology competence and organizational innovativeness), Environmental context (service quality) and control variable (organization size)
Eze et al. (2013)	Determinant factors of information communication technology (ICT) adoption by government-owned universities in Nigeria: A qualitative approach	Technology (electricity supply, expert skills, internet connectivity, obsolete technologies, technology support), Institution (embezzlement, institutional support and willingness to adopt, size, incentives), Environment(funding, requirements for adoption, legal protection and tax Laws)
Tome et al. (2014)	Barriers to open source ERP adoption in South Africa	Technology (sunk costs, reliability, compatibility or employee skill levels, lack of technical knowledge) Organisation (IT staff time, innovativeness and worker experience with platform) Environment (availability of skilled IT workers, availability of external support services)

Heeks & Nicholson (2004)	Software export success factors and strategies in 'follower' nations	Demand (national vision and strategy, international linkages, software industry characteristics) Supply Factors Infrastructure (people, technology, finance, research and development)
Macredie & Mijinyawa (2011)	A theory-grounded framework of Open Source Software adoption in SMEs	Constructs: relative advantage, complexity, compatibility, peer influences, superior influences, self-efficacy, resource facilitating conditions, technology facilitating conditions
Mergel (2018)	Open Innovation in the public sector: drivers and barriers for the adoption of Challenge.gov	Inter-organizational (legal barriers, technological barriers designing crowdsourcing processes, cultural factors), institutionalization, inter-organizational and extra societal organizational barriers
Molero et al. (2019)	Key factors for the implementation and integration of innovative ICT solutions in SMEs and large companies	Operational area barriers, Psychological area barriers, Environmental area barriers, Technology area barriers, Corporate social responsibility area barriers, Maintainable area barriers, Economic cost area barriers.
Radu (2016)	Determinants of green ICT adoption in organizations: a theoretical perspective	Economic (Competitiveness, Pro-environment grants, company characteristics, entrepreneur's skills, technological and knowledge capabilities, organization strategy, supply and demand, cost reduction and human resource characteristics), Regulatory (Initiative of non-governmental institutions, pro-environment grants, internal and international policy and legal regulations) and Ethical (social responsibility, company characteristics, entrepreneur's skills, environmental conditions, entrepreneur's altruism, human resource characteristics and organization strategy)
Ferradas et al. (2016)	Relevant factors of innovation contests for SMEs	Internal factors (IP management, corporate culture, ambidexterity), External Factors(Technological turbulence, market turbulence, Intermediaries and proximity), Design Factors (Attraction and Facilitation)
Ades et al. (2013)	Implementing open innovation: The case of Natura, IBM and Siemens	Enablers (Culture, Support from top management, Integration between

		departments, vision to bring OI opportunities to the firm, dedicated unit for patenting and licensing, creativity and strategic alignment) Barriers (Inhibiting culture, insecurity of researchers, need of adaptation, unpreparedness to manage intellectual property, complex project management, difficulty to match commercial projects with timing)
Ryan & Prybutok (2001)	Factors affecting the adoption of knowledge management technologies: a discriminative approach	Technology (User-centric technology installed and IT investment per employee) Environment Context (Industry classification) Organizational context (Strategic relevance of IT)
Klein & Knight (2005)	Innovation implementation: Overcoming the challenge	Barriers (Complexity in use, Technical knowledge and skills, expensive and time-consuming, Management support, change in roles, routines and status quo) Enablers (organization climate, management support, long term orientation and managerial patience, learning orientation and availability of financial resources)
Seidel et al. (2010)	Enablers and barriers to the organizational adoption of sustainable business practices	Strategy Definition, Organizational Support, Traceability, Motivation
Sharma (2010)	Crowdsourcing Critical Success Factor Model Collective Intelligence	Vision and Strategy, Human Capital, Infrastructure, External Environment, Linkages and Trust = Motive alignment of the crowd
Bigliardi & Galati (2016)	Which factors hinder the adoption of open innovation in SMEs	Financial and strategic barriers (lack of strategic vision of the firms), knowledge barriers (loss of know-how or imitation by competitors), collaboration barriers (partners' opportunistic behaviour, difficulty in finding the right partner, both in knowledge and cultural terms), organizational barriers (lack of managerial skills for effective collaboration with external players and resistance to change)
Huda, Hidayah & Utami (2017)	Exploring the organizational factor contributing to effective IT implementation	Human Resources Availability, Implementation Climate, Implementation Policies and Practice and Top Management Support
Awa, Ukoha & Emecheta (2016)	Using TOE theoretical framework to study the adoption of ERP solution	Technology: ICT infrastructures, technical know-how, perceived

		compatibility, perceived values, and security; Organisation: demographic composition, SBOs, subjective norms, and size of the SMEs; Environment: external support and competitive pressure
Ven & Verelst (2012)	A qualitative study on the organizational adoption of open-source server software	Technology (Hardware and software cost advantage, switching cost and compatibility, reliability, triability, open standards attitudes, Source code availability, License management); Organization (Innovativeness and Boundary spanners) and Environment (External support availability, Vendor lock-in, Platform long term viability, Availability of skilled IT workers)
Yang & Lee (2019)	An investigation of enablers and inhibitors of crowdfunding adoption: Empirical evidence from start-ups in China	Enablers (Relative advantage, Compatibility, Visibility, Results demonstrability) Inhibitors (Cost, Complexity, Reputational risk and Information disclosure)
Yusof et al. (2016)	Open Innovation and Social Media Use towards Informatics Reporting: A systematic review	Stakeholder engagement, Flexibility, Search new ventures, Transparency, Optimum utilization of resources and Open flow of knowledge and information

A general overview of studies on the adoption and utilization of similar mechanisms like open innovation, open-source systems, and ICT systems provides a base for this study in understanding and examining the technology, organization and environment (TOE) model, thus the TOE model is chosen as a relevant framework to be examined for this study. According to Awa, Ukoha and Igwe's (2017) study comparing relevant factors for the adoption of an innovation, the authors proposed that technology, organization, and environmental factors are more significant than individual factors. Hence, this study tends to classify the range of factors that can inhibit or support the utilization of crowdsourcing as an innovation. Although certain factors can be derived from examining the DOI theory, the TOE framework is utilized, as it examines broader contexts (organizational, external task environmental, and technological context) (Ven & Verelst, 2012).

3.5.2.1 Technology Context

The technological context relates to the perception and features of an innovation. This includes technologies that are either in use within the organization or those available in the marketplace, but not currently in use (Baker, 2012). A variety of factors have been found to significantly influence the adoption of an innovation, but some have proved more consistent (Tornatzky & Fleischer, 1990). Consistent factors that have been identified for the adoption of innovation include relative advantage (perceived benefits), complexity, compatibility with an organization's procedures, and observability of results (Rogers, 2003; Dedrick & West, 2003; Macredie & Mijinyawa, 2011; Louis, 2013). Innovations are expected to generate some advantage due to an increase in efficiency, and production. The awareness of these benefits is said to be a pre-condition for the integration of an innovation (vice versa), so a lack of awareness would also create an impression about such an innovation. Generally, organizations have to be careful in adopting a new innovation, as some can have a dramatic impact, while some might have a small one (Baker, 2012).

3.5.2.2 Organization Context

This context relates to the characteristics and resources that influence the ability to adopt and integrate an innovation. Regardless of the benefits of an innovation, it would be meaningless if the organization lacked the right level of resources to support its use (Leung et al., 2015). A cluster of studies has identified factors relating to intra-firm communication processes, firm size, slack resources, organizational readiness related to finances, technology competence and innovativeness (Baker, 2012; Tome et al., 2014). Financial readiness relates to the availability of financial resources for implementing innovation, while technology competence relates to the level of technology usage. The lack of these factors is said to hinder the adoption of an innovation. Another factor that is related to the organizational context is the top management support for fostering change supportive of the organization's core missions and vision (Sharma, 2010). The vision and commitment of top management can create a hindrance or supportive climate for the use of innovation (Louis, 2013).

3.5.2.3 Environment Context

This context relates to the arena in which the organization conducts its operations (Tonartzky & Fleisch, 1990). Factors such as external pressure from industries, competitions, consumers' readiness, regulatory environment, and the presence or absence of technology service providers can all influence the adoption of an innovation (Zhu, Kraemer & Xu, 2003; Baker, 2012; Ramdani, Chevers & Williams, 2013). According to Sharma (2010), the external task environment is comprised of business, living, risk profiles, economic support and government support, which are considered factors for the success of crowdsourcing. Generally, fall under these three contexts- technological, organizational and environmental can present either enablers and/or barriers. Table 3.6 below illustrates a summary of some of the factors which are expected to be relevant for the utilization of crowdsourcing as an innovation.

Table 3.6: Technology, Organization and Environment Related Factors

Technological Context	**Organizational Context**	**External Task Environmental Context**
Perceived benefits	Top management support	Vendor support
Relative advantage	Organizational readiness	Consumer readiness
Compatibility	Financial readiness	Culture
Complexity	Innovativeness	Regulatory environment
Technology conditions	Quality of human capital	External pressure from industry
	Technology competence	Technology service provider
	Organization culture	

Based on the literature, there is no study that attempts to identify and unify the enablers and barriers of crowdsourcing under their contextual determinants by comparing crowdsourcing activities. This study will attempt to identify the factors (enablers and barriers) for organizations effective use of crowdsourcing.

3.5.3 Process and Integration of Crowdsourcing

Finally, the process of crowdsourcing is examined in the context of innovation and science activities to broaden the understanding of the crowdsourcing process. In terms of innovation activities, the reviewed literature—such as Ebner, Leimeister and Krcmar (2009), Lauto et al. (2013), Saldanha et al. (2014), Edgeman et al. (2015), Mack and Landau (2015), Zhu, Sick and Leker (2016) and Ghezzi et al. (2018)—reveal that the crowdsourcing process can be broken down into six stages. Table 3.7 illustrates the stages uncovered.

Table 3.7: Review of the Crowdsourcing Innovation Process

Stages						
Authors	1	2	3	4	5	6
Ebner, Leimeister & Kremar (2009)	**Awareness** Expert discussions Announcement of competitions	**Idea Generation** Online platform Course material Skype casts	**Community Evaluation** Online evaluation Comments Skype casts	**Expert Evaluation** Online evaluation Telephone Conference	**Idea Award Ceremony** Event recruiting	
Lauto et al. (2013)	**Preliminary Activities** Selection of screen team Selection of participants	**Conception** Idea submission Idea trading Commenting	**Screening** Identification of wildcards Ranking of top 25	**Maturation** Top ideas	**Selection** Pitch to R&D management Selection of winning ideas	
Saldanha et al. (2014)	**Original ideas**	**Mapping scenarios** Open questions	**Concept ideas** Topics Comment and vote	**Concept design** Precise questions Comment and vote	**Modelling** Ideas	**Launch**
Edgeman et al. (2015)	**Specify Task**	**Crowd selection and optimization**	**Create an environment**	**Crowd motivation and value proposition creation**	**Reach the crowd**	**Manage the input and communicate the value**
Mack & Landau (2015)	**Problem or Task identification** An external or internal stimulus	**Preparation** Building up or reactivation Store of relevant information Response algorithms	**Response generation** Search memory Generate response possibility	**Response validation** Test response against factual knowledge and criteria	**Outcome** Complete attainment of a goal Some progress toward a goal No reasonable response possibilities generated	
Mehtala et al. (2016)	**Submit ideas**	**Filtering**	**Expert evaluation**	**Selection**	**Production**	
Zhu, Sick & Leker (2016)	**Deliberation** Define expected outcomes Define kind of online platform	**Preparation** Define task Define crowd Define incentives Define the procedure	**Execution** Mobilize and activate the crowd Keep up the activity level	**Assessment** Evaluation criteria Evaluation mode with expert judges/peers	**Implementation** IP regulation Rewarding ceremony Prove feasibility of the ideas Feedback about the next steps	
Panchal (2015)	**Design** Problem Requirement hierarchy	**Selection initiative** Crowdsourcing contests Open call with direct rewards Open call with indirect benefits Micro tasks	**Making design decisions** Structural decisions Problem-related decisions Evaluation and incentive related decisions	**Incentives** Game-theoretic model Solution	**Outcome** Quality of solution Overall cost Cost of filtering solutions	
Ghezzi et al. (2018)	**Input** Problem	**Process** Session management	**Process** People management	**Process** Knowledge management	**Process** Technology	**Outcome**

Ebner, Leimeister & Kremar (2009); Lauto et al. (2013); Zhu, Sick & Leker (2016); Ghezzi (2018)	Preliminary activities and awareness	Preparation and idea generation	Execution and community evaluation	Maturation and expert evaluation	Selection and implementation	

The crowdsourcing innovation process varies depending on the perspectives and purpose. For this study, and to conceptualize the process, there are seven distinguishable phases when utilizing crowdsourcing innovation: problem during the phase of the innovation process; preliminary activities and awareness; preparation and idea generation; execution and community evaluation; maturation and expert evaluation; selection and implementation; and output (Ebner, Leimeister & Kremar, 2009; Shachaf, 2010; Lauto et al., 2013; Zhu, Sick & Leker, 2016). Figure 3.24 gives a breakdown of the described phases below:

- Problem during the phase of the innovation process: the phases of the innovation process consists of many activities such as ideation, planning, concept, detailed design, development, prototyping, branding, testing and so on (Koen et al., 2001; Tran, Hasan & Park, 2012; Panchal, 2015; Palacios et al., 2016). The identification of a problem in need of external contribution commences the process.
- Preliminary activities and awareness: this phase sees the decision to utilize crowdsourcing and the task's suitability. The crowdsourcer should be aware of the purpose and the expected output of the crowdsourcing project. As crowdsourcing outputs can vary depending on the problem, the decision on what types of results can be radical or incremental would be discussed. Furthermore, the decision on how to communicate and engage with the crowd will also be decided in this phase. The decision to utilize internal channels or external crowdsourcing platforms should be made (Zhu, Sick & Leker, 2016). It

is also considered essential to select the right crowd for specific tasks. This phase ends with the fulfilment of each aspect needed to start the project.

- Preparation and idea generation: this phase relates to the engagement of the selected crowd as the problem to be crowdsourced has already been defined. From the crowdsourcer's perspective, the formulation of the problem is prepared by an accurate presentation of a question in a not-too-general or narrow way. According to Lauto et al.'s (2013) study, the presentation of an open letter was made by the chief scientific officer on the company's intranet to create awareness. A piece of detailed information on the scope and process with web seminars of live question-and-answer workshops ensured engagement. The crowdsourcing process begins with dealing with the crowd needed for the problem and how to mobilize that crowd through incentives. The required team is also selected with the inclusion of experienced members of the organization and intermediary (Lauto et al., 2013).
- Execution and community evaluation: in this phase, the online activity with the crowd has commenced with the generation of ideas and solutions to problems provided (Zhu, Sick & Leker, 2016). Contributions submitted by the crowd are categorized, with crowd members given the option to remain anonymous. Crowd members also comment on ideas by liking them or making monetary contributions towards them. Communication and active facilitation with the crowd is considered important, as it can help manage and resolve differences during the time frame.
- Maturation and expert evaluation: this phase is considered to be crucial to crowdsourcing innovation, as this involves the selection of the best possible solution or idea for implementation. The organization and intermediary experts

work in filtering submissions and responses to reach the most satisfactory idea towards the focused problem. Attention must be paid to certain criteria with respect to the crowd, expertise, and the value of submissions. Here, the management or screen team ranks finalist ideas and the best are chosen based on their feasibility with respect to fitting the organization and its capabilities (Lauto et al., 2013).

- Selection and implementation: this phase sees the selection of the best idea and the decision of when and how the crowdsourcer will implement ideas being discussed with contributors. Clarity, transparency, and feedback are considered major, with the possibility of approaches such as profit sharing and cooperation with the idea originators for continuous access to their intelligence (Zhu, Sick & Leker, 2016).
- Output: this phase relates to the outcomes of the entire process. This could be related to the benefits, discoveries, and results.
- Barriers and enablers: these are any factors considered to support or inhibit the crowdsourcing process (Tornatzky & Fleischer, 1990).

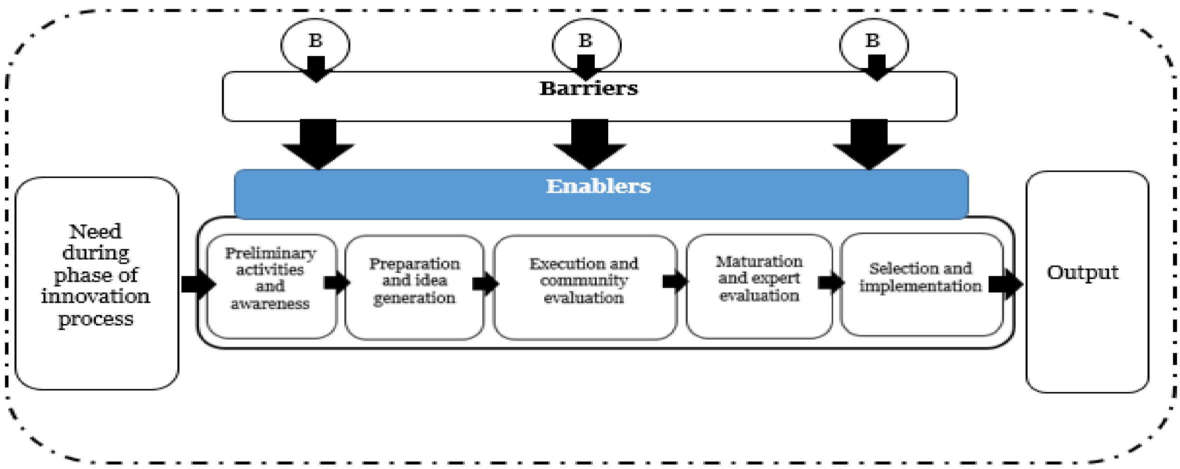

Figure 3.24. The conceptual framework for crowdsourcing innovation (Ebner, Leimeister & Krcmar, 2009; Lauto et al., 2013; Zhu, Sick & Leker, 2016; Ghezzi et al., 2018)

In terms of the use of crowdsourcing with science activities, the reviewed literature uncovered a number of authors, such as Cooper et al. (2007), Devictor, Whitaker, and Beltrame (2010), Newman et al. (2012), Shirk et al. (2012), Parrish et al. (2018). Table 3.8 gives a breakdown of the crowdsourcing science process.

Table 3.8: Review of the Crowdsourcing Science Process

	Stages					
Authors	1	2	3	4	5	6
Cooper et al. (2007)	Question	Study design	Data collection	Data analysis	Understanding results	
Devictor, Whittaker & Beltrame (2010)	Question	Protocol	Data	Results understanding		
Newman et al. (2012)	Gathering team, resources and partners	Defining research questions	Collecting and managing data	Analyzing and interpreting data	Disseminating results	Evaluation of project outcomes
Shirk et al. (2012)	Input Identify questions or issue	Activities Develop project infrastructure and manage project implementation	Outputs Observations and experiences	Outcomes Science: research findings; Social-ecological systems: action, legislation relationships; Individuals: skills, knowledge, identity	Impacts Conservation resilience sustainability	
Parrish et al. (2018)	Design	Development	Delivery	Data ingestion	Post-processing	Publication
Cooper et al. (2007); Newman et al. (2012); Parish et al. (2018)	Question, gathering team and resources	Design and development	Delivery, collecting and managing data	Data ingestion, analysis and interpretation	Disseminating results	

For this study and to conceptualize the process, seven distinguishable components can be observed when utilizing crowdsourcing for scientific activities: problem during the phase of the research process; question and gathering the team, resources and partners; design and development; delivery, collecting and managing data; data ingestion, analysis, and interpretation; post-processing and disseminating results; and output (Cooper et al., 2007; Newman et al., 2012; Parrish et al., 2018). These phases require varying activities based on the crowdsourcer's capabilities, which are described below:

- Problem during the phase of the research process: the phases of the research process are considered to fall into four phases—planning, acting, developing, and reflecting (Mertler, 2012). As problems can arise during these phases, this study would recognize the arising tasks that can be completed by utilizing crowdsourcing.
- Question, gathering team and resources: in this phase, the drive to utilize crowdsourcing is clarified by formulating the goals and objectives (Cooper et al., 2007). The declared purpose is set, which can either be for science, education, or community empowerment (Parish et al., 2018). The identifying of participants and program coordinators are also covered. To enhance participation, audiences can be targeted through the internet, and media, as well as neighbourhood organizations, protection groups, and outdoor hobby groups (Cooper et al., 2007). The research questions are formed through either a top-down or bottom-up process.
- Design and development: this phase relates to the development of protocols that assist in achieving the purpose of the project. As high data quality is essential, measures are included, such as the training of participants to improve confidence and efficiency. Training media is created through written tutorials, online training, and one-on-one training programs (Masters et al., 2016). Retention of the participants is also emphasized, as this can create a core participant level with experience, leadership, and contributions to the project.

- Delivery, collecting and managing data: data collection is said to be determined by the institutional capacity of the organization. The collection of data can be reported through worksheets and online data submissions through software (Cooper et al., 2007). Emerging technologies are also said to improve the efficiency of collecting data through mobile networked devices (Newman et al., 2012). Although the collection of data are done by participants, the attention to ability, level of skill, and knowledge of participants is important (Parrish et al., 2018). To maintain quality assurance, the testing of participants' attention to sampling and knowledge is performed. For instance, online projects can insert the proportion of images where the result is already known to create a baseline for each individual participant. This can be witnessed as an embedded assessment that can lead to improved retention levels (Parrish et al., 2018).
- Data ingestion, analyzing and interpretation: this phase relates to the quality control measures. As tasks can vary from simple tasks, which can require little-or-no deductive reasoning from participants in tasks that require meticulous effort. Quality control is said to be improved via measures such as algorithm voting, consensus metrics, statistical pruning, participant profiling, and expert intervention (Parrish et al., 2018). Depending on the complexity of tasks, expert intervention measures can be utilized. Through these measures, the collected data is interpreted.
- Disseminating results: this relates to the publication of results within scientific literature validated through scientific peer review. The sharing of results with participants also allows for fulfilling the social contract with the participants, which can be set as a precondition for participation (Cox et al., 2015). The results can be integrated into real-world decision-making processes.

- Output: the phase relates to the outcomes of the entire process. This could be related to the benefits, discoveries, and results.
- Enablers and barriers: this phase concerns emerging factors that support or inhibit the crowdsourcing process (Tornatzky & Fleischer, 1990). Figure 3.25 gives a breakdown of the described phases below:

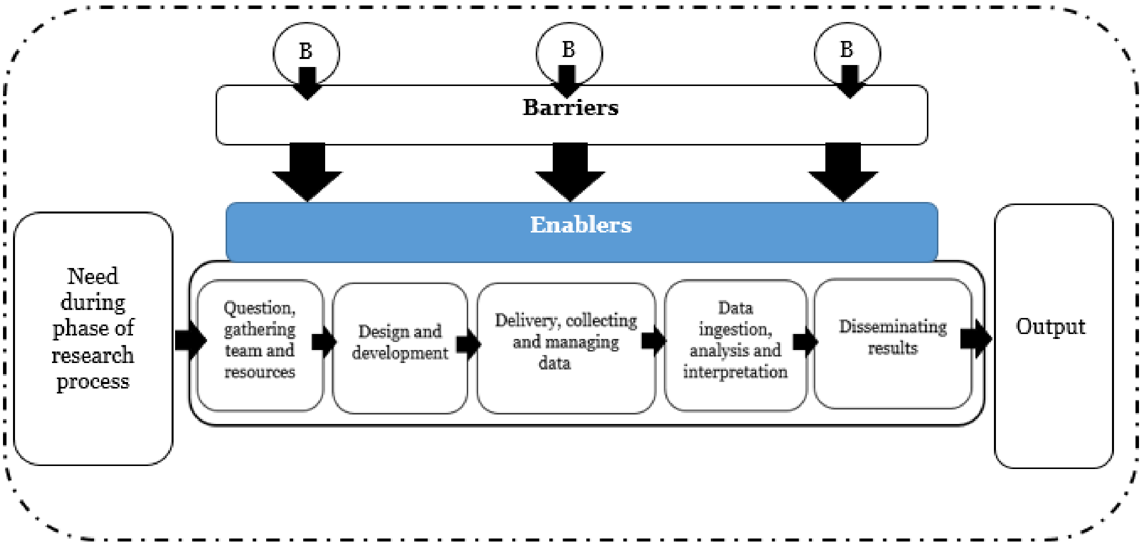

Figure 3.25. The conceptual framework for crowdsourcing science (Cooper et al., 2007; Newman et al., 2012; Parrish et al., 2018)

Despite the increasing amount of studies on the benefits and, guidelines to successfully implementing crowdsourcing to advance open science and innovation activities, it is still challenging to derive commercial value due to a lack of or delay in the process (Chesbrough, 2015; Shirk & Bonney, 2018; DITOS & WeObserve, 2019). Based on previous studies, this study fills the gap in studies comparing crowdsourcing science and innovation activities with the purpose of deriving a general holistic crowdsourcing process. This comparison could uncover underlying management activities from an organizational perspective, as well as elements that influence the success, strengths and weaknesses of crowdsourcing efforts. Secondly, this study fills the gap of studying organization integration of crowdsourcing during the innovation process. Based on the reviewed studies, there are no studies that examine organization integration of two or more crowdsourcing activities (science and innovation) to aid the transformation of science into innovative outcomes. Table 3.9 below illustrates the key studies for the overall research study.

Table 3.9: Key Studies for this Research Study

Reviewed Sections	**References**
Crowdsourcing innovation	Ebner, Leimeister & Krcmar (2009); Lauto et al. (2013); Saldanha et al. (2014); Edgeman et al. (2015); Mack & Landau (2015); Zhu, Sick & Leker (2016); Ghezzi et al. (2018)
Crowdsourcing science	Cooper et al. (2007); Newman et al. (2012); Parrish et al. (2018)
Success factors in terms of skill and capabilities for crowdsourcing science and innovation	Cunha et al. (2017); Rutten et al. (2017); Cox et al. (2015); Lüttgens et al. (2014); Podmetina et al., (2018); Sharma (2010); Aris et al. (2013); Ghezzi et al. (2018)
Enablers and inhibitors of crowdsourcing science and innovation	Zhao & Zhu (2014); Mergel, (2018); Turrini et al. (2018)
Emerging trends and domains of crowdsourcing	Ranard et al. (2014); Tripathi et al. (2014); Kullenberg & Kasperowski (2016); Malik, Aftab & Ali (2019)
Crowdsourcing as a medium linking science and innovation	Stodden (2010); Woelfle, Olliaro & Todd (2011); Athey & Ellison (2014); Bücheler & Sieg (2011); Schildhauer & Voss (2014); Chesbrough (2015); Smart et al. (2019)

Given the uncovered areas of this study and said gaps, the aim of this study is:

"To examine the effective use of crowdsourcing science and innovation activities by examining the growth and development of crowdsourcing as well as examining the process, success factors (skills and capabilities) and unifying the enabler and barriers that influence its integration and utilization."

The objectives of this study are as follows:

- To examine the crowdsourcing process as well as uncover the crowdsourcer's required skills, capabilities and evaluation mechanism for science and innovation;
- To examine the contextual determinants and factors that act as enablers and barriers to the use of crowdsourcing by crowdsourcers;
- To examine the process of crowdsourcing from science to innovation from the crowdsourcer's perspective;
- To uncover and identify the trend of emerging domains and sub-domains that crowdsourcing is applied;
- To contribute to the knowledge of the crowdsourcing field.

As crowdsourcing has the potential to solve problems and serve as a means for organizations to capture value with a reduction in cost, there is a lack of confidence in its results and outcomes that make it not convincing from the perspective of managers and professional scientists. Consequently, many theoretical frameworks have been developed to broaden the concept of using crowdsourcing during the science and innovation process as a tool, technology, and strategy. This research study intends to develop a conceptual framework that would assist in observing the phases of the crowdsourcing process and assist in the achievement of the research aim and objectives of the study.

Chapter 4: Research Methodology

4.1 Introduction

This chapter covers the following: the nature of the research design, its philosophical stance, research method, research strategy, data collection method, data analysis and interpretation and the presentation of the findings meant to enable the aim and objectives in this study to be achieved. This section covers the methodology employed in this study, as the research aim and objectives have been identified.

According to Saunders, Lewis, and Thornhill (2007), the research onion is used to illustrate the stages of this study with regards to methodological concerns and to explain how this research is conducted. This study also makes a methodological contribution to the field, which is explained further in the research methods section. The next section will cover the research design and philosophy adopted for this study.

4.2 Research Design and Philosophy

The research onion model is utilized to assist in the design of this study. The research onion possesses layers for evaluating different philosophical principles, such as obtaining information for research, and the principles and procedures involved (Bell, Bryman & Harley, 2018). The design of any research is vital to the identification of gaps and the implementation of plans to fill gaps identified in the literature. According to Bell, Bryman, and Harley (2018), a research design is described as a framework for the collection and analysis of data. Figure 4.1 below shows the research layers that guide the research process.

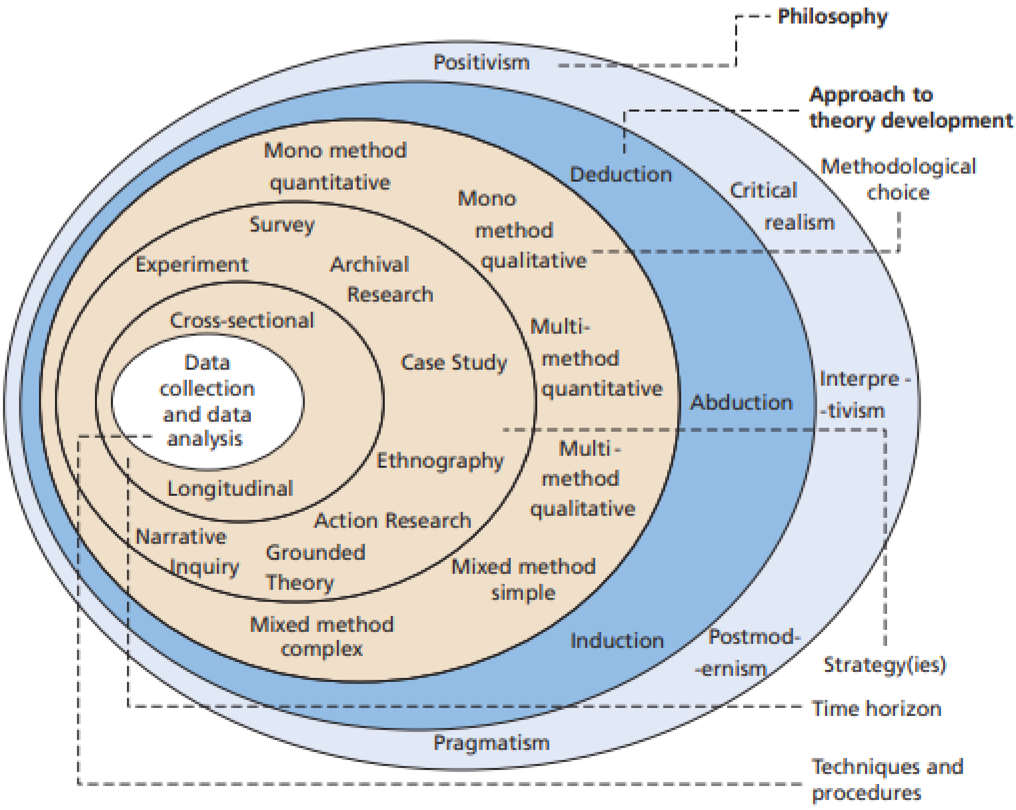

Figure 4.1. Research onion (Saunders, Lewis & Thornhill, 2007)

Choosing a research philosophy enables a researcher to identify the knowledge required to address a research problem, and the strategies essential to acquire, analyze and interpret data. The research philosophy contains assumptions about the lens through which a researcher views the world, and which further influences a chosen research strategy and method for research. As a researcher, the view of the world is referred to as a *'paradigm'*, or a school of thought that guides the conduct of research and establishes a reality (Creswell & Creswell, 2017).

This notion of paradigms was first introduced by Kuhn (1970) and can be characterized through methodology, ontology, and epistemology to assist in identifying a philosophical foundation. Ontology is the nature of reality with consideration of a social entity to be observed. This consideration is in three-fold: 1) a socially constructed world which is built on the perception and actions of social actors

2) an objective world which is independent of social actors; and 3) individually constructed worlds viewed as the construction of reality by actors through varying experiences (Fox et al., 2009). Through a closer observation of a worldview, which can either be objectively, individually, or socially constructed, a researcher can hold distinguished positions varying from objectivism, realism, and constructivism (Matthew & Ross, 2010). According to Bell, Bryman and Harley (2018), objectivism is a position that argues that a "social phenomena's existence is independent of social actors." The social phenomena are objective entities, which are not subject to human perceptions, beliefs, or culture. This ontological position enables the reality of a social phenomenon to be verified using reliable measures, such as experiments to gather information and test hypotheses.

Another ontological position—one that is of an opposing viewpoint— is constructivism, which argues that the dynamic role of actors and actions constructs a social phenomenon. It emphasizes that there is no single reality, as a social phenomenon changes as the people and society in which they reside change. A researcher with this position ascribes their own meanings and understanding to their study (Matthews & Ross, 2010). The ontological position *realism* emphasizes that reality can partly be accepted by the social actors involved, as well as the researchers who act as co-constructors (Matthews & Ross, 2010). As the data acquired is understood through a reflective approach with the aim to reach some level of objectivity, that guarantees interpretation, experiences, and biases have no influence on the results. In the literature, there are different paradigms which the research philosophy can follow. Table 4.1 below illustrates a comparison of these paradigms.

Table 4.1: Research Philosophy (Modified from Patel, 2015)

Paradigm	Ontology	Epistemology	Theoretical Perspective	Methodology	Method
Positivism	Single reality	Reality can be measured hence focus is on reliable and valid tools to obtain	Positivism Post positivism	Experimental research Survey research	Use of quantitative approach: • Sampling • Statistical analysis • Questionnaire • Focus group
Constructivism	There is no single reality of truth. Reality is created by individuals in groups	Reality needs to be interpreted to discover underlying meaning of events and activities	InterpretIvism Critical inquiry Feminism	Ethnography Grounded theory Phenomenological research Action research Discourse analysis Feminist Standpoint research	Use of qualitative approach: • Qualitative interview • Observation • Case Study • Life History • Narrative • Theme identification
Pragmatism	Reality is constantly renegotiated, debated, interpreted in light of usefulness in unpredictable situations	The best method s one that solves the problems. Finding out is the means, change is the underlying aim	Deweyan pragmatism Research through design	Mixed methods Design based research Action research	Combination of approaches: • Data mining • Text mining • Expert review • Case study • Usability testing
Subjectivism	Reality is what we perceive to be real	All knowledge is purely a matter of perspective	Post modernism Structuralism Post structuralism	Discourse theory Archaeology Genealogy Deconstruction	• Auto ethnography • Semiotics • Literary analysis • Pastiche • Intertextuality
Critical	Realities are socially constructed entities that are under constant internal influence	Reality and knowledge is both socially constructed and influenced by power relations from within society	Marxism Queer theory Feminism	Critical discourse analysis Critical ethnography Action research Ideology Critique	• Ideological review • Civil actions open ended interviews • Focus groups • Open ended questionnaires • Open ended observations • Journals

The description of these paradigms starts with the interpretivism philosophy, positing that universal cause-and-effect statements are impossible to be meaningfully formulated for human behaviour as they can only be formulated for fairly limited groups of people (Thanh & Thanh, 2015). Interpretivism criticizes the positivism approach for the application of scientific theories to social sciences, arguing that evidence can change in the course of time, so it is only possible to state the truth for a certain point in time (Thanh & Thanh, 2015). The level of criticism is based on social relationships being highly complex as it is impossible to generalize theories applicable to every single case. A positivist believes that scientific theories and models can be applied to phenomena to either discover the truth or in the generalization of the phenomenon (Riley & Love, 2000). A realist believes that some theoretical interconnections between social phenomenon cannot be known absolutely, but through casual relationships, they can be identifiable in a probabilistic case, prone to change over a time period (Clegg, 2012).

Pragmatists embrace a point of view that accepts the combination of qualitative and quantitative methods in a research study from both objective and subjective standpoints (Teddlie & Tashakkori, 2003). For this study, a pragmatic research philosophy is utilized to arrive at the desired and most reliable findings as it is argued to be the best paradigm for mixed-method research. Pragmatism opens the door to multiple methods that complement different worldviews, assumptions, and forms of data collection and analysis (Creswell & Creswell, 2017). As the researcher is influenced by a pragmatism paradigm with the epistemological position of uncovering reality and finding the best method, the approach for the study in this thesis was a mixed-method approach.

4.3 Research Approach

According to the literature, there are three main types of approaches, which are inductive, deductive and abductive (Saunders, Lewis & Thornhill, 2007; Bell, Bryman & Harley, 2018). The deductive approach involves the analysis and testing of the validity of assumptions (theories or hypotheses). Inductive approaches involve the design of a research strategy, contributing to the emergence of new theories and generalizations.

The abductive research approach starts with a surprising fact that the research strategy would be devoted to explaining. This study employs a research cycle where inductive and deductive approaches are used together to develop the framework to examine the relationship between the integration of crowdsourcing during processes; the same approaches will be used to test the framework further.

The research cycle is a sequence of reasoning where generalization is based on inductive logic, and then general inferences are transferred to deductive logic, where the generalizations are tested (Teddlie & Tashakkori, 2003). To develop frameworks for the use of crowdsourcing for either innovation and/or science activities, an inductive approach will be applied and to test the frameworks, the deductive approach will be applied.

4.4 Research Strategy

The term research strategy refers to the general position from which one conducts research, collects data, and performs data analysis to achieve a research aim (Bell, Bryman & Harley, 2018). To undertake any research, there are two different data sources, which are either primary or secondary (Saunders, Lewis & Thornhill, 2007). Primary research is designed to collect data directly from a data source, while secondary research consists of using data previously collected (such as published pieces of research), with both types having their advantages and disadvantages (Bell, Bryman & Harley, 2018).

The use of primary data has benefits which give researchers more control and up-to-date information when compared to secondary data, but the downside to this is the accessibility, time, and cost incurred during data collection. Although secondary data has its advantages, such as ease of access and size, the data are not collected for a very specific purpose, as they are usually for descriptive purposes. Research strategies are classified into two levels, firstly quantitative and qualitative research; with strategies ranging from action research, experiments, surveys, case studies, ethnographies and grounded theory (Bell, Bryman & Harley, 2018).

In this study, primary data sources were used to acquire up-to-date information, as crowdsourcing is an emerging field. Both qualitative and quantitative data were directly collected from sources such as a publication database (Web of Science) and interview data from managers, academicians, and professional scientists that utilize and apply crowdsourcing. Quantitative data was mined to improve the study and establish linkages within the crowdsourcing field to help guide the researcher and enhance the validity of this research.

4.5 Mixed-Method Approach for the Research

The use of multiple data collection methods dates back to early social science research studies, and has gradually gained steam as a viable alternative research method with a variety of articles published on this approach (Hanson et al., 2005). Its growth does, however, come with a number of issues, debates, and benefits. A consistent issue that has encouraged debate is over which paradigm method is the best fit, a debate that has multiple perspectives (Teddlie & Tashakkori, 2003). Pragmatism draws on many ideas, including using “what works” in conjunction with using diverse approaches and valuing both objective and subjective knowledge (Hanson et al., 2005).

Recently, mixed-method researchers have expanded on the reasons to conduct any mixed-method investigation (Mertens, 2003; Newman et al., 2003). Hanson et al. (2005) suggested that mixed methods could be used in certain situations such as: to better understand a research issue by merging numeric trends from quantitative data and specific details from qualitative data; to identify constructs which may be measured through the development of new ones or the use of existing instruments; to convey the needs of a group who are marginalized or underrepresented; and to acquire statistical, quantitative data from a population sample, which can be used to identify individuals who can magnify results through qualitative data and findings.

For a researcher to use a mixed-method approach, certain steps are followed, such as having a theoretical lens, having a data collection procedure, and performing data analysis and integration procedures (Teddlie & Tashakkori, 2003; Hanson et al., 2005). The data collection procedure refers to the order in which data is collected for a study, which can either take place concurrently or sequentially, with either equal or unequal weight given to the type of data collected. The third step to a mixed-method approach involves integrating data, which occurs by transforming and connecting the analysis of both data sets in some way (Hanson et al., 2005). A researcher can analyze the qualitative data separately, and arrive at some emerging themes that could be transferred into counts or ratings compared to quantitative data. Alternatively, a researcher can analyze quantitative data, and create categorical variables that enable the researcher to explain outcome variances, which would then be followed up by a qualitative research approach (interviews) with individuals who can be representatives of each of the categories. This would help in creating connections for guiding the identification and selection of individuals who participate in the interviews (Teddlie & Tashakkori, 2003; Hanson et al., 2005). The classification of mixed-method procedures can be further broken down into six primary types, which are evenly divided into the two main groups mentioned above: concurrent (triangulation, nested, and transformative types) and sequential (explanatory, exploratory, and transformative types). Figure 4.2 below illustrates the design and procedural notations that can be followed.

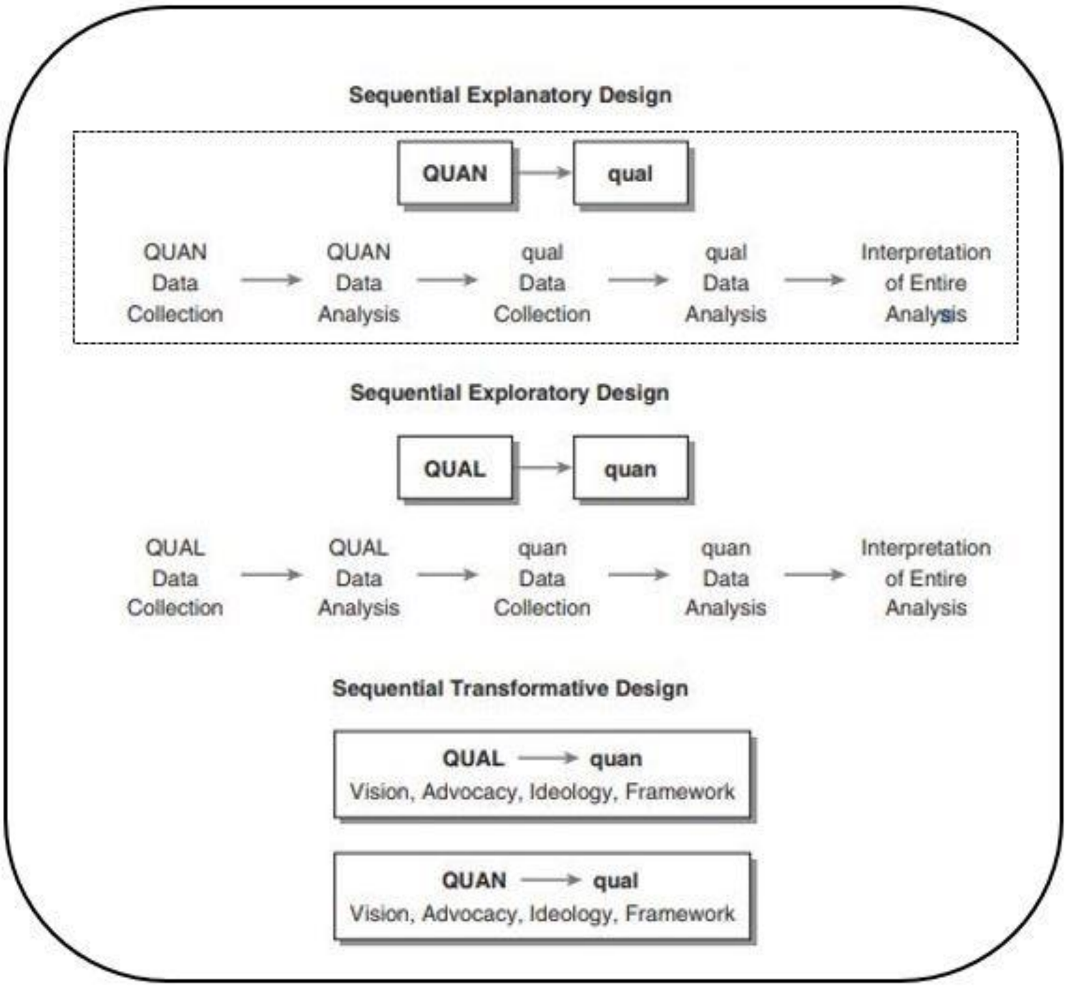

Figure 4.2. Description of data collection procedures (Creswell et al., 2003)

There are a number of reasons why the mixed-method approach has been used for this study. Firstly, uncovering what crowdsourcing applications are linked with research domains would assist with understanding the general perspective of crowdsourcing's relationship to these domains. Secondly, the results derived from the quantitative method are enhanced with qualitative methods to produce more descriptive frameworks, which are particular to specific research domains in which crowdsourcing is utilized. Thirdly, as the research area to be studied is multidisciplinary in nature, specific factors, determinants, and mechanisms related to these research domains can be uncovered. By using a quantitative method, those factors, determinants, and mechanisms would be assumed, but with qualitative methods, the analysis of uncovered factors, determinants, and mechanisms could be studied in depth.

4.6 Research Method

Research methods are vital aspects of any study as they bring in detailed technical issues related to data collection and analysis (Ghauri & Grønhaug, 2005). Standard data collection methods used in the literature are statistical, questionnaire methods, and case study methods (Creswell & Creswell, 2017). According to Creswell and Cresswell (2017), there are three strategies of inquiry regarding the use of a mixed-method approach—sequential, concurrent and transformative procedures. This research study followed a sequential explanatory mixed-method procedure which allowed the researcher to elaborate on the findings of one method using another method (Creswell & Creswell, 2017).

This study was conducted in phases using the mixed research method utilizing a quantitative method followed by a qualitative method to explore the findings with key informants. Phase 1 employed a quantitative method to reveal the applications and application areas of crowdsourcing. Then phases 2 and 3 uncovered the process, tasks, and mechanisms needed for the application of crowdsourcing within innovation and science activities, respectively. The application of mixed-method is explained with regard to its suitability for this study. Due to the existence of different types of mixed-method approaches, the details of this study—in terms of steps and techniques performed, such as the text-mining method and analysis of key informant interviews—are explained in detail to illustrate how the data is collected and analyzed. Figure 4.3 below illustrates the general process of methods used in this study.

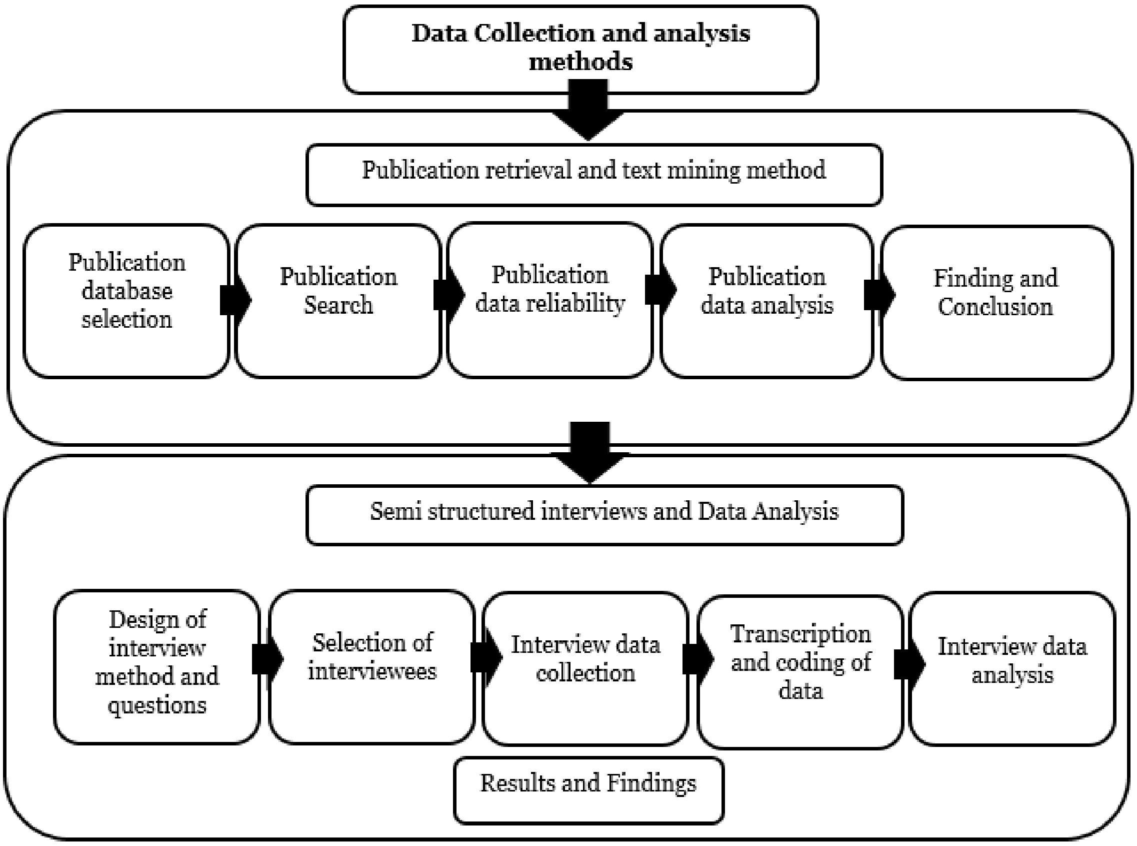

Figure 4.3. Sequential research method

Previous studies have identified publications as a useful source for understanding the linkages and development within research fields. As the application of crowdsourcing is ever-growing, the challenge of gathering the required information would require the use of special analytical tools by the researcher. Hence, for quantitative analysis, text-mining methods are used to gather information relating to the domains, subdomains, and clusters of crowdsourcing applications which would help identify linkages between crowdsourcing-related tasks and practices. The details of this study's research method and publication related analysis are explained in the following sections.

4.6.1 Quantitative Methods

In relation to the use of quantitative methods, numbers are the focus as they support statistical and quantifiable elements. Surveys, structured interviews, questionnaires, and other types of numerical studies are mainly used; particular importance is placed on sample size and error sampling as the reliability and validity of results depends on the accuracy and data coverage on groups and segment statistics in order to test hypotheses and generalize theory-like outcomes. Observing approaches utilized in business studies, the use of surveys/questionnaires is most popular, which supports the analysis of groups and segments statistics to test hypotheses and generalize themed theoretical outcomes.

Crowdsourcing studies have focused on specific areas, such as public health, business management, information systems, bioinformatics, and agriculture, to identify its models, activities, applications, and emerging trends (Ranard et al., 2014; Sivula & Kantola, 2016; Palacios et al., 2016; Minet et al., 2017; Ghezzi et al., 2018). The review of studies reveals extensive research on grouping the field, its components, characteristics, and perspectives (Rouse, 2010; Pederson et al., 2013; Zhao & Zhu, 2014). Table 4.2 illustrates different levels of focus for crowdsourcing, starting from definition-level crowdsourcing studies and moving to more advanced uses of crowdsourcing in various conditions and fields.

Table 4.2: Breakdown of Crowdsourcing Literature

Focus	Authors	Research contributions
Examining of crowdsourcing characteristics	Howe (2012); Rouse, (2010); Schenk & Guittard (2011); Estelles & Gonzalez (2012); Hetmank (2013); Nakatsu, Grossman, & Iacovou (2014)	• Definition of crowdsourcing • Identifying the capabilities and tasks performed • Identification of benefits of crowdsourcing on an individualistic and community level • Identifying motivations for crowd involvement in crowdsourcing • Identifying task characteristics and complexities (simple, creative and complex) • Examining the perspectives of crowdsourcing (organizational, technical, process, and human-centric) • Identifying components of crowdsourcing systems (user, task, contribution and workflow management) • Exploration of crowdsourcing typologies
Utilization of crowdsourcing within research fields	Good & Su (2013); Solemon et al. (2013); Pedersen et al. (2013); Brabham et al. (2014); Ranard et al. (2014); Hosseini et al. (2014);Buettner (2015); Estellés et al. (2016); Minet et al. (2017)	• The use of crowdsourcing in higher education (crowd wisdom, crowdfunding, crowd voting, and crowd creation) • Examination of crowdsourcing focus within information systems: conceptualization, application and system • Pillars of the crowdsourcing models in information systems • The use of crowdsourcing in bioinformatics: tasks (micro and mega tasks) and application systems (volunteer labour, purposive gaming, microtask markets, and open-innovation contests) • Use of crowdsourcing in health and medicine: tasks performed (problem-solving, surveying, surveillance, monitoring and data processing) • Understanding crowdsourcing in human resource management: jobs (routine, complex and creative tasks), workforce planning, training and development, recruitment fit (person-organization, person-group, and person-job), compensation, legal, and ethics • Use of crowdsourcing in agriculture: tasks (knowledge, data, and visual observations),
Taxonomy of crowdsourcing research	Brabham (2008); Zhao & Zhu (2014); Tripathi et al. (2014); Hossain & Kauranen (2015); Hosseini et al. (2015); Ambreen & Ikram (2016); Zuchowski et al. (2016); Ghezzi et al. (2018); Malik, Aftab & Ali (2019)	• Understanding aspects of crowdsourcing: application (voting system, information sharing, game and creative systems) algorithms, performance (user participation and quality management and cheating) and dataset • Organization level (acceptance, implementation, management, quality, evaluation), technology level (incentive mechanisms, technological issues), and

		participation level (crowd motivation, organization's employees' behaviours) • Examining aspects of crowdsourcing: process, characteristics, motivation to participate, motivation to crowdsource, and limitation • Examining the models (intermediary, citizen media production, collaborative software development, digital goods sale, product design, P2P financing, consumer report, knowledge base and collaborative science project), issues (level of collaboration and type of service outsourced), and control mechanisms (compensation schemes, trust-building, voting and commenting) • Breakdown of internal crowdsourcing (problems, governance and outcomes) • Breakdown of crowdsourcing process: input (problem/task), process (session, people, knowledge and technology management), output (solution, seekers and solvers benefits)

Based on the review, there are only a few studies that uses a quantitative metric approach to examine the field as a whole (Hossain and Kauranen 2015; Malik, Aftab & Ali, 2019). Careful investigation with additional analysis of the literature using objective metric tools and network analysis can provide insights that are not currently understood. Scientometric analysis can help examine the past, present and future scientific developments of a field, revealing pictorial trends. Due to the limitations of previous crowdsourcing reviews and the multidisciplinary nature of crowdsourcing, text mining as a methodological approach is important to address and provide a scientometric analysis of the crowdsourcing field. This study's text mining data analysis will be explained in the following section, with details of data collection.

4.6.1.1 Publication Data Information Retrieval and Text-Mining Methods

Quantitative analysis of publications is used to measure research activities in the context of scientific fields of study. The variety of studies that utilize publications to understand trends and propose selected areas for future studies are present in the literature (Ziegler, 2009; Arora et al., 2013; Biesenthal & Wilden, 2014; Rafols et al., 2014; Kovács et al., 2015; Darko et al., 2019). In the literature, studies exist attempting to review the literature and categorize the field using varying quantitative approaches. Table 4.3 below gives a breakdown of identified studies.

Table 4.3: Identified Quantitative Approaches

Approaches	Authors	Scope
Systematic literature review	Hetmank (2013)	Components of Crowdsourcing systems
	Lenart-Gansiniec (2018)	Crowdsourcing research field
	Créquit et al. (2018)	Health
	Schröter et al. (2017)	Supporting ecosystem assessments
	Ranard et al. (2014)	Health and medical field
	Naslund et al. (2015)	Conducting randomized trials
	Ghezzi et al. (2018)	Management
Systematic mapping methodology	Ambreen & Ikram (2016)	Computing
Bibliometric analysis	Malik, Aftab, & Ali (2019)	Crowdsourcing research field
Scientometric analysis	Kullenberg & Kasperowski (2016)	Citizen science
Review	Zuchowski et al. (2016)	Internal crowdsourcing
	English, Richardson & Garzón-Galvis (2018)	Environmental health
	To & Lai (2015)	Crowdsourcing in China
	Tripathi et al. (2014)	Information systems
	Follet & Strezove (2015)	Crowdsourcing science
	Leicht et al. (2015)	Software development
	Xintong et al. (2014)	Data mining
Survey	Yuen, King, & Leung, (2011)	Crowdsourcing systems
	Zhao & Zhu (2014)	Information systems
Case study	Li & Hongjuan (2011)	Crowdsourcing Model
Bottom up approach and cross case analysis	Aris & Din (2016)	Crowdsourcing Initiatives
Quantitative analysis of citizen science projects	Pocock et al. (2017)	Ecological and environmental research
Statistical and content analysis	Hossain & Kauranen (2015)	Crowdsourcing research field
Keyword co-occurrence and co-authorship networks analysis	Wang et al. (2016)	Crowdsourcing ITS publications
Content analysis and hermeneutic reading principle	Saxton, Oh, & Kishore (2013)	Crowdsourcing research field
Snowballing review methodology	Sauerwein et al. (2016)	Crowdsourcing in information security

In general, considering the field as a whole, this study requires a set of public data covering crowdsourcing research, rather than specific research domain data that discounts other integrated research fields. By analyzing all publications within a time period, it would be possible to examine the concentration of research and better understand the boundaries of crowdsourcing research and quantify trends, metrics, tasks, and visualize fields and subfields. The steps taken to analyze publications can be seen in Figure 4.4, with details of each step explained in the following sections.

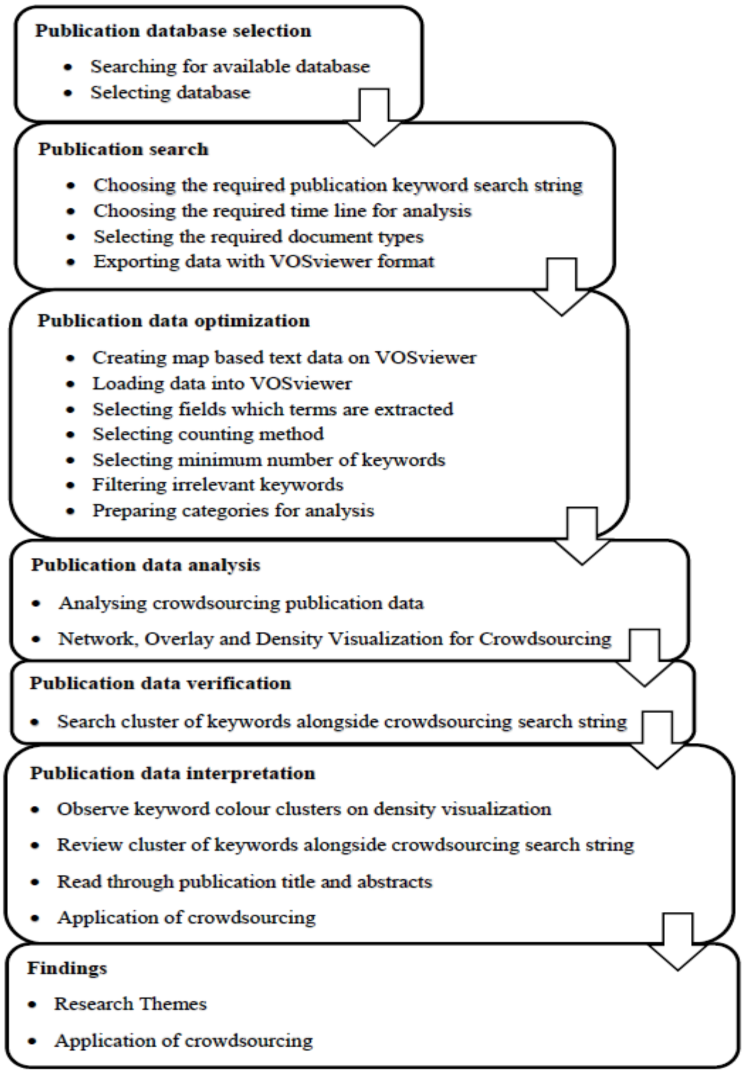

Figure 4.4. The outline of the publication data analysis process

4.6.1.2 Scientometrics, Publication and Selection of the Publication Database

The science of measuring science—which involves counting artefacts, and the production and use of information—is called scientometrics. It involves the analysis of scientific publications to explore the structure and growth of science (Rajendran, Jeyshankar & Elango, 2011). A number of studies have been done in the literature to examine the contribution of published articles with disciplines ranging from medicine

(Sanni & Zainab, 2010), semi-conductors (Guan & Ma, 2007), and physics (Nattar, 2009). The key factor for this form of analysis is publications, which can represent the size and stabilization of the overall literature in a field (Hood & Wilson, 2001).

Databases provide a vital avenue for the sourcing of publications. In this study, the use of a database that would enable the researcher to arrive at accurate results was very important. Various publication databases were examined to find the best offering in terms of time, the number of publications, research field coverage, and data readable format to support the analysis of this study. Existing databases such as PubMed, Citeseer, Google Scholar, and Scopus allowed access to view publications but compared to Web of Science, these databases were insufficient. The Web of Science database offered more for the researcher in terms of research field navigation, ease of use, maximum export quantity of publication documents, number of publications downloaded per visit and its software readable file export format (tab-delimited)—the sources were gathered and analyzed using a text-mining software (VOSviewer).

4.6.1.3 Method for Crowdsourcing Publication Data Collection and Selection

This section illustrates why the collection of required publications in the crowdsourcing field is a challenge, as well as the importance of the collected publications. In the case of the crowdsourcing field, two major difficulties arose, which were the selection of the right database and the search for common keywords. One of the biggest challenges in publication analysis is to gather the required publication data; this is done by selecting the appropriate keywords for the search to acquire an accurate data set, which includes relevant publications and excludes unnecessary publications, thus increasing the validity of the research. Moreover, it is also expected that crowdsourcing would not be bounded to one scientific field due to its multidisciplinary nature impacting other research fields.

Firstly, to acquire the right publications, a keyword search string was developed to source all relevant publications. To assist in achieving this, a general keyword string (crowdsourc* OR crowd-sourc* OR "crowd sourc*") was utilized to arrive at cited publications related to the filed. Following this, a top-down searching through publications is done to detect more keywords. Suitable keywords from related publications are added to the general string leading to the refined and developed study's keyword search string. Table 4.4 below illustrates the breakdown of related keywords and references.

Table 4.4: Key Terms Specific to the Crowdsourcing Field

Terms	References
crowdsourc* OR crowd-sourc* OR "crowd sourc*"	Howe (2012); Tripathi et al. (2014); Prpic et al. (2015); Estelles & Gonzalez (2012)
crowdfund* OR "crowd fund*"	Tripathi et al. (2014); Mollick (2014); Estelles-Arolas (2015)
((macrotask* OR "macro task*" OR "micro task*" OR microtask*) AND crowd)	Hossain & Kauranen (2015); Prpic et al. (2015); Haas et al (2015); Tong et al (2016)
crowdsourc*, citizenscienc* OR "citizen scienc*"	Minkman, Overloop, & Sanden (2015); Kullenberg & Kasperowski (2016)
"crowd scienc*" OR citizenscienc* OR "citizen scienc*"	Franzoni & Sauermann (2014); Prpic & Shukla (2016)
"crowd sens*" OR crowdsens*	Ganti, Ye & Hui (2011); Ota et al. (2018)
"mobile crowdsourc*"	Chatzimilioudis et al (2012); Niu & Qin (2017)
crowdsourc* OR "crowd solv*" OR crowdsolv*	Pastore, Mariani & Fraser (2013); Zhao & Zhu (2016)
"crowd vot*" OR crowdvot*	Tripathi et al. (2014); Prpic et al. (2015); Ali-Hassan & Allam (2016)
"crowd test*" OR crowdtest*	Leicht et al. (2015); Hoßfeld et al (2013); Gardlo et al. (2014)
"crowd mapp*" OR crowdmapp*	Higuchi, Yamaguchi & Higashino (2014); Furtado et al. (2012)
"crowd financ*" OR crowdfinanc*	Sørensen (2012); Mollick (2014)
"crowd comput*" OR crowdcomput*	Kawrykow et al. (2012); Chatzopoulos et al (2016)

Following the search through cited publications, the final search string mentioned below was used in the "topic" field of WOS, which allows the accumulation of title, abstract, and keywords, as they play a very important role in the data collection and analysis process:

“crowdsourc* OR crowd-sourc* OR “crowd sourc*” OR “mobile crowdsourc*” OR crowdfund* OR "crowd fund*" OR “crowd financ*” OR crowdfinanc* OR “crowd vot*” OR crowdvot* OR “crowd scienc*” OR citizenscienc* OR “citizen scienc*” OR “crowd test*” OR crowdtest* OR “crowd mapp*” OR crowdmapp* OR “crowd sens*” OR crowdsens* OR “crowd comput*” OR crowdcomput* OR “crowd solv*” OR crowdsolv* OR ((macrotask* OR “macro task*” OR “micro task*” OR microtask*) AND crowd)”

Secondly, as mentioned earlier in sub section 4.5.1.2, the right database was one where data could be retrieved in a format that was computer-readable, easy to analyze, and had linkage to key journals. The publications were collected strictly using the WOS database, given that it offers large abstracts, citations, and a tab-delimited format of files. Furthermore, the thomson reuters’s Web of Science database also includes publication journals (Science Direct, Jstor, Research Policy, and IEEE) combined with a range of categories which include business, management, zoology, computer science artificial intelligence, and so on. This is ensured the multidisciplinary can be thoroughly assessed based on word metrics.

An initial search during the period returned 13, 371 articles, but, with further processing and limitation of documents (to only English-language, scientific articles), a final search of a total of 7,059 articles published in the period between 2006-2019. A further breakdown of the search string into subsets, allowed for a deepened analysis on the field. Table 4.5 below illustrates the breakdown of publications’ science fields.

Table 4.5: Breakdown of Search Strings

Research Themes	Research Theme Search String	Research Categories
Cluster 1	crowdsourc* OR crowd-sourc* OR “crowd sourc*” OR crowdfund* OR "crowd fund*" OR “crowd financ*” OR crowdfinanc* OR “crowd vot*” OR crowdvot* OR “crowd test*” OR “crowdtest*” OR “crowd solv*” OR crowdsolv* OR ((macrotask* OR “macro task*” OR “micro task*” OR microtask*) AND crowd) NOT “crowd scienc*” NOT citizenscienc* NOT “citizen scienc*” NOT “mobile crowdsens*” NOT “crowd mapp*” NOT crowdmapp* NOT “crowd sens*” NOT crowdsens* NOT “crowd comput*” NOT crowdcomput*	Management, Business, Art, Operations Research and Management Science, Economics, Health Care Science Services, Psychology Multidisciplinary, Law, Business Finance, Hospitality Leisure Sport and Tourism, Green Sustainable Science Technology, Ergonomics, Political Science, Engineering Manufacturing, Infectious Diseases, Public Administration, Food Science Technology, Social Sciences Biomedical, Engineering Industrial
Cluster 2	crowdsourc* OR crowd-sourc* OR “crowd sourc*” OR “mobile crowdsourc*” OR “mobile crowdsens*” OR “crowd mapp*” OR crowdmapp* OR “crowd sens*” OR crowdsens* OR “crowd comput*” OR crowdcomput*OR ((macrotask* OR “macro task*” OR “micro task*” OR microtask*) AND crowd) NOT “crowd scienc*” NOT citizenscienc* NOT “citizen scienc*”	Computer Science Information Systems, Telecommunications, Engineering Electrical Electronic, Computer Science Artificial Intelligence, Computer Science Software Engineering, Computer Science Theory Methods, Computer Science Interdisciplinary Applications, Computer Science Hardware Architecture, Instruments Instrumentation, Transportation Science Technology, Chemistry Analytical, Engineering Civil, Regional Urban Planning, Computer Science Cybernetics, Electrochemistry, Engineering Environmental, Transportation, Automation Control Systems, Imaging Science Photographic Technology, Acoustics, Behavioural Sciences, Physics Applied, Mathematics Interdisciplinary Applications, Medical Informatics, Language Linguistics, Linguistics, Information Science Library Science, Materials Science Multidisciplinary, Construction Building Technology, Neurosciences, Psychology Experimental, Engineering Multidisciplinary, Radiology Nuclear
Cluster 3	crowdsourc* OR crowd-sourc* OR “crowd sourc*” OR “crowd scienc*” OR citizenscienc* OR “citizen scienc*”	Ecology, Environmental Sciences, Biodiversity Conservation, Multidisciplinary Sciences, Communication, Geography, Environmental Studies, Remote Sensing, Geography Physical, Public Environmental Occupational Health, Geosciences Multidisciplinary, Marine Freshwater Biology, Zoology, Water Resources, Meteorology Atmospheric Sciences, Astronomy Astrophysics, Biology, Education Educational Research, Entomology, Ornithology, Urban Studies, Evolutionary Biology, Sociology, Oceanography, Plant Sciences, Mathematical

		Computational Biology, History Philosophy of Science, Fisheries, Forestry, Biochemistry Molecular Biology, International Relations, Chemistry Multidisciplinary, Genetics Heredity, Development Studies, Medicine General Internal, Biotechnology Applied Microbiology, Geochemistry Geophysics, Biochemical Research Methods, Statistics Probability, Education Scientific Disciplines, Psychiatry, Humanities Multidisciplinary, Psychology-Clinical, Pharmacology Pharmacy, Medicine Research Experimental, Substance Abuse, Surgery, Microbiology, Biophysics, Clinical Neurology

4.6.1.4 Methods for Publication Data Optimization and Analysis

The scientometric mapping of keywords is an attempt to discover intellectual collections within a changing system of scientific knowledge, with the aim of displaying structural and dynamic aspects of scientific research (Van Eck et al., 2010). The analysis is enabled by the graphical representation of scientometric maps with enhanced labelling and density metaphors (Van Eck et al., 2010). The computer program VOSviewer was used to construct maps of authors and journals based on citations data as well as to construct maps of keywords based on co-occurrence data. VOSviewer stands for *visualization of similarities viewer,* which uses a mapping technique to present distance-based maps. These maps show the strength of the relation between items, and they allow the building of clusters.

The relationship strength of terms can further be displayed in three or four different views, i.e. label, density, cluster density, and scatter view. After the item densities have been calculated, the colour of a point in a map is determined in steps, where the colours of clusters are mixed together by calculating a weighted average of the colours (where the weight of a colour equals the item density for a corresponding cluster). Furthermore, the colour obtained in the first step is mixed with the (black or white) background colour of the cluster density view. The total item density of a point reflects the proportion in which the two colours are mixed. The closer the colour of the point is to the background colour, the lower the total item density of that point. The visualized and clustered domains of the crowdsourcing field were arrived at based on the *'betweenness', 'closeness',* and *'degree centralities'* using the frequency of terms (Ozcan & Islam, 2017). By using a colour coding with red, blue, yellow and so on, terms in their respective colour coding are associated with density and relationship strength (Van Eck et al., 2010).

Text mining is an unstructured ontological technique used to deal with the challenge of extracting useable information from large and complex data sets, thereby providing conceptual insights by shifting the level of analysis from authors and their citations to the actual words used by the authors to reach a content-driven, unbiased, and systematic review of the literature (Biesenthal & Wilden, 2014). This study utilizes the co-occurrence text-mining technique to examine the large and developing dataset in the research field. Co-occurrence analysis of terms within clusters enabled the authors to find evolutionary trends and relational patterns on the study of crowdsourcing to understand the dynamics of crowdsourcing as a research field. The underlying assumption is that the co-occurrence of words defines its context, and words that co-occur reflect categories and concepts (Randhawa, Wilden & Hohberger, 2016).

4.6.1.5 Data Verification and Interpretation

In this section, the validity and reliability of the publication collection method are explained further as the reliability and validity of data are key aspects of a research project. As crowdsourcing is dynamic and multidisciplinary in nature, its application areas are continuously changing, which is a source of uncertainty. It was, therefore, essential to utilize a methodology for searching and extracting accurate crowdsourcing publication data.

The data collection process was not a linear process, as it required the use of expert opinions, feedback on keywords, and the extension of keywords to retrieve the data. It was more of an iterative process. Firstly, the researcher used of reliable search string of keywords based on previous literature to ensure reliability. Secondly, the publication from which sources were checked to ensure the relevant articles from bottom-to-top had been completely searched, and at least 20% of the articles were reviewed. Thirdly, to further improve the search string, the researcher reviewed keywords of publications to uncover new emerging keywords strongly related to the crowdsourcing field, such as "crowd sensing," which was then added to the search string to re-perform the process. Fourth, the Web of Science categories, which cover a wide range of disciplines, proved very useful in differentiating the final results for this study.

For the interpretation of the results, the researcher also utilized expert opinion to ensure the visuals were reliable. The researcher visualized and examined clustered domains of the crowdsourcing field with regards to the *'betweenness', 'closeness',* and *'degree centralities'* using the frequency of terms.

The analysis of data reveals clusters of keywords within our map based on text data. As results are based on the titles and abstracts of publications, this study followed through with the process of searching the Web of Science database by combining our main search string with the research cluster's search string and keyword clusters to reveal more publications. The researcher examined the occurring terms based on the positioning of terms, closeness, map strength linkage, and the introduced 10% of publications search threshold, then read through the titles and abstracts of relevant publications to arrive at proposed themes, domains, sub-domains, and application areas within the crowdsourcing field. Consequently, the results are accurately verified leading to the interpretation of the final visuals using in-depth qualitative examination approach.

4.6.1.6 Data Reliability and Validity

The reliability and validity of the data utilized for this study were emphasized through a number of checks, expert opinions, and past keyword strings. At different stages of the data collection, checks were done to ensure the coherence and validity of the data. This section will provide a breakdown of this process.

Firstly, the search terms used for the initial search for publications were derived from past research and literature. Secondly, publications are limited to just English-language, and scientific articles. Thirdly, the search is carried out to check the resulting publications on the Web of Science using the search string. The publications were checked according to the relevance score on Web of Science from the bottom to top of the pages. Fourthly, the publications are checked thoroughly to confirm they are related to crowdsourcing and contain relevant data. To confirm this, publications included that are not strongly linked crowdsourcing materials are deleted by editing the original search string. Lastly, when examining the revealed publications from the re-edited search string, the researcher realized new keywords used by past authors that are relevant to crowdsourcing. The identification of the new keyword is assessed and included to improve the original search string to ensure relevant publications can be retrieved.

Following the confirmation of the data's reliability and validity, the final visual is examined with the help of four experts to ensure the final visuals are reliable. In conclusion, the process is not a linear, but rather a more iterative back-and-forth process, checking for confirmation. Figure 4.5 illustrates the process for ensuring the reliability and validity of the data.

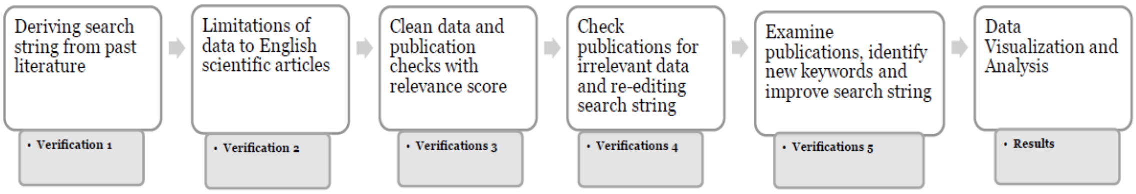

Figure 4.5. Data reliability and validity process

Following the main domain's data visualization, and to increase the reliability and validity of this output, a further check was introduced for the sub-domain analysis and visualization. The researcher utilized individual search strings, combined with subject-specific Web of Science categories to filter, arriving at the finalized sub-domain visualizations. The search string is illustrated in Table 4.5 above.

4.6.2 Qualitative Methods

The generalization and quantification of results based on numbers are not the main concern of qualitative methods; rather, it is to gain insight on a more personal level. This study uses an interview method to compensate for the limitation of publication analysis by gathering relevant information from experts in the areas uncovered by research. While the quantitative approach tends to use numeric forms in data collection with a deductive approach for analyzing data through statistical analysis to observe the causal relationship between theory and research (Bell, Bryman & Harley, 2018), qualitative approaches, on the other hand, produce research that is more empirical with textual data and the use of inductive interpretation from multiple realities to evaluate social actors within a context (De Vaus, 2002). Although qualitative approaches are often regarded as less valid and reliable than quantitative approaches, evidence of the usage is present in social science research, with key informant interviews being a major qualitative research methodology (Yin, 2009; Yazan, 2015).

The best use for the qualitative approach for this study is to analyze individual behaviours, a notion supported by researchers such as Yin (2009), as well as Bell, Bryman and Harley (2018), who argue that “[q]ualitative methods are the use of words to gather participant’s points of view to find meaning and contextual understanding.” To gain insight on crowdsourcing practices and uncover the choices and activities performed, the use of a qualitative approach is considered appropriate to answers specific research questions for this study.

As this piece of research examines how crowdsourcing can and may be applied during science and innovation activities, the use of methods such as surveys and questionnaires would have been limiting for this study. The use of qualitative methods enabled the researcher to examine the phenomenon from an alternative view, allowing participants to voice their perceptions, thereby uncovering capabilities, experience, knowledge, and needs that would have been missed using a quantitative approach. Table 4.6 below illustrates the differences between quantitative and qualitative research.

Table 4.6: Breakdown of Research Method Features (Bell, Bryman & Harley, 2018)

Quantitative	Qualitative
Numbers	Words
Point of view of researcher	Points of view of participants
Researcher distant	Researcher close
Theory testing	Theory emergent
Static	Process
Structured	Unstructured
Generalisation	Contextual understanding
Hard, reliable data	Rich, deep data
Macro	Micro
Behaviour	Meaning
Artificial settings	Natural settings

The next section will discuss the selection and use of key informants as a method for this research. Key informant interviews are qualitative, in-depth interviews with individuals who have prolonged experience, share a culture and an understanding of a particular issue. The purpose of this method is to collect information from individuals ranging from experts to community leaders to professionals who have the first-hand knowledge and understanding to provide insight into the nature of problems (Mannion et al., 2018). There are two standard techniques to conduct interviews: telephone and face-to-face interviews. Following this definition, the use of this methodology is for addressing the "how" or "why" questions regarding the study interest.

4.6.2.1 Use of Key Informant Interviews and Analysis

The key informant interview is considered to be the most suitable for this study due to the novelty of crowdsourcing. The use of the key informant technique is relatively common in organizational research because it is recognised as an approach appropriate for studying processes and actions (Faifua, 2014). This research is concerned with *"how"* crowdsourcing is applied during innovation and science activities. To achieve this, data is collected from accessible and well-informed individuals who can provide first-hand experience and precise insights (Gilchrist, Crabtree & Miller, 1992). Faifua (2014) argues that key informant techniques can be associated with particular conditions of social research, which has led to its widespread use in exploratory, and underdeveloped areas of research. The use of this approach would allow the researcher a deeper understanding of the strengths, support mechanisms, processes, factors, and inhibitions that may lead to more informed decision making. This is done due to the understanding that key informants have the most knowledge on these subject matters (Parsons, 2008). The researcher effectively utilized both face-to-face and telephone interviews, depending on the key informant's availability, preferred choice, and the researcher's feasibility.

4.6.2.2 Challenges with Key Informant Interview Approach

Although the approach is proposed as a methodology for this study, it does have some drawbacks. The disadvantages to the use of the key informant approach range from the difficulty of selecting the right informants that represent diverse viewpoints, to availability, to the time it takes to reach subjects and schedule interviews. Furthermore, it is difficult to generalize results unless many key informants are interviewed. The number of interviews and the amount of time required to attain richness in data needs to be considered as quite a lot of interview triangulation, and document triangulation is needed to arrive at a commonly agreed upon synthesis of organizational knowledge (Faifua, 2014). This study attempted to mitigate the anticipated issues of potential bias due to the selection of informants by interviewing a variety of participants with expertise, and their responses were taken verbatim (Cossham & Johanson, 2019). Regarding this study, this is not seen as a significant issue, as the findings can be compared to the works of previous scholars.

4.6.2.3 Qualitative Data Collection

The study has utilized the collection and analysis of a number of semi-structured interviews, documents and reports. The use of a semi-structured interview technique allowed for deep insight from a variety of perspectives. Key informants were sourced from platforms such as crowdsourcingweek.com and boardofinnovation.com, amongst others. A snowballing approach was taken for the selection of participants such as CEO's, managers, professional scientists and academicians, with a focus on the years of experience using crowdsourcing, skill sets, and the variety of their disciplines.

4.6.2.4 Key Informant Interview Methodology

The nature of semi-structured interviews followed a guide leading to consistency in the areas covered, but also allowing for individual differences, experiences and viewpoints. The iterative nature of the interview questions led to slight modification between interviews, particularly in the early stages of the research. The interview guide was followed to allow the same information to be obtained from participants whilst considering the limited time available during sessions (Patton, 1990).

Due to some uncertainties between the text-mining data and processes, the interview process is used to clarify results. Interviews were organized into two phases. Firstly, emerging crowdsourcing research domains were identified from the text mining analysis; following this, a selection of interviewees were chosen across the identified emerging research domains of the study. The interview duration varied between 35 minutes and 90 minutes on average. Interviews were conducted using instant messaging tools such as Skype, Google Hangouts, as well as face-to-face meetings and telephone calls. The use of this approach was due to comfortability; a sense of comfort promotes direct views in a less stressful manner.

4.6.2.5 Sample Selection and Participants

The researcher sought out key informants from crowdsourcing resources and communities such as Crowdsourcing Week, Board of Innovation, LinkedIn etc. Firstly, certain key informants were interviewed to pre-frame questions and appropriately identify the relevant issues. Based on the framing of issues, a purposively selected number of individuals were contacted via emails and a participation information sheet. Purposive sampling was utilized on the basis that participants are relevant to answering the interview questions around the subject of crowdsourcing applications (Bell, Bryman & Harley, 2018). The selected number of individuals interviewed remained anonymous, but their position and organizational affiliations are listed in Table 4.7.

Secondly, the consent was acquired from informants, and semi-structured interview sessions were organized. The interview questions were open-ended and framed to allow for the free flow of ideas, discussions, and note taking (USAID, 1996). Prior to the day of the interview, a follow-up email and semi-structured interview guide were sent to participants so they could familiarize themselves, as well as maintain consistency. These open-ended questions were also followed with probing questions and were written in the English language. The semi-structured interview guide was slightly altered over the process as more information was uncovered.

In total, almost 50 companies were contacted to arrange for interviewees, and 32 interviews were conducted. Individuals contacted were from across the UK, US, Germany, and Canada, and were product managers, platform managers, executives, academic researchers, engineers and professional scientists; each with great experience collaborating with clients, customers and participants during research and new product development projects. There were many individuals in organizations with "product manager" in their title, but they handled the management of projects that were not related to crowdsourcing. Some could not find the time to participate in this research study due to their busy schedules. Approximately 90% of the interviews were online, and 10% were conducted face-to-face. In some instances, interviewees were contacted again with follow up questions in light of the interview data results. Next, a summary of all interviews was organized according to questions following the interviews. This was done to prepare for the data analysis phase of the study. Following the number of participants interviewed, a saturation point was reached with similarities in answers from informants. Table 4.7 illustrates a breakdown of the participants of this study.

Table 4.7: List of Research Participants

No	Interview Code	Experience	Project Type	Area	Activity	Position
1	AA	20	Big Energy Physics	Volunteer Computing	Labour and Knowledge	Public Information Officer/ Managing Director
2	AB	7	Water quality monitoring	Data collection; Data analysis	Marine Conservation	Senior Innovation Lead
3	AC	7	Designing Synthetic Protein Structures	Creative Problem solving	Labour and Knowledge	Assistant Professor
4	AD	9	Space exploration and safety	Data analysis and Interpretation	Classification	Professor
5	AE	10	Environment and wildlife	Data collection; Experimental Design	Habitat monitoring	Senior Research Associate
6	AF	2	Antibiotics Resistance	Data analysis and Interpretation	Labour and Knowledge	Senior Researcher
7	AG	2	Wildlife Sea Lion	Data Collection	Habitat monitoring	Project Leader and Fish Biologist
8	AH	10	Designing Synthetic Protein Structures	Creative Problem solving	Labour and Knowledge	Assistant Professor
9	AI	5	Finding Fossils	Data collection and verification	Mapping	Project Manager

10	AJ	10	Predict invasive plant trends	Data collection	Mapping	Research Scientist and Plant ecologist
11	AK	7	Biodiversity of hedges; Garden moth scheme;	Data collection	Habitat monitoring	Senior Lecturer
12	AL	8	Public engagement	Data collection	Public engagement	Community scientist
13	AM	4	Geo chemical cycles	Data collection	Marine conservation	Professor
14	AN	2	Transcription of	Data collection	Labour and knowledge	Professor
15	AO	10	Infrastructure (Platform)	Design of projects	Design	Exoplanetary scientist and communication lead
16	AP	2	Biodiversity	Data collection and data interpretation	Habitat monitoring	Coordinating manager (Biologist and Statistician)
17	AQ	5	Litter Picking	Data collection and Volunteer geographic information	Mapping	Chief Executive Officer
18	A	5	Product development	Insights	Innovation	Product Manager
19	B	10	Product development	Ideation	Innovation	Sales Manager
20	C	4	Product development	Testing and Commercialisation	Innovation	Executive Manager
21	D	7	Product	Ideation	Innovation	Chief Innovation Officer
22	E	8	Product	Ideation (Fuzzy Front End)	Innovation	Business Development Manager
23	F	10	Product and service	Insights	Innovation	Executive Director
24	G	3	Product and service	Expert/Niche Collaboration; Ideation/Designing Solution/Work Fragmentation; Testing Concepts/Feedback	Innovation	Crowdsourcing Lead
25	H	20	Product Development	Product development	Innovation	Product Innovation Manager
26	I	9	Strategy Development	Strategy and Innovation	Innovation	Chief Executive Officer
27	J	4	Energy efficient lighting	Product Development	Innovation	Head of Co-creation and people insight
28	K	6	Hyperloop	Ideation, Design Thinking and Testing	Innovation	CEO

29	L	7	Consultancy	Hackathons; Design Thinking	Innovation	Program Director
30	M	3	Product	Design and development	Innovation	Product Manager
31	N	10	Product	Ideation	Innovation	Head of Business Strategy
32	O	17	Product	(Front end) Idea generation	Innovation	Customer Success and Innovation Services Director
33	P	10	Product and service	Ideation, Design Thinking and Testing	Innovation	Chief Social Scientist

The transcription and data analysis enabled the uncovering of the study's findings. The next section describes the data analysis and strategy.

4.6.2.6 Interview and Data Analysis

The researcher followed a three-step data analysis process that involved data preparation, data reduction, and the display of data. Attached in Appendix 4 is a sample of a semi-structured interview guide used in this study.

Interviews took place online or in-person, and was recorded on a digital recorder. Following interviews being conducted, data preparation was done through transcription. Transcriptions were carried out verbatim to arrive at the most accurate data. The researcher read through to check for accuracy and necessary corrections. Participants were made anonymous by using certain codes (AA, AB) to protect their identity, due to the interviews allowing for free flowing discussion and observation of the general perception of participants. The researcher read through the transcripts several times to be immersed in the data (Burnard 1996; Polit & Beck 2004), as complete familiarity is considered necessary to develop (Braun & Clarke, 2019).

The data reduction process was performed using Nvivo software packages (versions 11 and 12) to arrive at information themes and common trends. A thematic analysis was utilized in searching for themes, and patterns in relation to the ontological and epistemological position (Braun & Clarke, 2019). According to Braun and Clarke (2019), there are six steps to arriving at results: 1) familiarize yourself with the data; 2) generate initial codes; 3) search for themes; 4) review themes; 5) define and name themes; and 6) produce a report and interpretation.

A deductive/inductive approach was utilized by the researcher to commence a descriptive coding process. Using content analysis, the researcher developed a categorization of codes based on the background theories and literature review. Although background theory guided the categorization of codes, a line-by-line reading of the text was performed to develop connections between participants' information and themes. Following the generation of codes, the axial coding of repeated codes allowed for synthesis and grouping according to constructs of the background theories' IPO (*input, process, output*) and TOE (*technology, organization, environment*). As the aim of the study was to answer questions in relation to "what, where and how," selecting aspects of the data that fit was the general approach utilized to testing models (Elo & Kyngäs, 2008).

The semi-structured interview guide was slightly altered over the process as more information was uncovered. Attached in Appendix 4 is a sample of a semi-structured interview guide used. The categories of questions were:

A. Knowledge, background and experience
B. Usage
C. Crowdsourcing process
D. Enablers
E. Barriers to use
F. Evaluation process

G. Success factors and criteria

H. Benefits of crowdsourcing

The process of generating codes involved the use of free node list categories that were further moved under tree nodes following a hierarchical structure created in Nvivo. Table 4.8 illustrates a sample extract of the key informant content analysis.

Table 4.8: Key Informant Content Analysis

Core Themes	**Context (Tree)**	**Properties**	**Sample of participant discussion**
Enablers	Technology	Access to local knowledge, insights and specific regions	*"Also new insights from local knowledge that could not have been possible or known because a lot of that local knowledge is not published and just in the minds of people."*
Barriers	Organization	Lack of empathy	*"The biggest challenges are to fully understand the needs and pains of customers. When it is about the ideas and concepts, it is often experimenting but it is difficult because there are other ways to do it."*

Following the data reduction process, the analyzed data is presented, which enabled the researcher to gain new insights on seekers' perspective management of crowdsourcing science and innovation activities. The analysis was based on the independent judgement of the researcher and supervisors, deepened with dialogue to aid analyses of the key informant interviews. The conclusion of the analysis was verified and evaluated through participant member checking. Figure 4.6 gives a breakdown of participants and expertise in crowdsourcing initiatives.

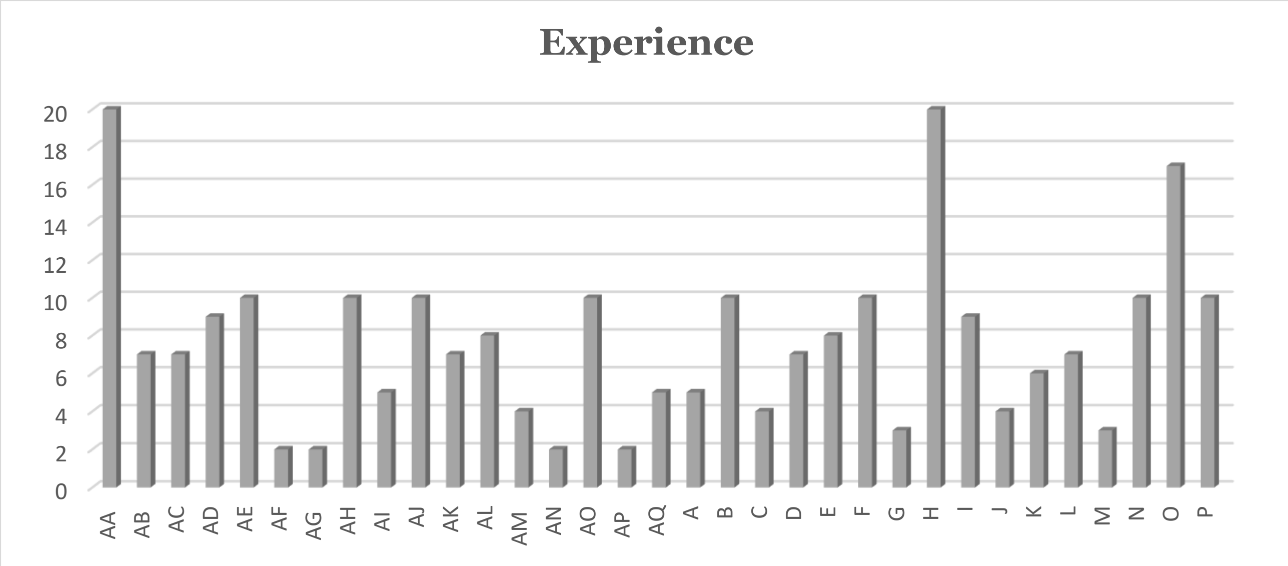

Figure 4.6. Breakdown of participants and experience in years

4.7 Ethical and Legal Issues

Although the text-mining analysis does not raise ethical issues, the study used an ethical retrieval approach (robot.txt protocol), which is a principal set of rules for retrieving data over the internet. Interview analysis is the only method followed in this research that requires the following ethical guidelines in accordance with the Portsmouth Business and Law Ethics Committee's well-designed set of guidelines and a checklist to determine if the research is conducted ethically or not. Approval from the supervisors and the BAL Research Ethics Committee was sought to conduct interviews with appropriate participants. Accordingly, interviewees were informed that anonymity and confidentiality would be respected, that gathered information would only be used for research purposes, and that the data gathered would not be used beyond the terms of initial consent given. As many interviewees preferred their identity to remain anonymous due to agreements, their names are not disclosed.

4.8 Conclusion

This chapter has presented and described the methodology and procedures utilized in the study, by providing information on the choice of strategy, methods, and cases and why they were chosen. This research followed a mixed-method (sequential approach) to enhance its reliability and validity. The study utilized both scientometric analysis and content analysis of key informant interviews. To demonstrate the accuracy of this research, this chapter is presented in a clear and detailed manner with regards to the steps taken. This research also allows other researchers to be able to follow similar methods in a different or similar field. The next chapter provides the trends, relationships, and influences that factor into the research question, which guides this research, as well as the conclusions.

Chapter 5: Scientometric Analysis and Mapping of the Crowdsourcing Field

5.1 Introduction

This chapter reveals the findings of the quantitative analyses, and is divided into two sets which are 1) bibliometric and research domains within the crowdsourcing field 2) research sub-domains, application typologies, and emerging crowdsourcing tasks. The analyses within this chapter were done with the assistance of the text mining methods described in the methodology section. Accordingly, the analyses were done using a large publication dataset collected from the Web of Science database with visualization carried out using VOSviewer. The publication dataset is highly optimized and of great reliability due to the use of methodological procedures with Web of Science research categories. This section is the first phase of this sequential research, and has the aim of identifying key terms, countries, research domains, and sub-domain clusters in the crowdsourcing field—further linking to the next research phase, the analysis of interviews. This section helps in identifying dominant research clusters, crowdsourcing tasks and application typologies. It fills a gap in the field by providing a model to assist in examining the clusters and domains related to crowdsourcing research.

5.2 Analyses of the Crowdsourcing Field: Publication Analyses

This section sheds more light on the quantitative analyses utilized—scientometrics, text mining and co-occurrence analyses. The term scientometrics was coined by Nalimov and Mulchenko in 1969, and is mainly used to measure and analyze quantitative aspects within a scientific field, including the practices of researchers, the management of research and development, the socio-organizational structures of a field, and government policies towards a scientific field (Hood & Wilson, 2001). Scientometric quantitative analysis is a method for the analysis of the past, present, and future scientific developments to map the existing intellectual core and landscape of a research field. It follows a quantitative method to identify patterns in data sources such as the literature output of research fields (Hood & Wilson, 2001). An example of an application of approach was deployed by Darko et al. (2019), who performed an analysis of global green building research and identified main research areas and collaboration networks existing in the body of knowledge.

This form of analysis first requires a dataset retrieved from a database such as Web of Science, a tool to analyze the patterns within the set of retrieved documents, and the human capability of sense-making. Similar quantitative analyses were also identified in the literature review by scholars such as Arora et al. (2013), Kovács et al. (2015), Kullenberg and Kasperowski (2016), Chen et al. (2018), and Malik, Aftab and Ali (2019) as advantageous methods when it comes to analyzing large data sets. Various studies identify problems that exist with this method of analysis in terms of data collection and optimization. This issue was also identified when it comes to the crowdsourcing field.

The identified issues in the literature review regarding methodological issues and the need for a quantitative approach led to the use of text-mining analysis of publications. The optimized data set of 7,059 articles was analyzed to provide results on the trends, the mapping of keywords and linkages. Generally, the mapping of the crowdsourcing field to reveal key scientific research domains will be followed by linkages within subdomains and emerging tasks performed.

5.2.1 Overview of Crowdsourcing Research Publications

This section gives an overall account of the crowdsourcing field with regards to the publication outputs, scientific fields contributions, country-specific outputs, and top keyword analysis. In general, there appears to be an increase in publications and research activities within the field as the years have progressed.

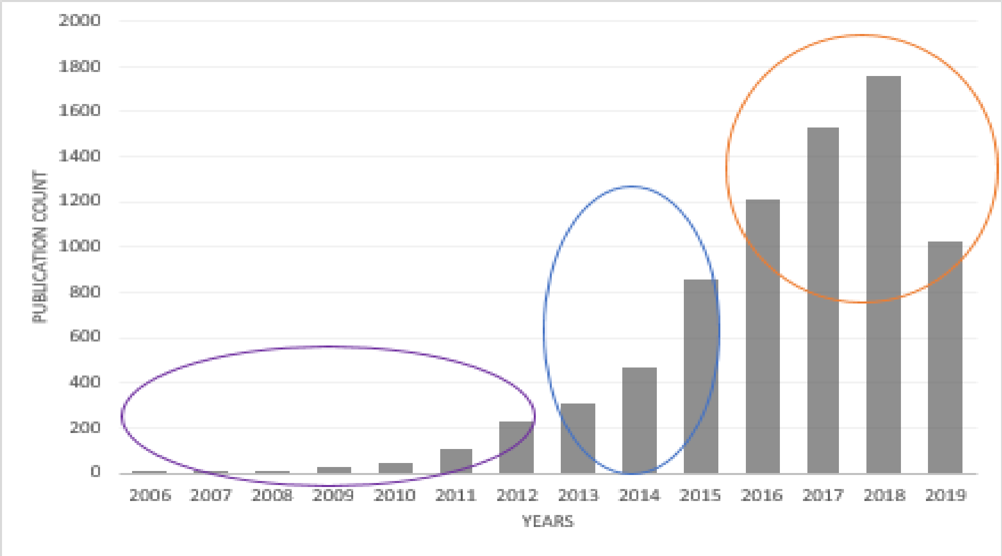

Figure 5.1. Publication trends during the period of 2006 to 2019

As shown in Figure 5.1, there are three stages that can be observed as the crowdsourcing field has grown: development stage, growth stage and peak stage. Publications during the development stage (439) ranged from the breakdown of crowdsourcing, to the recognition of crowdsourcing as a tool within scientific fields and well-cited studies from authors. Table 5.1 illustrates the top-cited articles within the examined period.

Table 5.1: Top Cited Articles from 2006 to 2012

Authors	**Top Cited Articles**
Sullivan et al. (2009)	eBird: A citizen-based bird observation network in biological science
Silvertown (2009)	A new dawn for citizen science
Bonney et al. (2009)	Citizen science: A developing tool for expanding science knowledge and scientific literacy
Dickinson et al. (2010)	The current state of citizen science as a tool for ecological research and public engagement
Cooper et al. (2010)	Predicting protein structures with a multiplayer online game
Raykar et al. (2010)	Learning from crowds
Ganti, Ye & Hui (2011)	Mobile crowdsensing: current state and future challenges
Estellés & Guevara (2012)	Towards an integrated crowdsourcing definition

Poetz & Schreier (2012)	The value of crowdsourcing: Can users really compete with professionals in generating new product ideas
Mason & Suri (2012)	Conducting behavioural research on Amazon Mechanical Turk

The growth stage witnessed an influx of publications, with the number of publications rising to 1,641 articles focusing on areas such as behavioural research, financing, data quality, and knowledge base creation. Some of the highly cited articles during this time-frame are by the authors Mollick (2014), Vance et al. (2015), Belleflamme, Lambert, and Schwienbacher (2014). These are further presented in Table 5.2 below.

Table 5.2: Top Cited Articles from 2013 to 2015

Authors	**Top Cited Articles**
Mollick (2014)	The dynamics of crowdfunding
Vance et al. (2015)	Nanotechnology in the real world: Redeveloping the nanomaterial consumer products inventory
Crump, Mcdonnell & Gureckis (2013)	Evaluating Amazon Mechanical Turk as a tool for experimental behavioural research
Belleflamme, Lambert & Schwienbacher (2014)	Crowdfunding: Tapping the right crowd
Casler, Bickel & Hackett (2013)	Separate but equal? A comparison of participants and data gathered via Amazon Mturk, social media and face to face behavioural testing
Helmstaedter et al. (2013)	Connectomic reconstruction of the inner plexiform layer in the mouse retina
Peer, Vosgerau & Acquisti (2014)	Reputation as a sufficient condition for data quality on Amazon Mechanical Turk
Warriner, Kuperman & Brysbaert (2013)	Norms of valence, arousal and dominance for 13,915 English lemmas
Chandler, Mueller & Paolacci (2014)	Nonnaivete among Amazon Mechanical Turk workers: consequences and solutions for behavioural researchers
Lehmann et al. (2015)	DBpedia: A large-scale, multilingual knowledge base extracted from Wikipedia

The peak stage has witnessed the output of 5,634 articles with a focus on top-cited publication topics on big data analytics, data acquisition, deep learning behavioural data research, incentive mechanisms, quality assessment, and so on. Table 5.3 below reveals the top-cited articles within this time-frame.

Table 5.3: Top Cited Articles from 2016 to 2019

Authors	**Top Cited Articles**
Wang et al. (2016)	Sharing and community curation of mass spectrometry data with global natural products social molecular networking
Sun et al. (2016)	Internet of things and Big data analytics for smart and connected communities
Peer et al. (2017)	Beyond the Turk: Alternative platforms for crowdsourcing behavioural research
Litman, Robinson & Abberbock (2017)	TurkPrime.com: A versatile crowdsourcing data acquisition platform for behavioural sciences
Albarqouni et al. (2016)	AggNet: Deep learning from crowds for mitosis detection in breast cancer histology images
Zhang et al. (2015)	Incentives for mobile crowd sensing: A survey
Zaveri et al. (2016)	Quality assessment for linked data: A survey
Ota et al. (2018)	QUOIN: Incentive mechanisms for crowdsensing networks
Krishna et al. (2017)	Visual genome: connecting language and vision using crowdsourced dense image annotations
Ding et al. (2015)	Cellular base station assisted device-to-device communications in TV white space

The growth in the number of articles shows the development of the field, which has bred contributions to the understanding of the field in general. Through a quick overview of studies, it is identified that the range of research publications benefiting from its applications is becoming more multidisciplinary in nature. This contributes to the multifaceted view of crowdsourcing. The next section will examine the results uncovered from the quantitative analyses with a more pictorial view of the emerging domains, and sub-domains of the field.

5.2.2 Domain and Keyword Analysis in the Crowdsourcing Field

In this section, the breakdown of scientific research contributions between 2006 and 2019 will be examined to illustrate the development of the crowdsourcing field in terms of publication outputs. As identified in section 5.2.1, a variety of research fields have been involved with its applications and research. Through the analysis of the Web of Science research areas, productive fields with varying contributions can be revealed.

Figure 5.1 below illustrates the classified research fields with ranging levels of contributions.

Observing the research fields with major contributions thus far, it is revealed that the research field with the most contribution is "computer science," leading the crowdsourcing research by 2,035 publications, making up 26% of all research during the period of observation. It is assumed that the reason for this significant contribution is that, crowdsourced efforts are considered major components within areas such as software development, with emerging platforms such as Github, FLUX, and so on (Yu et al., 2016; Silva, Marques & Lopes, 2018). Another reason for this is the heavy linkage of crowdsourcing to areas like artificial intelligence research and open-source software. Areas like machine learning capabilities are expanding with the use of undefined crowd in data labelling (Geisler, Willard & Ovalle, 2011) and access to mobile devices for applications such as crowdsensing (Guo et al., 2015).

The next research field identified contributing to crowdsourcing research is environmental sciences and ecology, with 1,058 publications, a 15% share of the dataset. This substantial share is easily explained by the rise of the involvement of citizen scientists in environmental research (Parrish et al., 2018), along with other environmental sub-fields, such as biodiversity conservation (405 publications, 5%), zoology (195 publications, 2%), and marine freshwater biology (158 publications, 2%).

The next field is engineering, with 997 publications making up 14% of all research in the dataset. It was identified that the research field is much interrelated with other fields such as telecommunication (674 publications, 9%), science and technology (427 publications, 5%), operations research and management science (175, publications, 1%), and transportation (101 publications, 1%).

After engineering in the ranking of fields that compose crowdsourcing is business economics with more than 600 publications, representing 10% of research during the examined period. A notable application of crowdsourcing—crowdfunding—is considered strongly related to this scientific field, as it is a major sub-domain of crowdsourcing research effecting fields such as management, business, and entrepreneurship. In addition, innovation management and new product development are other fields that may explain why crowdsourcing applications are prevalent in this research area. It is expected to see the rise of business research among hard science fields. The diversity of research fields in Figure 5.2 presents evidence that crowdsourcing research is multi-dimensional and interdisciplinary, combining different perspectives, and theories, as well as a variety of applications for solving complex problems.

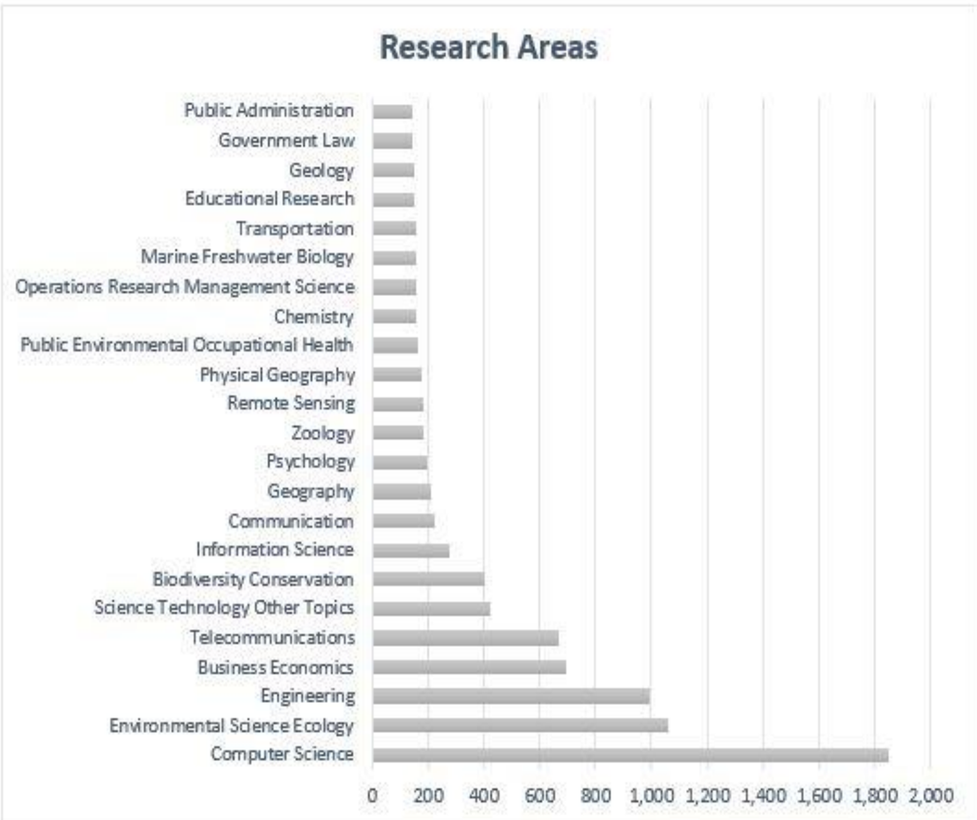

Figure 5.2. Breakdown of research fields utilizing crowdsourcing

The next section will attempt to deepen the trends within the crowdsourcing field to allow for a better understanding of the interrelationship between scientific research fields, as well as revealing emerging trends.

5.3 Scientometrics Analysis: Keyword Analysis, Research Themes and Crowdsourcing Applications

In this section, the emerging and trending keywords would be analyzed. A keyword analysis is an effective way to explore topical emphases with the use of text mining methods. The main aims of these analyses are, first, to understand the concentration and domains of research within the field; second, to test the proposed conceptual framework of this study; and, third, to identify sub-domains and applications of crowdsourcing by analyzing the trending terms within the field.

The terms were extracted by natural language processing and filtering to remove common scientific terms, as well as terms with little-to-no relevance (‘e.g. *research methodology’ ‘conclusion’, ‘future research’, ‘literature review’ ‘crowdsourcing’ ‘citizen science’* ‘and *crowdsensing)’*. Through this cleaning process, a total of 297 keywords were used to quantify, identify patterns and map the crowdsourcing field. Through the analysis, a table of keywords for each emerging cluster was revealed. Through further analysis, three main clusters developed and are distinguished by observing the top 15 keywords for each cluster. These keywords, along with the cluster map in Figure 5.3, enable the visual identification of the main research areas and themes. In general, the network contains 297 keywords, 20,258 occurrence links, and three main clusters. Table 5.4 shows the 15 most occurring keywords.

Table 5.4: Keyword Statistics

	Cluster 1		**Cluster 2**		**Cluster 3**	
	Terms	Occurrence	Terms	Occurrence	Terms	Occurrence
1	Idea	551	Task	1602	Volunteer	926
2	Concept	464	Algorithm	1306	Site	876
3	Campaign	462	Performance	1053	Observation	849
4	Social medium	423	Worker	862	Pattern	719
5	Product	382	Solution	746	Conservation	444
6	Motivation	377	Sensor	615	Detection	441
7	Reward	274	Device	445	Habitat	440
8	Firm	255	Smart device	405	Temperature	319
9	Contest	216	Classification	398	Biodiversity	304
10	Rating	207	Privacy	319	Ecosystem	262
11	Language	199	Mobile crowdsensing	226	Road	173
12	Entrepreneur	198	Machine	180	Surface	84
13	Regulation	149	Computation	170	Monarch	61
14	Fund	121	Mobile user	140	Water quality	50
15	Developer	91	Payment	90	Opportunistic data	39

By looking at Table 5.4, the keyword analysis revealed the focus of crowdsourcing research and emerging clusters. Through close examination and interpretation of related keywords such as *idea, concept, campaign*, *organization*, *task, algorithm, annotation, observation,* emerging research themes were revealed. During the period of 2006 to 2019, respective keywords were identified for each cluster: C1 (117), C2 (94), and C3 (86). These three main clusters are, respectively, crowdsourcing and innovation (C1), crowdsourcing and engineering (C2), and crowdsourcing and science (C3).

For clarification, C1 is named as such due to having top keywords such as *idea, concept,* and *campaign* in the cluster, which is greatly related to areas such as new product development and innovation. Further analysis of keywords reveals sub-domains within the emerging cluster in Figure 5.3 which can provide direction for further research on the crowdsourcing field as a whole. Figure 5.3 illustrates the mapping of the crowdsourcing field based on keywords.

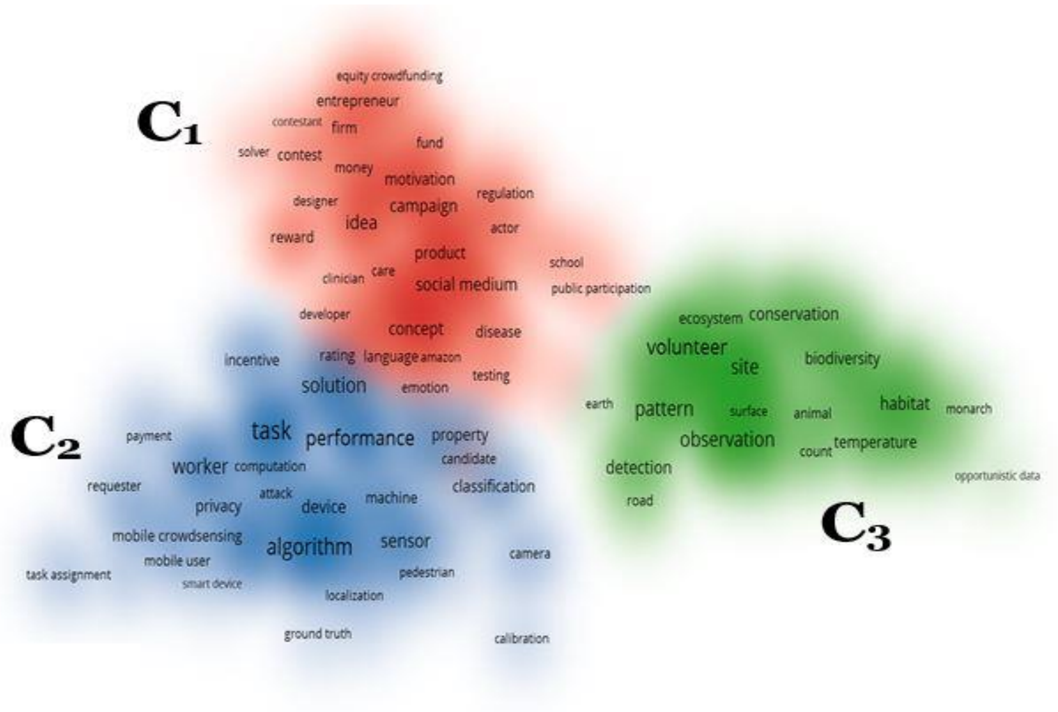

Figure 5.3. Clusters of crowdsourcing keywords

The Vosviewer normalization method was utilized to assist the human interpretation of occurring term networks, and is based on the closeness, relativity of terms, and an overview of a 10% threshold of publications within each cluster in Figure 5.2. Following the examination of emerging clusters, each cluster was closely studied with the complimentary use of Web of Science categories to arrive at sub-domains, application of crowdsourcing and visualization of terms. The Web of Science (WOS) categories were selected regarding the occurrence of related study words. For example, *habitat, observation,* and *volunteers*—words are closely related to the application of crowdsourcing in science fields. The complete grouping of WOS categories can be found in Table 4.5, which assisted in the framing of each domain and sub-domains. The core keywords were selected based on the size of words, the centrality of words showing interlinkages of surrounding words, and words with no linkage (Ozcan & Corum, 2019). Keywords are suitable for providing a high level of description of a document, and the analysis of keyword occurrences could reflect hotspots. Examining the map nodes in Figure 5.3 shows large words representing research hotspots in the crowdsourcing field, with visibly smaller words reflecting less occurrence of the respective subjects (Desul & Magapu, 2019).

5.3.1 Cluster 1: Crowdsourcing and Innovation

Cluster 1 in Figure 5.3 has at its core, *campaign, idea, and product* coupled with the five most frequent words for this cluster in Table 5.4 (*idea, concept, campaign, social medium, product*). These high-frequency words, coupled with words around them, are collated in searches for publications. For example, *idea* is collated alongside words such as *designer, campaign, money,* and *reward* to uncover publications related to crowdsourcing innovation. Related Web of Science categories—business, management, economics, political science, engineering industrial, etc.—assisted the researcher in fine-tuning of the domain. This cluster clearly points to the broader theme of ideation contests, whereby companies outsource their innovation activities to crowds via innovation campaigns through social media platforms (Huang, Singh & Srinivasan, 2014).

An isolated mini-cluster is also identified within, which is related to a sub-application of crowdsourcing like equity crowdfunding. This mini-cluster points to start-up development through crowdfunding (Mollick, 2014). Thus, the broader theme for this idea emerges to be "innovation," whether by innovating for big companies or funding for start-ups. Therefore, the theme in this cluster is labelled as "Crowdsourcing and Innovation (C1)."

5.3.2 Cluster 2: Crowdsourcing and Engineering

With words such as *algorithm, task, worker, performance,* and *solution* as high frequency words, the collation with surrounding words assisted in defining this domain. For example, the algorithm collated with words such as *sensor* or *GPS* or *localization* results in publications related to the named domain. The Web of Science categories utilized in this research theme are *computer science, information systems, telecommunications, chemistry analytical, engineering civil, transportation, engineering environmental and regional urban planning*, etc.

Cluster 2 points to the general mechanism of the crowdsourcing applications (Mason & Suri, 2012). This realization is further reinforced by the words such as *sensor, smart device, privacy, computation,* and *mobile user*, which indicate the general development of crowdsourcing applications (Wu, Yang & Liu, 2014). This motivates the labelling of this cluster as "Crowdsourcing and Engineering (C2)." To emphasize, *solution* and *incentive* are co-opted by Cluster 1 and Cluster 2 due to the terms *incentive mechanisms* and *solution's* linkage to relevant concepts for both the general engineering applications and innovation campaigns.

5.3.3 Cluster 3: Crowdsourcing and Science

Cluster 3 is a rather standalone one with keywords such as *volunteer, site*, and *observation*, and supported with other frequent words such as *detection, habitat, biodiversity*, and *ecosystem*. These were collated with surrounding words to assist the researcher in understanding the named domain. The Web of Science categories for this research theme includes *biodiversity conservation, geography, environmental studies, water resources,* and *oceanography*, etc.

It is significantly obvious that this cluster comprises all citizen science activities carried out by the crowd willing to participate in scientific data collection by reporting their observations (Beaumont et al., 2014). Thus, this cluster is labelled as "Crowdsourcing and Science (C3)."

As the crowdsourcing field presents such wide and multidisciplinary breadth and applications, further analysis is conducted to garner a deeper understanding of these clusters. By focusing on each cluster individually, underlying relationships can be identified which may not be revealed by just examining the main clusters C1, C2, and C3 explained above.

5.4 Research Clusters and Sub-Clusters Within the Crowdsourcing Field

This section covers the emerging research clusters to understand and give a deeper insight into the crowdsourcing field. The emerging research clusters should allow researchers and experts to gain clarity whilst exploring the multidisciplinary field. This section is broken down into 1) the emerging clusters that have been identified, and 2) the typology applications of crowdsourcing. The first section is broken down into two sub-sections, which are the research cluster and sub-cluster. The network of occurring terms is based on closeness, relativity and an overview of a 10% threshold of studies within each research cluster.

During the analysis period of 2006-2019; C1, C2, and C3 account for 117, 94, and 86 keywords, respectively. Using Table 5.4 and qualitative coding for each cluster (Table 4.5 in Chapter 4), three new search strings were defined. To elaborate, the general crowdsourcing search string is utilized to arrive at the main query. To differentiate each cluster further, each identified cluster is utilized and then combined with related scientific fields. For C1, crowd financing terms were utilized for differentiation, leaving out *citizen science* and *mobile crowdsourcing*. For C2, terms such as *crowd sensing, crowd mapping,* and *crowd computing* are utilized, leaving out citizen science-related publications. For C3, terms such as *citizen science* and *crowd science* are utilized.

5.4.1 Crowdsourcing and Innovation (C1)

This cluster is defined by the concentration and linkage of terms, which reveal the use of crowdsourcing as a model or capability to enable firms' access to internal and external sources of labour, wisdom, creativity, and funding through users, consumers, and stakeholders. This cluster includes terms such as *idea, campaign, capital, consumer, contest, fund, product, motivation* and *reward*. To assist the researcher in defining and presenting a scope of the cluster, the Web of Science field categories utilized were *business, economics, engineering industrial, public administration, law, hospitality leisure, sport tourism,* etc. The prominent use of crowdsourcing applications includes areas such as *idea crowdsourcing, crowdfunding,* and *crowd creation,* as established previously, on a broad scale. The Vosviewer software was further used to assist the researcher in investigating temporal trends and sub-domains in more detail through the identification of closely related terms, illustrated in Figure 5.3.

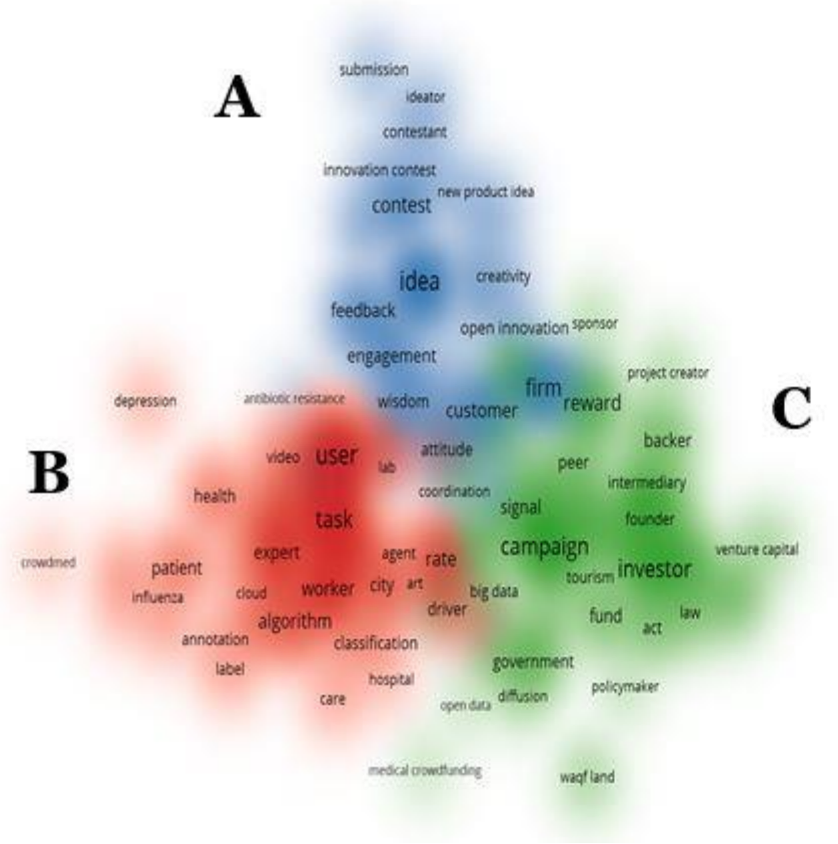

Figure 5.4. Clusters of crowdsourcing and innovation keywords

5.4.1.1 Idea and Wisdom (A)

The focus of Idea and Wisdom is investigating tasks related to research on the use of crowdsourcing for new product development and engagement with the crowd within innovation-related research. Since organizations expand their boundaries and reach out to employees and external communities during stages of product development, idea quality, the effects feedback, the wisdom of the crowd, increasing new product market value, collective intelligence, customer ideation, and identification of new product ideas research are all located in this domain (Mortara, Ford & Jaeger, 2013; Martinez & Walton, 2014; Zahay, Hajli & Sihi, 2018).

Another area of focus within the cluster is related to the motivation and engagement of the crowds during competitions or contests with studies focused on idea competitions, idea implementation based on idea popularity, task design, participation in a contest, recruiting valuable participants and modelling prizes (Frey, Lüthje & Haag, 2011; Schemmann et al., 2016; Geri, Gafni & Bengov, 2017; Suh & De Weck, 2018).

5.4.1.2 Micro and Macro Tasks (B)

Micro and Macro Tasks focus is investigating crowdsourcing as a tool for solving tasks which can be broken down into sub-domains such as crowdsourcing for HIV testing interventions, review of videos for bladder cancer research (Tang et al., 2016), optimal task allocations, improving consensus scoring, leveraging non-expert workers, identifying reliable workers (Tarasov, Delany & Mac Namee, 2014; Baba et al., 2014) and the last area on the use of crowdsourcing for mapping activities and disaster management (Granell & Ostermann, 2016).

5.4.1.3 Donation and Investment (C)

Donation and Investment focus is on the funding of innovative projects, campaigns and startups with research on problems hindering promised rewards, motivation to crowdfund (Schiavone, 2017; Zhang & Chen, 2019) and signaling in crowdfunding campaigns (Kunz et al., 2017).

5.4.2 Crowdsourcing and Engineering (C2)

This section would cover the application of crowdsourcing with related studies majorly centered within the engineering domain. The general mechanisms of crowdsourcing identified based on the concentration and existence of terms such as *annotation, ground truth, map device, incentive, mechanism, fingerprint* and *sensor*. The Web of Science categories utilized in this research theme are *computer science, information systems, telecommunications, chemistry analytical, engineering civil, transportation, engineering environmental,* and *regional urban planning,* etc. Through deep examination to understand the emerging cluster, prominent design, and varying crowdsourcing applications are crowdsensing, mobile crowdsourcing, spatial crowdsourcing and volunteered geographic information. To run this investigation of temporal trends in more detail, the use of the VOSviewer software assisted the researcher in identifying close linkages between terms to shape the emerging clusters and sub-clusters. Figure 5.5 illustrates the arrived findings of the analysis.

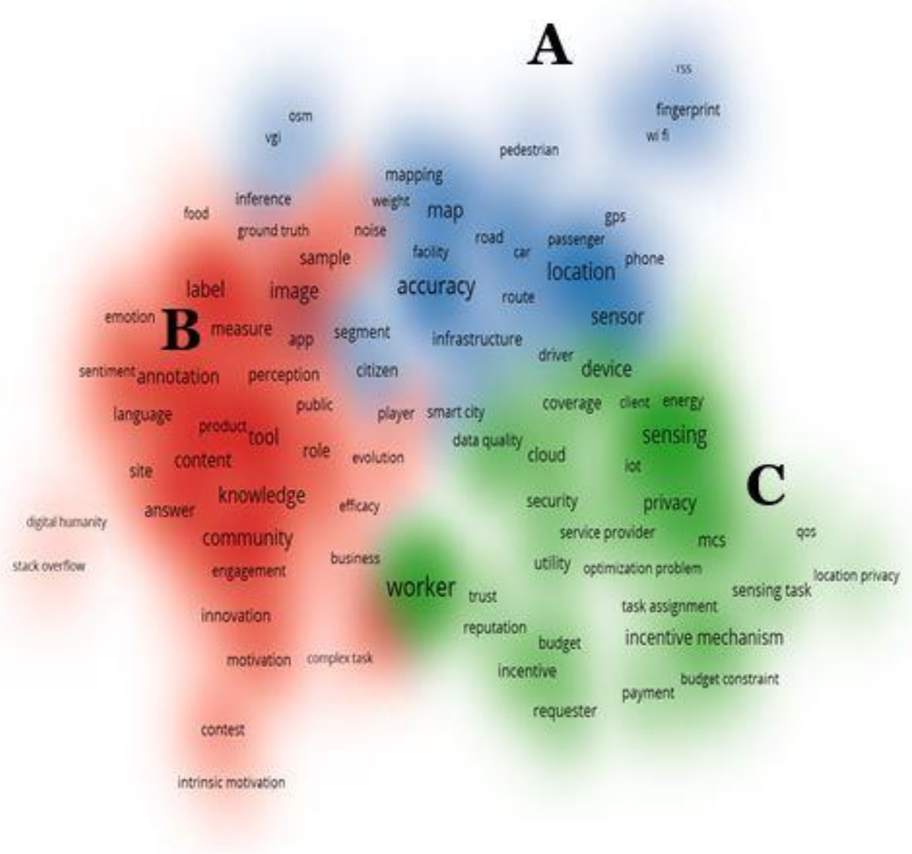

Figure 5.5. Clusters of crowdsourcing and engineering keywords

The following section will discuss the emerging sub-clusters within the main cluster to define and signify their relationship and linkage within CS2.

5.4.2.1 Mapping (A)

This sub-cluster is comprised and defined by terms such *map, fingerprint, pedestrian, location, GPS and route, etc*. These terms illustrate the relationship to crowdsourcing tasks for the improvement of geographic information systems and acquiring geographic information about the Earth and environment, which can be disseminated via social media or collaborative projects such as Flickr, Twitter, Facebook, and OpenStreetMap (Dror, Dalyot & Doytsher, 2015; Mooney, Corcoran & Ciepluch, 2013). Another stream of studies in this sub-domain is related to indoor localization, path estimation and floor plan construction (Zhou et al., 2015; Zhang et al., 2017). The third stream of studies is on the use of devices such as smartphones, sensors to perform crowdsourcing activities related to mapping and construction, estimation of road conditions and applications in smart cities (Kalim et al., 2016; Liu, Zhou & Zhang, 2015).

5.4.2.2 Labour and Knowledge (B)

This sub-domain is defined and illustrated with the use of terms such as *knowledge, community, annotation, engagement, site, label* and *stack overflow,* etc., which points to two streams of literature in which the crowd can be efficiently and effectively utilized for crowdsourcing activities. As the crowd is a major pillar of the crowdsourcing phenomenon, other forms of literature within this sub-cluster are on engagement and their labour. Firstly, the studies observed investigating tasks relate to human assessments for facial image quality, rating images from photo-sharing websites, and language processing (Zhai et al., 2013; Best-Rowden & Jain, 2018; Siahaan, Hanjalic & Redi, 2016). The second stream of studies in this sub-domain is related to the presence of the online community with a variety of skill sets, benefits of human intelligence, and the extraction of knowledge (Diven, 2013; Hajibayova, 2018).

5.4.2.3 Architecture and Design (C)

This sub-domain is comprised of terms such as *data quality, incentive, sensing, task assignment, payment, worker, location privacy* and *budget constraint,* etc. Research studies in this sub-domain are related to studies on design mechanism for the assignment of tasks as well as incentive schemes to reward and motivate the crowd (Gao, Chen & Liu, 2015; Cheng et al., 2016; Guo et al., 2017) as well as privacy preservation scheme for the crowd whilst performing spatial crowdsourcing and mobile crowdsourcing tasks (Shin et al., 2015; Gisdakis, Giannetsos & Papadimitratos, 2016). Through further examination, overlap does exist between sub-domains A and C around topics such as privacy and security illustrated by the existence of sensing and mobile crowdsourcing (MCS). The applications enable the collection of data through mobile devices, creating privacy concerns which are investigated both in sub-domain 2A and 2C. The next section examines another emerging cluster within the crowdsourcing field.

5.4.3 Crowdsourcing and Science (C3)

This section covers the cluster of crowdsourcing applications within the science-related domain and studies. This research theme contains many terms from natural sciences such as *amphibian, beach, butterfly, bird, egg, forest, habitat, island, parasite, plant and wildlife,* coupled with keywords such as *camera, conservation, disaster, engagement, image, planning and trap;* C3 implicates the popular application of crowdsourcing in natural sciences. The Web of Science categories for this research theme includes *biodiversity conservation, geography, environmental studies, water resources,* and *oceanography*, etc. A prominent use of crowdsourcing applications in C3 is crowd science, citizen science, volunteer geographic information, participatory crowdsourcing, action research, and passive crowdsourcing.

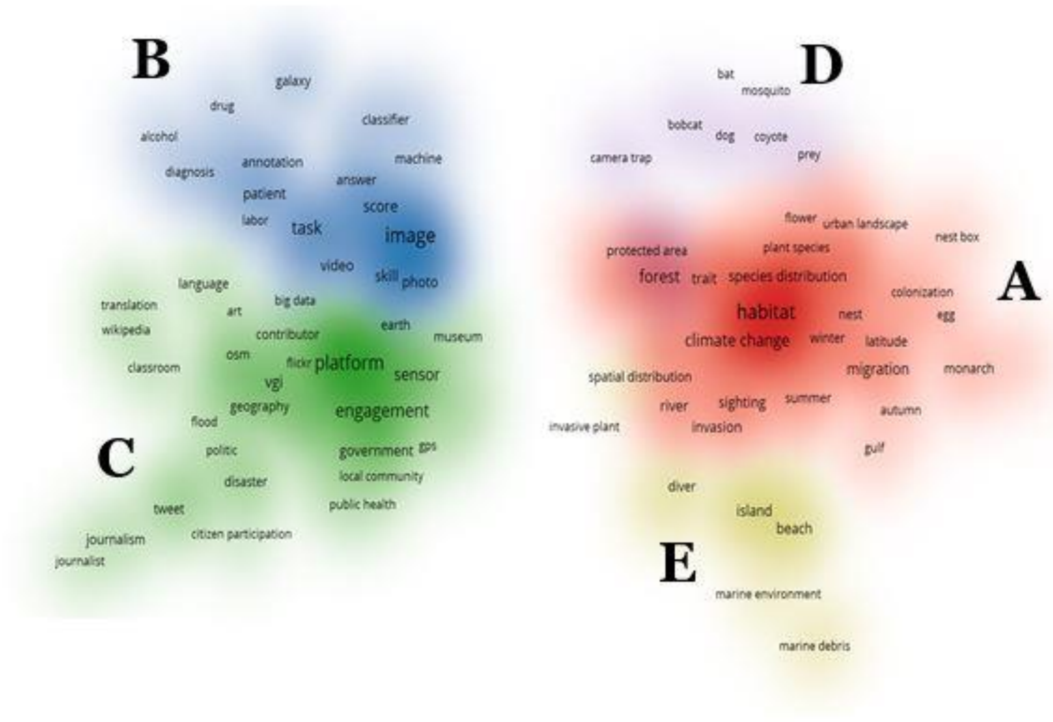

Figure 5.6. Clusters of crowdsourcing and science keywords

To investigate temporal trends in more detail, the VOSviewer software was utilized to enable the identification of closely related terms with further clustering of this research theme into sub-domains illustrated in Figure 5.6 above. C3 displays a relatively dispersed cluster, with five emerging sub-domains according to tasks and focus of research. Even though there is a lower semantic similarity of terms within C3, the investigation into the studies shaping the sub-domain helps the identification of common themes within these clusters.

5.4.3.1 Habitat Monitoring (A)

Non-professionals (citizen scientists) relate the clustering of terms such as *habitat, species distribution, migration,* and *sighting* to crowdsourcing tasks on monitoring nature, climate, and habitats. Research in this area includes pollination by insects, the attractiveness of flowers to pollinators, and impact of pesticides on insects (Birkin & Goulson, 2015; Bahlai & Landis, 2016; Muratet & Fontaine, 2015), distribution of butterfly species during seasons, climate change impact on population trends of moth and butterfly species, and temperature-induced changes in plants (Boulton et al., 2012; Karlsson, 2014).

5.4.3.2 Classification (B)

Terms such as *accuracy, classification, deep learning* and *image* point to crowdsourcing tasks related to general image annotations for research and improving machine-learning capabilities. Research in this sub-domain includes quality assurance within health care and patient safety (Car et al., 2016; Shackelford & Bowyer, 2017), as well as machine learning for identification of bubbles, Earth observation, enhancing image precision, and image coverage (Beaumont et al., 2014; Frank et al., 2017).

5.4.3.3 Public Engagement (C)

Terms such as *disaster, flood, politic, tweet, museum, wikipedia* and *classroom* point to varying streams of engagement in social tasks. Research in this sub-cluster deals spatial collective intelligence, humanitarian mapping, producing digital geospatial artefacts (Ballatore & Mooney, 2015; Vaz & Jokar Arsanjani, 2015), public participation in science-related projects that influence resource management and policies, public understanding of science, conservation outcomes and models of engagement (Silva & Krasny, 2016; Bonney et al., 2016).

5.4.3.4 Wildlife Preservation (D)

Terms such as *bat, mosquito, bobcat* and *coyote* point to detections tasks for wildlife preservation. Research in this sub-domain is comprised of studies on the trends in bat populations, the influence of citizen science on conservation attitudes and behaviours, urban ecosystem relationship between humans and coyote, differential responses of bat species, and detection of invasive mosquitos (Barlow et al., 2015; Toomey & Domroese, 2013; Weckel et al., 2015; Schneider et al., 2016).

5.4.3.5 Marine Conservation (E)

Terms in this sub-domain are similar to "Wildlife Preservation" in terms of scarcity of keywords. A varying number of terms, such as *island, beach, shark, marine debris* and *marine environment* are related to crowdsourcing tasks for marine conservation. Research in this sub-domain is comprised of studies on the distribution of small plastic debris on beaches, reproductive seasonality of fisheries, air temperature data collection, and monitoring sea turtle populations (Hidalgo-Ruz & Theil, 2013; Overeem et al., 2013; Syakti, 2017; Williams et al., 2015).

Figure 5.7 (the breakdown of the domains and sub-domains) illustrates the extent to which academic, industrial, and public involvement differ in terms of the application of crowdsourcing towards specific tasks. The proposed framework reveals the variety of crowdsourcing applications have a common relationship in terms of the overarching mechanism but vary in terms of the crowdsourcing domains, interrelated application contexts and tasks.

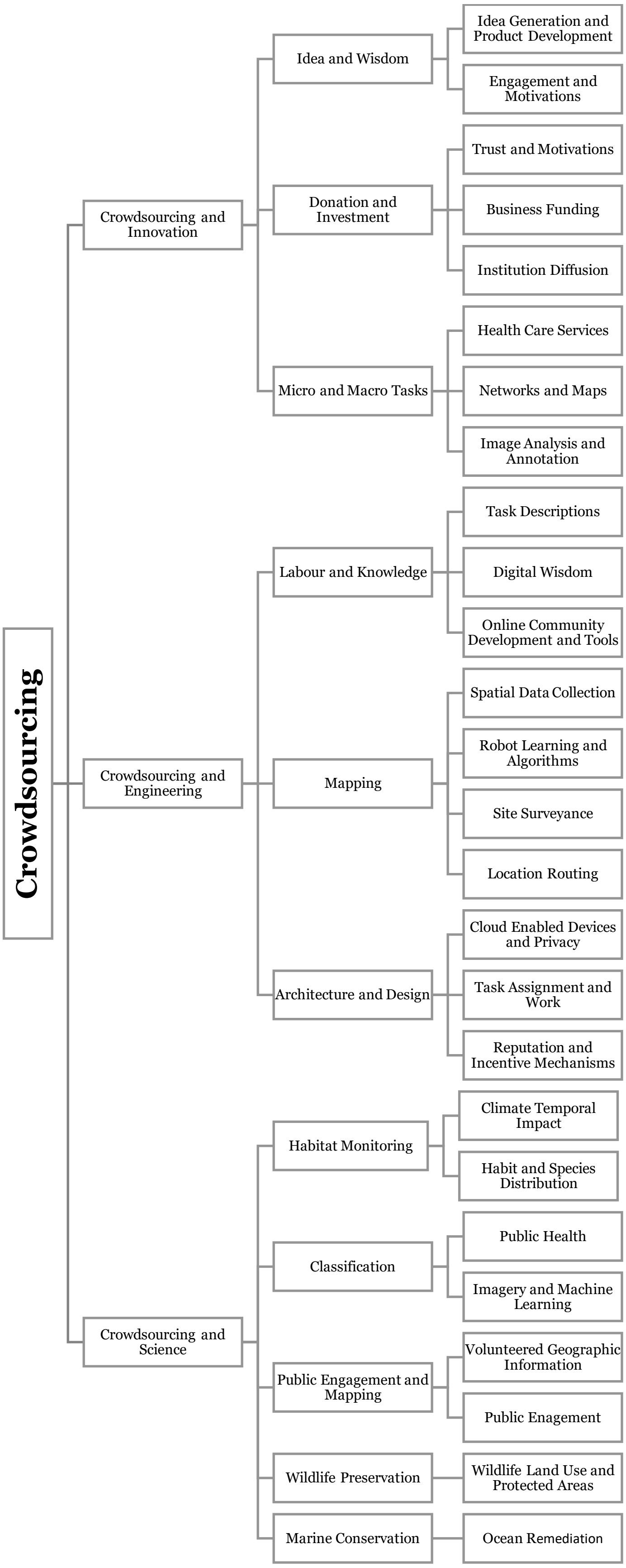

Figure 5.7. Breakdown of crowdsourcing domains

The next section will classify the emerging applications of crowdsourcing revealed according to the examined period of study.

5.5 Crowdsourcing Application Types

In this section, the identification and classification of crowdsourcing applications thus far are revealed following this study's analysis. Through the methodological approach, crowdsourcing applications and application areas are illustrated in Table 5.3, Figure 5.2 and Figure 5.3, which reveals the field's growth. To arrive at the identified applications and application areas such as crowd watch, crowd mapping, crowd science, crowdmed, civic crowdfunding, and mobile crowdsourcing, the search string alongside the term '*application*' were utilized. The high prominence mobile crowdsourcing and crowdsensing approaches reveal the shift of crowdsourcing approaches toward more technology and mobile forms of crowdsourcing, thereby effectively engaging more participant involvement from the crowds. Research into the development of crowdsourcing applications such as crowd science in terms of data quality, and mobilizing participants' involvement in fields such as social science would be a great avenue for research for utilizing this approach for certain tasks. Table 5.5 gives a further breakdown of existing and emerging crowdsourcing applications, application areas, platforms, and techniques utilized thus far.

Table 5.5: Crowdsourcing Applications

Application	**Application Typologies**	**Platforms/Techniques**
Crowdsensing	Mobile Crowdsensing, Citizen sensing, Sparse Crowdsensing	CrowdTracker, MobiGroup, IONavi
Crowd Testing	Crowdbased testing, Software development, Software Crowdsourcing Documentation, Coding, Design, QoE Crowdtesting	CrowdBuild, Topcoder, CrowdOracles, Crowd Debugging, Innovation Contest, Crowdsmelling, CrowdEV, Code Hunt, Stack Overflow, GitHub, Open Source Software, AppCheck.
Crowdfunding	Crowdfunded Journalism, Equity Crowdfunding, P2P	Kickstarter, Crowdcube, Syndicate room, Gofundme,

	Crowdfunding, Reward-Based Crowdfunding, Civic crowdfunding	Indiegogo, Seedrs, Patreon, Crowdfunder, RocketHub, LendingClub, Angelist, Prosper
Crowdsourcing science	Volunteered Geographic Information, Smartphone Citizen science, Volunteer Computing, Crowd science, Citizen science	Phylo, Safari Science, CoralWatch, Foldit, Season Spotter, CrowdCurio, SeaCleaner, Google Earth, Amazon Mechanical Turk
Micro Tasking/ Macro task Crowdsourcing	Cloud sourcing, Emergency Information Systems	Foodswitch, Fiverr, Amazon Mechanical Turk, ReCaptcha
Mobile Crowdsourcing	Mobile Crowd computing, Volunteered Geographic Information, Spatial Crowdsourcing, Mobile Crowdsensing	SmartSource, MobiCS, CrowdMonitor, CrowdPic, NoiseSense, Crowdsourcing Air Quality, CrowdSenSim, CrowdWIFI, MapLocal, Voice App, CityCare, Project Spear, Project Jagriti, AppLERT, Pazl, FlySensing, ShopProfiler, CrowdGIS, Clothes Radar, CRATER, Buy4Me, CrowdTracker, CrowdWatch, FindingNemo, FlierMeet, Hysense, WeCrowd, SecureFind, NoiseCo, CrowdOut, Txteagle
Crowd computing	Crowd social media computing	Wildlife@Home, Blockchain, CrowdEyes, SETI@home.
Crowd creation	Idea Crowdsourcing, Design Crowdsourcing	Ideastorm, Ideascale, Innocentive, Eyeka, Chaordix, Fiat, Muji, Lego, Jovoto
Crowdsourcing Systems	Open-source software, Cloud Computing, Vehicular Fog Computing	OpenStreetMap, System Medicine, Crisis Mapping
Crowd Wisdom	Crowd sharing, Crowd networking, Fan sourcing, Crowd rating, Crowd voting	Youtube, Twitter, BzzAgent, Facebook, LinkedIn, Wikipedia, Delicious, Needle, Zuberance.

Crowdsourcing is being used by organizations within the literature for a wide variety of tasks, such as monitoring of species, classification of galaxies, developing product designs, solving complex problems, sensing environments, and transcribing documents; this study confirms its ever-increasing forms of applications. Research on crowdsourcing has thrived since it was first introduced in 2006 by Howe. Existing studies in the literature also divide crowdsourcing into seven categories: crowd-voting, idea crowdsourcing, crowd evaluation, crowd creation, micro-tasking, solution crowdsourcing, and crowdfunding (Tripathi et al., 2014; Prpic et al., 2015; Hosseini et al., 2015; Sivula & Kantola, 2016). Although many fields of study have researched the phenomenon, the prominent crowdsourcing uses are:

- Crowd creation: the engagement of the crowd during product innovation and innovation processes;
- Crowd wisdom: the engagement of the crowd as a collective in decision making, innovating, and the prediction of outcomes;
- Crowdfunding: the engagement of the crowd in the funding of projects;
- Mobile crowdsourcing: the use of mobile devices to solve problems in a variety of locations;
- Crowd testing: involves the engagement of the crowd in prototype product and software testing;
- Crowdsourcing Systems relate to platforms that are enriched by the voluntary crowd inputs;
- Crowd computing: this relates to the solving tasks which are hard for computers by using the distribution of crowd intelligence inputs over internet;
- Crowd sensing: the engagement of the crowd in the sensing of the environment;
- Micro/Macro tasking: the engagement of the crowd in simple or complex problem-solving tasks;
- Crowdsourcing science: the involvement of a broader public who are mostly non-professional scientists to support data-rich or labour-intensive projects, and perform simple tasks to advance research at a relatively low cost.

5.6 Conclusion

This chapter presents various metrical and analytical findings which enabled the researcher to identify existing and emerging crowdsourcing research fields. The publication data was used to uncover trends in crowdsourcing research domains such as innovation, engineering and science. The use of crowdsourcing was broadly classified into these clusters with respect to the activities of actors, institutions, the industry, and academics. To date, a total of 7,059 scientific publications have been found with an exponential increase in computer science (26%), environmental sciences (15%), engineering (14%), and business (10%) categories. The publication data was used to uncover trends in crowdsourcing research domains such as innovation, engineering and science. The top trending articles during the period examined are Sullivan et al. (2009), Mollick (2014) and Wang et al. (2016). The keyword analysis of publications further reveals a concentration of research within three main emerging clusters with a range of top trending terms within each cluster. The emerging clusters and their most used terms are 1) crowdsourcing and innovation (*idea, concept, campaign, social medium* and *product*) 2) crowdsourcing and engineering (*task, algorithm, performance, worker,* and *solution*), and 3) crowdsourcing and science (*volunteer, site, observation, pattern,* and *conservation*).

Furthermore, an examination of these main clusters reveal sub-domains in relations to tasks and research. For crowdsourcing and innovation, there was: 1) idea and wisdom, 2) micro and macro tasks, 3) donation and investment. For crowdsourcing and engineering, they were 1) mapping, 2) labour and knowledge, and 3) architecture and design. For crowdsourcing and science, the sub-domains were 1) habitat monitoring, 2) classification, 3) public engagement, 4) wildlife preservation, and 5) marine conservation (Follett & Strezov, 2015). The findings of this study contribute to the stream of literature on crowdsourcing by providing a scientometric-based methodological analysis of its use in the domains of science, engineering, and innovation (Palacios et al., 2016; Hossain & Kauranen, 2015).

Some of these findings are in line with past research studies. This study, in comparison to previous studies, contributes value in relation to uncovering the scientometric categorization of the crowdsourcing field as a whole based on quantitative and text-mining analyses to reveal literature resides in either innovation-, engineering-, and science-related domains. The findings of this study partially correlate with other studies (Tripathi et al., 2014; Sivula & Kantola, 2016). Tripathi et al. (2014) categorized crowdsourcing types into crowdfunding, crowd wisdom, crowd creation, co-creation, tools, and crowd voting, while Sivula and Kantola (2016) divided crowdsourcing into seven main categories. Similar categories were identified but with further contributions by grouping the categories into applications such as crowdsensing, crowdtesting, crowdfunding, crowdsourcing science, micro-tasking/macro-tasking, mobile crowdsourcing, crowdsourcing systems, crowd computing, crowd creation and crowd wisdom.

The findings of this study also correlate with Follett and Strezov's (2015) study, and reveals crowdsourcing science projects have proliferated to scientific disciplines such as biology, marine, astronomy, etc. Compared to the findings of Kullenberg and Kasperowski (2016), this study partially confirms and contributes by revealing crowdsourcing science as the main domain in the crowdsourcing field with five sub-domains. As the study was done in 2016, it might be that much progress has occurred since then. Comparing this study to the findings of Malik, Aftab, and Ali (2019), this study correlates the top fifteen frequently used words in the field, but further contributes by clustering the top keywords to related crowdsourcing domains C1, C2, and C3 as well as further sub-domains. This study further contributes by organizing the crowdsourcing field in a pictorial, hierarchical, and metric fashion.

These findings identified through a scientometric approach reveal how different applications and research on crowdsourcing align with main domains, sub-domains and applications. Through the examination of publications on the crowdsourcing field, it is realized that there is a strong linkage between technology, science and innovation. The researcher will focus on the use of crowdsourcing within specific areas of research, such as innovation and science, to fulfil further objectives of this study. The objective of exploring how crowdsourcing is used within these specific areas would allow for more understanding of the crowdsourcing process, management activities and for the uncovering of the barriers faced and the factors that enable users to overcome these barriers to ensure for the effective use of crowdsourcing. The next section will cover the findings from the qualitative analysis of this study.

Chapter 6: Management, Key Factors and Integration of Crowdsourcing Science and Innovation Activities

6.1 Introduction

The previous chapter answered research question one (1) by revealing the field's main domains, sub-domains, and existing task-specific crowdsourcing applications/techniques. This chapter provides an analysis of the in-depth interviews used to answer the remaining research questions.

The chapter presents the findings based on the underpinning theories, thematic and comparative analysis. The chapter is arranged as follows: Section 6.2 presents the domains of the study's research participants, Section 6.3 crowdsourcing innovation process, 6.4 presents the crowdsourcing science process, 6.5 presents the holistic crowdsourcing process based on comparative analysis of crowdsourcing innovation and science process, 6.6 presents the factors supporting (enablers) and inhibiting (barriers) organization's use of crowdsourcing innovation, 6.7 presents the factors supporting (enablers) and inhibiting (barriers) organization's use of crowdsourcing science, 6.8 presents the factors supporting (enablers) and inhibiting (barriers) organization's use of crowdsourcing based on comparative analysis, 6.9 presents the integration of crowdsourcing activities during the innovation process.

6.2 Domains of Research Participants

This section provides a general overview of the research participants. A total of thirty-three (33) organizations were interviewed. Figure 6.1 gives a breakdown of the research participant's domains.

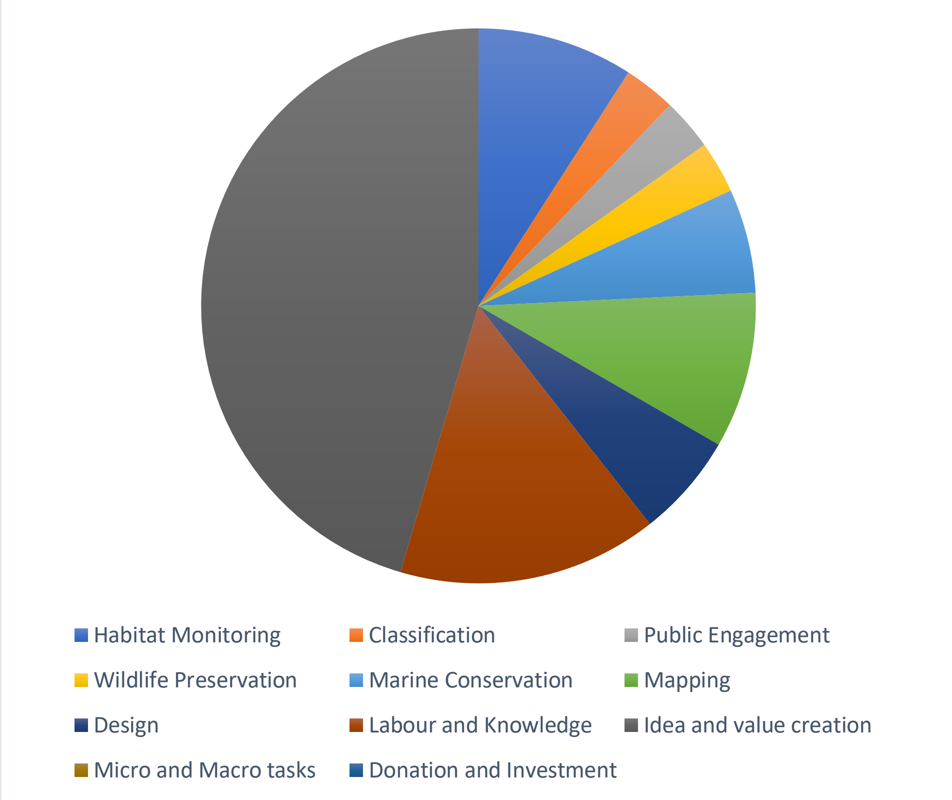

Figure 6.1. The examined research sub-domains

Figure 6.1 shows the type of domains examined in the study; all performing crowdsourcing activities but noted to provide different outcomes as they include professional scientists, product managers, etc. The average number of years of crowdsourcing experience amongst participants is 7.75, ranging from 2 to 20 years of direct involvement with crowdsourcing applications. Having identified the domains associated with the participants, the process, management activities, influencing factors and integration are revealed. The following section will present the crowdsourcing innovation process.

6.3 Crowdsourcing Innovation Process

This section will cover the crowdsourcing innovation process. Figure 6.2 illustrates the crowdsourcing innovation process and underlying activities derived from the data analysis. In accordance with previous studies (e.g. Ebner, Leimeister and Krcmar, 2009; Zhu, Sick and Leker, 2016), figure 6.2 is a five-stage process of how the stages fit together with the underlying management activities and feedback channels.

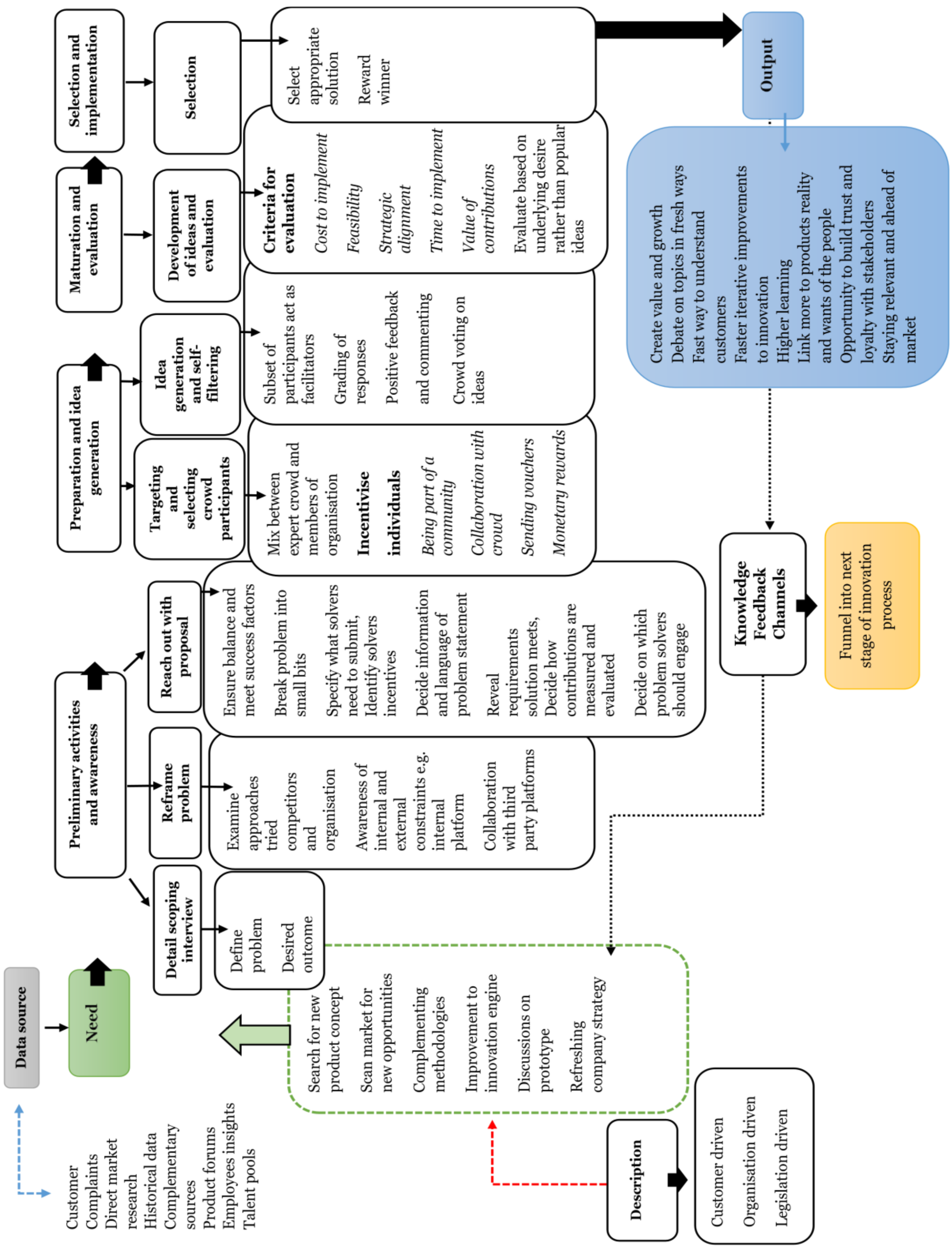

Figure 6.2. Crowdsourcing innovation process

The findings reveal that the crowdsourcing innovation process starts with a need at a specific time, ranging from 1) scanning market opportunities; 2) generating insights for a new product or concept; 3) beta testing of prototypes or improvement of services and so on (Erickson, 2013), which can be driven by either the internal or external crowd members. Participant J explained:

"*….we are scanning the market for new opportunities, we already have the idea, but we want people to come up with new concepts around that.*"

A cross-functional team manages the process and can derive information from either internal or external data sources. The data sources support the preliminary activities and awareness stage involving the detail scoping and framing of the organization's need into a research proposal inviting collaboration with the crowd or competition amongst themselves (Hutter et al., 2011). Creating a clear listed brief with criteria, the design and the involvement of skilled project members are essential for attracting experience crowd members (Ghezzi et al., 2018). Participant D said:

"…. it would have a little preamble of what the organization is trying to achieve. A headline that is eye-catching to draw the solution providers in and to respond. All that is put together and launched on our platform."

The preparation and idea generation stage involves 1) targeting and selecting certain participants and 2) idea filtering. The findings show that an organization's balanced participative style of selecting experienced crowd members is facilitated through a platform with mechanisms to ensure communication and task contributions towards the project. The project team attract and facilitate communication through mechanisms such as peer2peer apps, social media group discussions, embedded web or mobile advertising, and so on, as well as incentivize the crowd based on their intrinsic or extrinsic motivations. The findings reveal the attention to crowd characteristics, showing appreciation and rewards towards contributions is a good means of moderating the process (Afuah & Tucci, 2012; Ghezzi et al., 2018). Participant B describes:

"Some of the practices we have observed is they have someone who is responding, such as saying 'Thank you for your idea or thanks for participating'."

Effective communication between the team and the crowd facilitates the generation of ideas, which are then filtered through a phased evaluation process. It was found that criteria and techniques such as cluster validation, voting, popularity, simulated spending, pre-buying, choice ranking by comparing team, and crowd-ranked submissions, amongst others, are utilized to filter the magnitude of crowd submissions which challenging (Girotra, Terwiesch & Ulrich, 2010). The top submissions are evaluated based on their appropriateness and benefits. Following this stage, the integration of ideas is guided by varying metrics such as the feasibility, ease of implementation and return on investment (Jouret, 2009; Aitamurto, Holland & Hussain, 2013), ultimately leading to the reward of a winner and project outputs. The introduced feedback channels allow for continuous improvement of the process and readiness levels towards future projects. Generally, the success of crowdsourcing innovation activities can be determined by metrics such as the quantity and quality of ideas submitted and taken forward, speed of achieving results, crowd engagement, and participation rate (Shao et al., 2012; Zhu, Sick & Leker, 2016).

6.4 Crowdsourcing Science Process

This section will cover the crowdsourcing science process. Figure 6.3 illustrates the uncovered crowdsourcing science process and underlying activities derived from the data analysis. In accordance with previous studies (Cooper et al., 2007; Newman et al., 2012), figure 6.3 is a five-stage process of how the stages fit together with the underlying management activities and feedback channels.

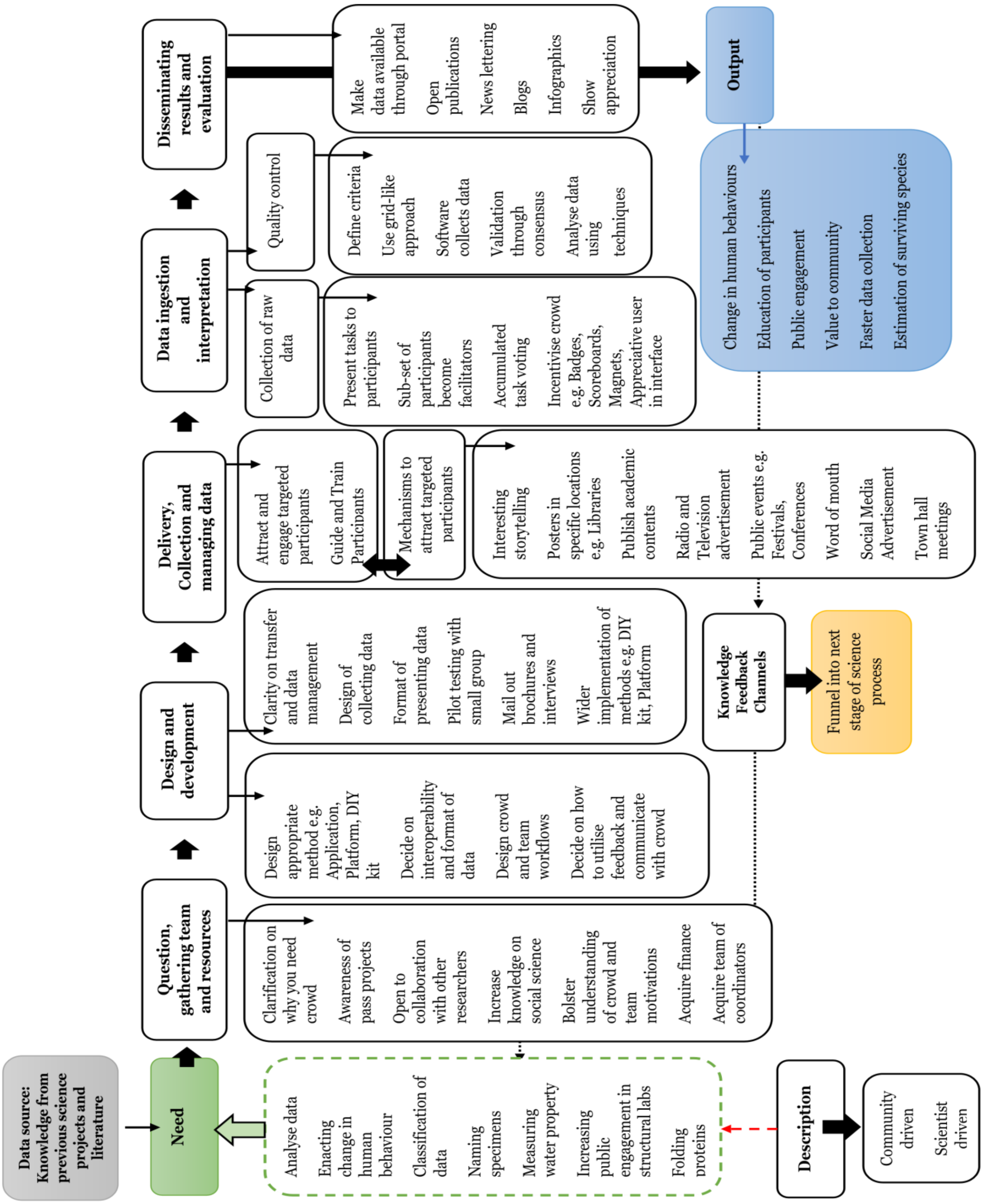

Figure 6.3. Crowdsourcing science process

The findings reveal that the crowdsourcing science process starts with a need at a specific time, depending on the research question and the advantages of crowd involvement. Motivated by either a community or professional scientist, tasks ranging from but not limited to running software simulations, measuring water quality, data collection, searching for fossils, monitoring and identifying species are utilized to solve the need (Liu et al., 2014; Follett & Strezov, 2015; Flower et al., 2016). This study's findings confirm that the purpose of crowdsourcing science can either be a contribution to open science or obtaining support from a community (Schildhauer & Voss 2014). As described by AA:

"There are many if you look at the number that exists but the most standard ones such as data collection such as taking pictures, measure stuff. You also have a decider aspect with what is called volunteer thinking and this can just be a person sitting in front of a computer just analysing images, tagging images, transcribing text, looking for specific information in documents, tracking setting streets, classifying galaxies."

During the design and development stage, a cross-functional team acquires adequate resources to design the project, perform platform beta testing, select appropriate methods, and form engagement. It was found that projects can be either co-created, competitive or contributory (Schröter et al., 2017; Follet & Strezove, 2015) but are designed following a "horses for causes" notion such that the selected designs and mechanisms are task-specific. The delivery and data collection stage entails crowd recruitment, crowd submissions and engagement through mediums varying from word of mouth, advertisements on platforms, workshops and events. These mediums offer avenues to provide training on a project's task. Participant AC described:

"we tried to make it approachable by teaching how to use the tools and how a protein should be folded up. So there is variety of training that can be done from project to project."

Participants were of the view that providing training, and guidelines, as well as determining the reliability of the crowd beforehand, ensures the collection of valid and reliable data (Minkman, Overloop, & Sanden, 2015; Rutten et al., 2017; Parrish et al., 2018). The data interpretation and ingestion stage involves ensuring the task is completed, and the collected data is valid and of good quality. It was found that participants utilize many methods and techniques such as statistical and consensus methods, automatic machine learning and filtering techniques during the design stage and after task completion. Participant AB mentions:

"then you have to go through this quality control process so you need to ensure that data collected have particular quality (High or Low) but you need to define it."

This leads to data evaluation through professionals and dissemination through open channels such as publications, newsletters, and infographics. From the responses, outputs can lead to a change in behaviour and aid decision making. Following this, the introduced feedback channels allow for continuous improvement of the process and readiness levels towards future projects. Generally, outputs are available.

In the next section, a comparative analysis of crowdsourcing activities is performed to reveal the general crowdsourcing process, its phases and sub-components.

6.5 Comparative Analysis of Crowdsourcing Activities- General Crowdsourcing Process, Management Activities and Evaluation Mechanisms

This section will cover the general crowdsourcing process. Figure 6.4 is a holistic view of the general crowdsourcing process based on the I-P-O components and analysis comparing its use during science and innovation activities. From the perspective of systems theory, this study uncovers the relationship between the key phases, activities and components (Simsek, 2009; Ghezzi et al., 2018).

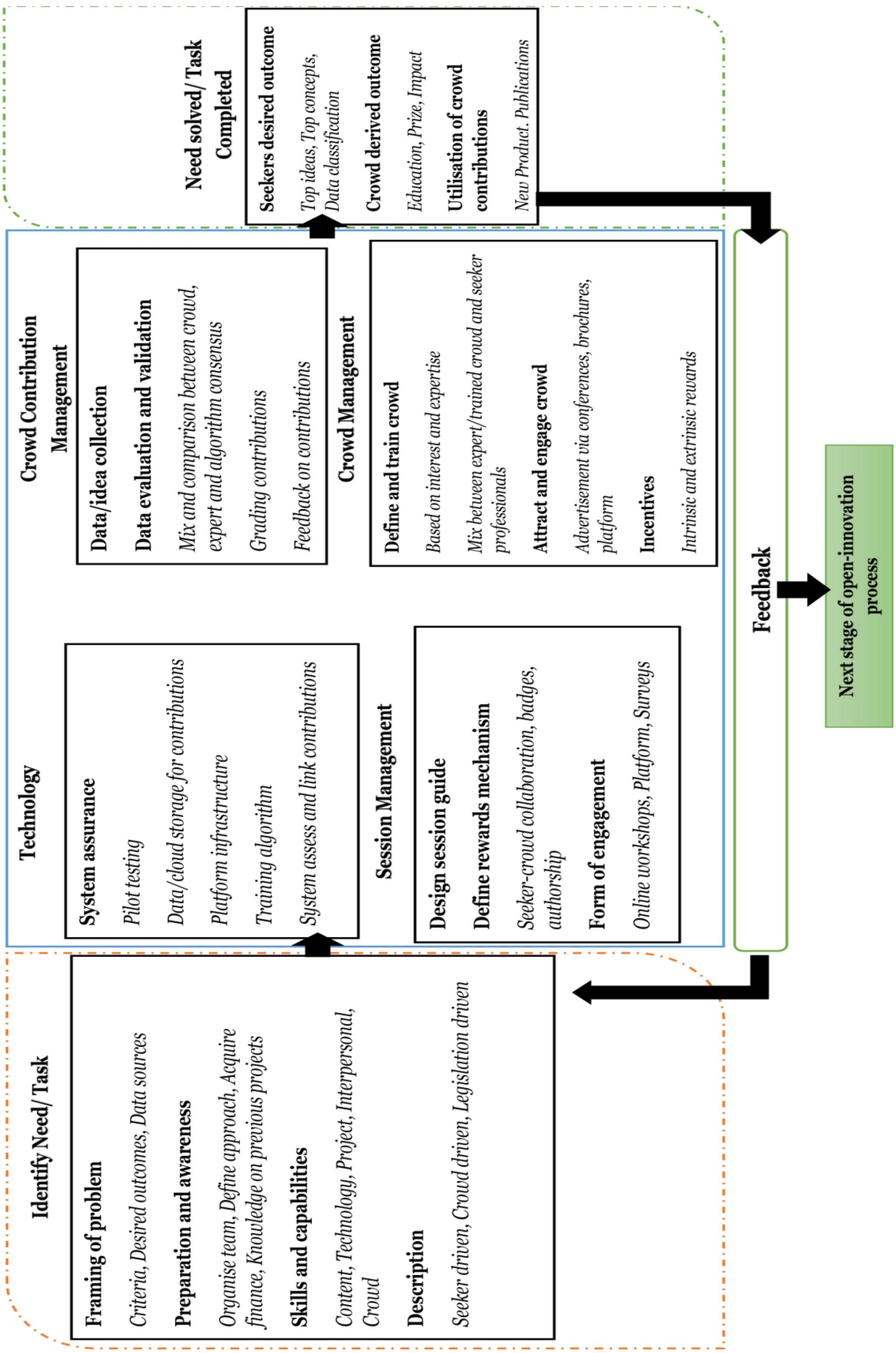

Figure 6.4. General holistic crowdsourcing process based on science and innovation activities

6.5.1 The Input Phase

The findings reveal that the crowdsourcing process consists of three main phases and feedback channels. The input phase is divided into sub components - *preparation and awareness, drive, framing of the problem, skill and capabilities needed*. The identified subcomponents facilitate the preparation and acquiring of the right resources to manage the entire process before the start of crowdsourcing initiatives. Data sources within internal and external networks are utilized to support the process, which can be initiated by the crowd or seeker (Newman et al., 2012). Comparing both activities, similarities in purpose exist, but the outcomes achieved differ. In science domains, crowdsourcing is not performed with the sole reason to achieve commercial value like innovation (Palacios et al., 2016). Instead, outcomes are for scientific discovery, creating awareness, generating data, and improving non-professional knowledge and skills (Stodden, 2010).

The crowdsourcer's purpose to utilize the crowd should be driven by a cross-functional team involving a champion and diverse team. The decision to involve the crowd has to be driven by a champion that believes in the crowdsourcing project and encourages a team's willingness to collaborate in this approach through the commitment of resources (Zhu, Sick & Leker, 2016). In the case of AM (science), the involvement of a champion (professional scientist) with a diverse team—also acquired funding from the government. This approach was successful, as the measurement of water quality and quantity involved volunteers participating for a year, even with reduced interaction. Success was also achieved for innovation activities, such as in the case of Participant J.

"We have people within the organization that understand these things and can talk about it. In the end, its about communication to enable people understand what is about. The ability to convince who make decisions within that environment and there are quite a lot of people and they all work in there own groups and field some are scientist, developers, designers etc.

how do you make them understand this is where we are going and it does make sense that they are in a position of power to decide on things."

The framing of the problem consists of breaking the problem into solvable tasks, which encompasses the objectives, criteria, and measure of success. According to previous studies, the skills and capabilities are categorized into dimensions (Ghezzi et al., 2018; Podmetina et al., 2018). It was found that the required skill set of the team managing the crowdsourcing project can be grouped into 1) Content–process, 2) Human–crowd, 3) Technology–process, 4) Human-interpersonal, and 5) Project-process. Table 6.1 below gives a breakdown of the skills and capabilities required for managing crowdsourcing science and innovation.

Table 6.1: Breakdown of Success Factors in terms of Skills and Capabilities for Managing Crowdsourcing Science and Innovation Activities

Skills and capabilities for managing the crowdsourcing process	**Descriptions**
Content – Process skills and capabilities (*ability to analyze and assess crowd contributions; sense-making abilities (critical, transformational thinking and making connections); ability to recognize high-quality ideas; ability to be a visionary; attention to details)*	These skills and capabilities are utilized when seekers have commenced crowdsourcing activities. The organizing party is responsible for having expertise in assessing ideas beyond lateral thinking and connect ideas based on future prospects and knowledge
Human – Crowd skills and capabilities *(ability to align and communicate with the crowd; guidance and coaching the crowd; empathy; assessing and strategic selection of crowd participants; showing appreciation to the crowd; understand the motivation of crowds)*	These skills and capabilities are related to the seekers' responsibility of ensuring the participating crowd take in the knowledge required to complete, as well as the capability to tutor crowd in achieving the aims of initiatives. The involved team personnel ensure the achievement of outcomes through empathy and valuing of the crowd.
Technology – Process skills and capabilities (*creative and less repetitive activities; design time-bound and direct questions; offering time and adding elements of surprise and fun; designing an engaging campaign; the presence of a reward system)*	These skills and capabilities are related to the seekers' responsibility of designing platform infrastructure or selecting the right third-party vendor to achieve the required outcomes and create a soothing experience for the crowd and seeker.

Human – Interpersonal skills and capabilities (p*resence of diverse team; the presence of decision-making authority; the spirit of leadership and togetherness; courage and openness to experiments; the presence of designers)*	These skills and capabilities are related to the seeking team as the required team should imbue a diversity of skillset.
Project – Process skills and capabilities (a*bility to understand the problem and convert into exciting question based on the needs of customers; strategic use of crowd members; making the campaigns exciting and pleasurable for participation; accurate matching of the crowd with problems; providing an avenue to test ideas and experiment; viability and feasibility personnel; having a human element; facilitation of a creative process; providing incentives and rewards)*	These skills and capabilities are related to the seekers' internal components, project and management of the crowdsourcing process. The fit between seekers methodologies and achieving crowdsourcing outcomes is necessary for arriving at beneficial results.

6.5.2 The Process Phase

Following the preliminary phase, the process phase continues with various activities that can be grouped under *session management, technology, crowd management* and *crowd contribution management* (Thuan et al., 2015; Ghezzi et al., 2018). The identified components facilitate the achievement of the task at hand with support from the teams' group maintenance and development (Shachaf, 2010). The findings correlate with (Ghezzi et al., 2018), who identified similar components. Technologies utilized come in the form of the platform infrastructure, which can be inbuilt or from a third party and complemented with applications. Examples of identified platforms are Jovoto, Zooniverse (Panoptes system), Foldit (Rossetta), Pixel, Ideascale and Chaordix as well as digital tools and applications (Trello, Slack, Platowork, Litterati, etc.). Platforms utilized have some form of avenue for discussions and contributions, depending on the nature of the task. Science activities tend to allow more use of apps, mobile technologies such as drones, and sensors to perform tasks. Also, an underlying technological infrastructure with the necessary data storage and capability to assess and link contributions is a major component for achieving success with crowdsourcing.

The session management allows for the incorporation of technologies and tools to manage the crowdsourcing session. The design of an appropriate method to engage the crowd, the workflow, data interoperability, and format are selected according to the suitability towards solving the problem. In science, tasks performed can range from collaboration on research questions, building protein structures, litter picking, mapping regions, and so on. Compared to crowdsourcing for innovation, tasks can range from idea generation, testing prototypes, generating new recipes, new flavours, etc. Given the different tasks in both domains, appropriate incentives are decided.

Another component of the Process Phase deals with crowd management. Similarities occur in terms of motivating the crowd during the process. Management teams should ensure the crowd undergo training, as well as develop means to attract and continuously engage the crowd, ensuring the process is fun and making use of incentives (intrinsic/extrinsic) to encourage the crowd. The recruitment of participants is essential for both activities. For scientific activities, some researchers utilize public broadcasting channels such as radio, television, and word of mouth. While for innovation activities, engagement with the crowd occurs using communication channels such as online workshops, intermediaries, etc. Similarities further exist as the recruitment of the crowd is done in a selective and liberal manner to allow participation (Girotra, Terwiesch and Ulrich, 2010). Girotra, Terwiesch and Ulrich (2010) proposed the need for a screening process to select and employ the highest performers, thereby leading to a higher chance of arriving at valuable outcomes. Generally, both activities test and gauge crowd members capabilities to perform tasks. A multi-level incentive approach can be adopted to engage members.

For example, in science, co-authorships in publications are utilized. Participants from both activities revealed the importance of showing appreciation during the process, which can positively affect the engagement and participation level of the crowd. However, it was also identified that gamification mechanisms could have adverse effects on the process (Kavaliova et al., 2016; Morschheuser et al., 2017).

The process phase includes another component that deals with crowd contributions management, depending on the task. The analysis revealed similarities as the majority of participants combine evaluation methods in a stage like process. For science activities, the interoperability of data is essential, as this would ensure the data collected is sharable later on in the process. Depending on the task performed by the crowd—collaborated, co-created or contributory—quality assurance is ensured in two ways, either before the data collection or after data has been collected. Methods utilized to ensure data quality assurance involve gauging the crowd members' skill sets, provision of guides, pilot testing, weighting participants' ages against the capability of accurate data collection, and, generally, participants' training (Cunha et al., 2017). Table 6.2 below is a breakdown of the data evaluation mechanism.

Table 6.2: Data Evaluation Mechanism process during Crowdsourcing Science Activities

Stages	**Descriptions**
Pre-stage: Preparation	• Methodologies vary and are project dependent • Providing a task-appropriate method to a group of participants • The proposed method should be simple and easily understandable • A multistage process involving iteration stages
Stage 1: Piloting, design, and training participants	This stage involves the design and pilot testing of the project. Pilot testing with a subset of participants allows for the detection of possible errors. The scientist in charge also assesses the skillset of crowd

	members, provide manuals and supporting materials to guide the crowd. Members are guided on the use of tools such as smartphones, experimental data collection, map-to-guide the crowd. Quality control is also determined by certain criteria which are project-specific and are imbedded in tools utilized.
Stage 2: Mechanisms	This relates to the mechanisms utilized by projects. Commonly used mechanisms include the average consensus of different participants complemented automatic systems and weighting of participants data collection experience to arrive at high-quality data. A subset of the crowd can also work independently to evaluate the collected data. Alternatively, comparison of crowd participants' vs experts collected data, expert checking of crowd collected data and collected data to train automatic detection software are helpful.
Stage 3: Results	The decision to accept data and utilize it in the research process is finalized through an average threshold of answers from comparisons. The threshold approach can be considered subjective.

For innovation activities, crowd members who are knowledgeable and skilled for projects are selected to reduce noise in idea contributions ensuring the right ideas are generated (Zhu, Sick & Leker, 2016). Table 6.3 is a breakdown of the idea evaluation mechanism.

Table 6.3: Idea Evaluation Mechanism process during Crowdsourcing Innovation Activities

Stages	Descriptions
Pre- Stage: Preparation These are areas that should enable preparation and guide the organization.	• Sources of information: Sources fall into direct or indirect means. They range from customer complaints, customers suggestions through market research, historical data on current products and market trends.

	• Mediums of engagement: Means of engagement vary from workshops with empathic design, ethnographic sessions, end to end service report and innovation challenges. • Briefs and criteria: Emphasis should be made on ensuring invitational briefs are enticing and clear on expected outcomes, objectives and supported by asking the right questions. • Access to a targeted network of solution providers and evaluation experts.
Mechanism and Criteria	• Cost to implement • Feasibility or capability of the firm • Gut feeling • Money saved • Popularity and voting • Relevance to customers • Value to organization • Fit within organization scope and interest
Stage 1: Intuitive scaling, voting and popularity of ideas	This stage involves the crowd's contribution and voting on favourable ideas concerning the needs of the seeker. Methods such as crowd thumps up or down, simulated spending, and distributed crowd evaluation helps platform algorithms gain early preference.
Stage 2: Evaluation based on idea related criteria	Seeker product owners and project managers evaluate top ideas from stage 1. Strategic sprint sessions enable grading ideas according to the feasibility of the idea, impact, time or cost.
Stage 3: Evaluation based on seeker criteria	Ideas are further evaluated based on gut feeling, organization objectives and capabilities.
Stage 4: Comparison between outcomes in previous stages	Top ideas from each stage are clustered, validated, and compared against each other to weed out bias. Using stochastic analysis, decision trees, and Delphi, ideas are evaluated based on underlying desire rather than popularity.
Stage 5: Selection of winner and implementation	The selected winner is rewarded with a prize or involvement during the next steps of product development.

Generally, in the management of the crowd contributions submission phase, differences occur in the evaluation approaches to arrive at meaning results. This study finds that the combination of multiple evaluation mechanisms in a stage like process can assist organizations in achieving outcomes that can be valuable (Afuah & Tucci, 2012; Lauto and Valentin, 2016). Table 6.4 below illustrates the different mechanisms identified during both activities, respectively.

Table 6.4: Evaluation Mechanisms for Science and Innovation Activities

Evaluation Approaches: Science	**Evaluation Approaches: Innovation**
• Automatic checks • Machine-learning filtering techniques • Multiple volunteer visits • Peer-to-expert observations • Preferential sampling method • Providing training and guidelines • Researcher manual visits and comparison • Researcher use of statistical methods • Researchers rationality methods • Statistics and consensus • Using the reliability of users to ensure quality • Volunteer to crowd checks • Weighting participants' ages against the accuracy of data	• Alignment of stakeholders in the selection process • Choice ranking • Cluster validation • Compare team and crowd ranking • Criteria for success (Strategy, Innovation, Cost, Feasibility and Sales) • Estimated cost, time and return • Evaluation by the product owner • Evaluation with participants • Market trends • Number of likes and votes (1-5 Stars) • Pairwise • Pre-buy option • Select ideas by criteria • Self-filtering process due to targeting of experts • Simulated spending • Thumbs up or down • Voting and Popularity

6.5.3 The Output Phase

The output phase includes the *tasks completed, desired outcomes and utilization of crowd contributions*. Several authors propose variables that measure the performance and effectiveness, ranging from usefulness, individual satisfaction and completeness (Shachaf, 2010). The findings reveal this phase relates to the end of the crowdsourcing process comprising of the seekers and the crowd's desired outcome, as well as the utilization of contributions. Outcomes may differ, comparing the use of crowdsourcing for science and innovation. The outcome of crowdsourcing for science activities ends with the arrival of results, which can be a scientific discovery through publications and increasing the crowd's knowledge. Crowdsourcing for science can also end with the realization of innovations such as a new statistical model, algorithm, and so on, however, the end result of most science activities is the contribution to knowledge with little-or-no interest in commercialisation (Chesbrough, 2015). Unlike the use of crowdsourcing for innovation, most campaigns lead to tangible improvement to a product or service for commercial value. This study identifies that sharing data through open channels can increase the impact of initiatives, which correlates with the literature (Gharesifard and Wehn, 2016; Schlagwein et al., 2017). Generally, this study identified several factors determining the success of crowdsourcing innovation activities ranging from the quantity and quality of ideas submitted and taken forward, speed of achieving results, crowd engagement, and participation rate (Shao et al., 2012; Zhu, Sick & Leker, 2016). Table 6.5 reveals the general factors that determine the success of the examined activities.

Table 6.5: General Success Factors for Crowdsourcing Science and Innovation Activities

Crowdsourcing Science	**Crowdsourcing Innovation**
• Access to inaccessible regions • Access to local insights • Access to local knowledge • Amount of data • Availability of workforce • Base data for artificial intelligence • Cheaper alternatives • Enabling decision making	• Easy to understand outcomes • Engagement and participation rate • Enrichment of the product through collaboration • Feasibility and return on investment • Ideas taken forward • Quantity and quality of ideas submitted

• Engagement with the public • Fun • Greater community outreach • Greater outreach • Opportunity to educate a large audience • Scale and collecting more high-quality data • Scientifically correct data for changing policies • Speed of collecting data	• Speed of achieving results

After the overall process, the introduced *feedback channels* allow for reflections, continuous sharing, and information extraction for future projects. The proposed holistic process is iterative due to information concerning difficulties and changes needed, relayed back to improve the entire process. These channels enhance management teams readiness levels and can boost confidence for future crowdsourcing activities. In summary, the involvement of the crowd during science and innovation activities can provide beneficial outcomes.

Generally, the paradigm for performing science activities aims to achieve research discoveries and findings that result in publications. Compared to crowdsourcing for innovation, the paradigm shifts to the technical application of knowledge and development towards commercialization. This study contributes to the literature by providing evidence that different knowledge and efforts from internal or external sources can lead to valuable outputs (Chesborough, 2006). The following section will examine the significant factors influencing the utilization of crowdsourcing for innovation activities.

6.6 Enablers and Barriers for Crowdsourcing Innovation Activities

Figure 6.5 gives a breakdown of the uncovered factors and their underlying contexts. Following previous studies (Bigliardi & Galati, 2016; Zahay, Hajli, & Sihi, 2018), the findings show that influential factors fall within technological, organizational, and environmental contexts. The identified factors that influence crowdsourcing innovation are discussed according to their relationships and descriptive elements in the next sub-sections.

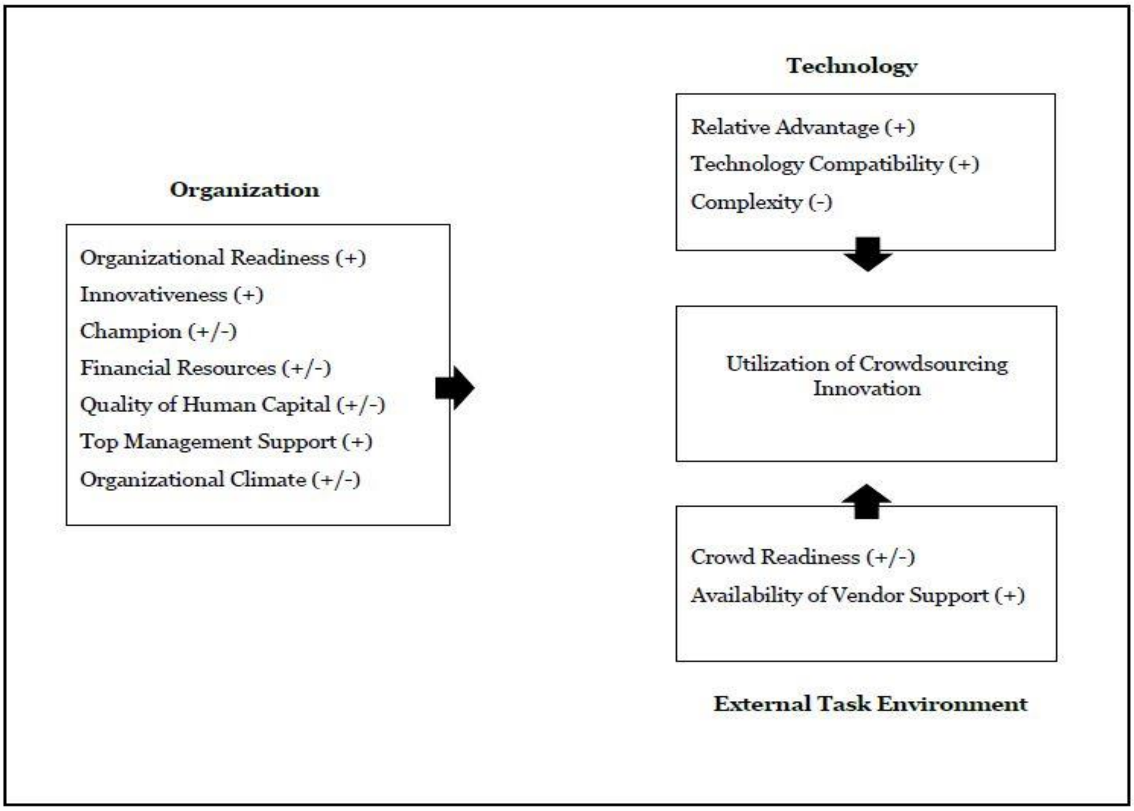

Figure 6.5. Contextual determinants, enablers (+) and barriers (-) for crowdsourcing innovation activities

6.6.1 Technology Context

This section covers how technologies can inhibit and enable the utilization of crowdsourcing innovation. The study identified three factors in this context, which are relative advantage, technology compatibility, and complexity.

6.6.1.1 Relative advantage (+)

The findings from interviews reveal that certain benefits enable the use of crowdsourcing as an effective means to achieve innovative activities. Relative advantage relates to benefits such as access to a large pool of ideas and the opportunity to create an outside-in perspective that acts as influencing elements when crowdsourcing for innovation. As described by Participant J:

"Outside-in Perspective which is customer-oriented and market-oriented is the new way which shows a new cultural change cos internally you cannot service that." - J

The study findings revealed that seekers benefiting from its use for innovation can encourage more experimentation, giving them the opportunity to link products to the reality and wants of the customer. This concurs with the findings of previous literature (Qin et al., 2016).

6.6.1.2 Technology Compatibility (+)

Based on the interviews conducted, the technologies available to seekers that fit in with industrial processes can enable the use of crowdsourcing for innovation activities. Participants expressed the fit of crowdsourcing and the existence of tools and platforms with certain features suitable for the innovation process, allowing for easy communication between seekers, crowds and other stakeholders. Tools such as Trello, Scrum, email management systems, feedback forums, automation algorithms, and social media allow for activities such as idea submission, idea voting, and idea commenting. For example, the compatibility of these tools allows for offering feedback and utilizing contributions for further developing innovative strategies, products and services to the benefit of organizations. As described by Participant G:

"…We find this incredibly important that if you know there is a particular idea that is way of track, you need to give that feedback so that it is a valuable exercise for the person/the crowd and also it is a valuable exercise for you the company so that the time spent on ideas that are going to make a difference for your company." - G

Inbuilt data security is also an element contributing to the technology compatibility factor. This can create a safe environment during crowdsourcing innovation activities, as ensuring trust through anonymity is necessary for the smooth running of initiatives

(Djelassi & Decoopman, 2013; Qin et al., 2016). It was found that too much transparency can create an unsafe environment for crowd members, such as participants choosing to support their bosses' ideas, even if they might not be the best contribution. This will tend to undermine the whole system. As described by Participant I:

"the problem is most platforms are built by technologist who come from purely a technology mind set and they get a little bit obsessed with perfect transparency and almost gamifying participation so you can build your own profile internally but actually what that does is not crowdsourcing but politicking which is creating a game around profiles rather than the game of fixing the problem which leads to losing track of a solution. If someone has been invited to share their ideas reviewing the ideas of others and their name is attached to those ideas, it psychologically creates an unsafe environment and the number/quality of those ideas automatically drops as the focus becomes game playing and becomes about politicking such as if you are my boss, I need to be seen to like your idea and build on your ideas because you are my boss." - I

In summary, the compatibility of technologies has an enabling effect.

6.6.1.3 Complexity (-)

The complexity of developing and utilizing crowdsourcing platforms is a barrier to performing crowdsourcing in innovation activities. An important reason was related to the engineer's idea of building platforms with many features. However, when used (features), participants instead preferred simple-to-use, appealing, and intuitive platforms due to unnecessary complications faced. Participant I described:

"*What is interesting is that engineers love to see a platform that looks quite complex. If an idea is posted on the platform, they like to give it some rating by a number of criteria. So we did some work with some physicists and we told them they were able rate this ideas by three different metrics but then working with the NHS organization, they liked it very simple and they wanted it to look simple and actually when you have got a multidisciplinary group the technology needs to look really simple to the point where is less intuitive and you don't have to teach people how to use it.*" – I

Participants also expressed the constraining nature of certain tools inhibiting usage during certain stages of the innovation process. This correlates with the findings of previous literature (Zahay, Hajli & Sihi, 2018; Evans et al., 2015). Evans et al. (2015)

revealed difficulties using crowdsourcing during certain stages of the NPD process. Hence, complexity has an inhibiting influence. Participant F said:

"In my experience and I have tested many, digital platforms are good to get creative directions, good for scenario thinking, good for feedback of what's happening, good to dream about ideal situations but not too create. It is good for input aspects of NPD process but not creating because it is an art of itself and I feel it is unnecessary. Testing again is also an aspect you can crowdsource and getting feedback. If you look at the whole NPD process, there are many things you can crowdsource except for the creation itself. There are creative platforms that we can do this nicely with a small group of people but it is not a crowd." - F

The next section will cover organizational factors that influence the use of crowdsourcing for innovation activities.

6.6.2 Organization Context

In this section, the organizational barriers and enablers are discussed, and they influence the use of crowdsourcing for innovation activities. Seven organizational factors inhibit and enable crowdsourcing, ranging from the presence of a champion, organizational readiness, organization climate, financial resources, innovativeness, quality of human capital and top management support. Within this theme, the researcher identified most of the influencing factors which could imply that seekers would face organizational difficulties when utilizing crowdsourcing for innovation activities.

6.6.2.1 Organizational Readiness (+)

Organizational readiness was identified as an influential factor that can enable crowdsourcing utilization for innovation activities. Interviews with 11 out of 17 participants revealed an organization's capability to perform crowdsourcing is vital. Elements such as the necessity of having the capability to set up campaigns, a strategy, complementing human ability with automation, and having a procedure for managing the intellectual property were key elements for ensuring firms can perform crowdsourcing. As described by Participant E:

"When you ideate on a big scale, you need some sort of tools and processes in place to ensure you do not just get a pool of ideas but a process for those ideas to be evaluated at the right time by the right people." - E

Organizational readiness has an enabling influence on the utilization of crowdsourcing innovation activities, which concurs with findings that an organization's capability to crowdsource is essential (Maiolini & Naggi, 2011; Oliveira, Ramos & Santos, 2010).

6.6.2.2 Organizational Climate (+/-)

An organization's climate can also be considered an enabler. The findings reveal an atmosphere that encourages openness, transparency and external experimentation can boost the use of crowdsourcing for innovation activities (Von Hippel, 2009). Participants revealed that open business models encouraging a collaborative culture, top-down changes in thinking, and willingness to innovate without fear of failure could enable the achievement of disruptive outcomes (Djelassi & Decoopman, 2013). Participant J explained:

"… but I would say we just opened up to it, we said lets do this in that manner, we have got a platform that allows doing it so it just made sense to do it."

Organizational climate, however, can also have an inhibiting influence. Elements of this factor are the inability to understand crowdsourcing's value, rigid nature and the unwillingness of company professionals to collaborate externally. This stems from employees' fears around meeting the crowd's expectations and restrictive culture. Participant M said:

".. a lot of these thing come down to the cultural aspect of what you do. Yes I feel ultimately, people would need to adopt this mentality into their culture and the challenge is how you harness it and drive it to visional company agenda and create a win-win with customers."- M

Organizations' structures that do not encourage experimentation and outside-the-box thinking push teams to not pursue risky activities. This finding concurs with previous studies (Simula, 2013; Evans et al., 2015), who identified the presence of organizational resistance and not-invented-here syndrome as challenges. Organizational climate has an enabling and inhibiting influence on crowdsourcing utilization for innovation activities.

6.6.2.3 Innovativeness (+)

Innovativeness is identified as a factor of influence that can enable the utilization of crowdsourcing to achieve innovative outcomes. Elements of this factor are the methodology to approach and solicit crowd contributions, the capability to refine contributions, and select the right sample—has enabling influence on the utilization of crowdsourcing. The methodology to approach, and solicit crowd contributions relates to asking specific and creative questions as well as selecting the right level of crowd members (Chao, Reid & Mavondo, 2012). Participant F said that *"you need to verily try to trigger creative questions thinking, critical thinking questions."* While Participant D expressed:

"It always works because we are targeting people." - D

Innovativeness also requires the using of new forms of thinking around crowd contributions. Team members with sufficient skillsets are essential, as the process requires outside-the-box thinking, attention to detail, making connections and sense-making abilities (Qin et al., 2016). Generating value by connecting inputs can support the effective use of crowdsourcing during innovation activities. Empathy is, therefore, needed to understand the crowd's underlying desires and refine contributions. As described by A:

"If you include consumers you need to listen according to their feedback or else why are you building them." - A

In conclusion, innovativeness shows to have an enabling influence on the use of crowdsourcing for innovative activities.

6.6.2.4 Quality of Human Capital (+/-)

The quality of human capital is identified as a key influential factor for utilizing crowdsourcing for innovation activities. Elements of this factor relate to 1) the skills to design and manage campaigns, 2) the capability to assess and spot profitable ideas, and 3) social skills and communication with the crowd. When it comes to designing campaigns, the findings reveal ensuring campaign sessions are intuitive to build an environment for contributions. The team responsible for managing these sessions are vital. As crowd contributions are not a given, receiving contributions depends on the relationship between the organization and the crowd. Ebner, Leimeister and Krcmar (2009) argue that lowering technical barriers can positively affect participation levels. As described by O:

"You need strategic sponsor, communications teams, moderators, SMEs, Innovation manager/s to help design and run the process." - O

Design and managing sessions are not enough. Sessions involve the expectation of numerous idea contributions (Mortara Ford & Jaeger, 2013). The capability to assess and recognise ideas can also enable the utilization of crowdsourcing. It is also essential to have the right personnel or team that can spot great ideas. This team would need to be in close collaboration with a department that facilitates intellectual property management. As F said:

"…getting someone who can read through the data as well. Just by creating a space and environment you probably would come up with the aha ideas but it still requires someone to recognise them." - F

The quality of human capital, however, can also act as a barrier, as the entire process can be slowed down by the lack of personnel or team with social science capabilities to communicate effectively with the crowd and retain crowd numbers. This aspect relates to the lack of understanding the intrinsic or extrinsic motivations of the crowd, and the use of specific gamification mechanisms can have adverse effects, as described by B and Q:

"The key skill to have is communications with participants, which is not something everyone is good at." – B

".. they usually really on leader boards and point systems which can be gained and can have a negative impact with a sense of belonging people have. In general, they are just not sustainable because many people tend to go away." - Q

These findings concur with previous literature, which states that gamification mechanisms should be used with discretion by organizations (Kavaliova et al., 2016; Boulet, 2012; Morschheuser et al., 2017) as well as team's unclear responsibilities (Maiolini & Naggi, 2011; Zahay, Hajli & Sihi, 2018). If these mechanisms must be used, the team's relationship with the crowd, motivations and empathy are important. The quality of human capital shows both inhibiting and enabling effects on crowdsourcing for innovative outcomes.

6.6.2.5 Top Management Support (+)

The utilization of crowdsourcing during innovation activities can be enabled through top management's belief that crowdsourcing activities will result in valuable outcomes. This belief can drive other employees to utilize crowdsourcing for innovation activities such as developing new products, developing new ideas for a brand, or designing a new concept. Participant D explains that

"...there needs to be an internal buy-in by senior management." - D

Furthermore, the top management's support for upcoming ideas will encourage a culture of collaboration and accelerate innovation pipelines. As described by E:

"[It is necessary for] *leadership to sponsor those ideas. Whenever you involve the crowd using the ideation programme, the leadership should be willing to support those ideas too." – E*

Top management support is identified as a key factor that enables the utilization of crowdsourcing for innovation activities.

6.6.2.6 Financial Resources (+/-)

Financial resources for fuelling crowdsourcing innovation activities can affect a variety of areas when implemented. Organizations' use is enabled by financial support in terms of budget to fund experiments and drive team efforts. As D explains,

"..set a budget and organization in place then those are the key elements that make this thing work." – D

The lack of financial resources, however, can also inhibit the use of crowdsourcing, as the process can be expensive. A limited budget or no financial resources can affect attracting motivated team members, motivated crowds, and the integration of an efficient infrastructure to arrive at well-filtered top ideas. Participant H said:

"The biggest challenge is to fully understand the needs and pains of customers. When it is about the ideas and concepts, it is often experiments but it is difficult because there are other ways to do it. It can be a quite expensive thing to do due to what you really getting out of it because the thing is there is never a shortage of ideas." – H

Therefore, finance is identified as a key factor that can enable and inhibit crowdsourcing for innovation activities (Zahay, Hajli & Sihi, 2018).

6.6.2.7 Champion (+/-)

The presence of a champion is perceived as a factor for the achievement of innovative outcomes through crowdsourcing. The empirical finding suggests the presence of an individual with positive promoting beliefs, relevant knowledge on the phases, activities, and skills needed can enable the utilization of crowdsourcing. The champion should be involved during the creation of the brief and further ensure crowd creatives stay on course. It was found that a champion who can connect, empathize and encourage crowd conversations can enable the free flow of contributions. This vital figure would also ensure conversations stay on topic and in line with the purpose of the session. Participants D described:

"the key is to have someone to champion such and make it a success." – D

The above findings suggest that professional personnel with leadership qualities can drive the achievement of success through deep understanding and ensuring contributions are implemented whilst utilizing crowdsourcing. However, the achievement of results also depends on the integration of contributions into processes within said organizations. The lack of integration can lead to poor results and negative perceptions (Maiolini & Naggi, 2011). Participant J shared a follow-up comment that reveals that champions can inhibit successful outcomes if they can not convince the decision makers.

"The ability to convince who make decisions within that environment and there are quite a lot of people and they all work in there own groups and field some are scientist, developers, designers etc how do you make them understand this is where we are going and it does make sense that they are in a position of power to decide on things. Everything starts with people understanding so that's all about communication, involvement so its like if people are engaged then those barriers are overcommable if there not it becomes very difficult then you have to explain things and then they have there own agenda or ideas. The question is how can you prioritize. Also doing something from the users point of view helps them."

Therefore, champions can enable and inhibit the utilization of crowdsourcing for innovation activities. The next section will cover the external environment factors that would influence the utilization of crowdsourcing.

6.6.3 External Task Environment Context

In this section, the external environment factors that influence crowdsourcing for innovation activities are discussed. There are two external environment factors: availability of vendor support and crowd readiness.

6.6.3.1 Crowd Readiness (+/-)

Crowd readiness was identified as an influential factor inhibiting or enabling crowdsourcing innovation. Elements such as the presence of a skilled community, the engagement of the crowd and willingness to participate, can facilitate contributions that are somewhat valuable from the start. This reduces the level of invaluable contributions during campaigns. Participant D said:

"So we have a large network across different sectors and we tap into that network as required based on the profile individuals and expertise to respond to challenges." - D

Although crowd readiness is witnessed as an enabler, it can also inhibit the utilization of crowdsourcing in achieving outcomes in some ways. Low participation and crowd members' inability to come up with profitable ideas can make the process more complex, as the organization already has to deal with the massive amount of contributions. Participant H stated,

"It is hard to gain really new ideas from persons not deeply involved in the matter." - H

The above insights concur with viewpoints that state crowd members have to be selected based on expertise and interests (Poetz & Schreier, 2012; Qin, 2016; Afuah & Tucci, 2012). Therefore, crowd readiness has both enabling and inhibiting effects on the utilization of crowdsourcing during innovation activities.

6.6.3.2 Vendor Support (+)

The presence of vendors or third-party platforms—such as InnoCentive, Chaordix, Quirky, and others—enables crowdsourcing to be applied during ideation, concept development, etc. Experts and professionals in these platforms assist the utilization and encourage more inclusive applications. Platforms ensure tasks are fun and rewarding for all stakeholders involved. Participant J said:

"It is very difficult for a lot of these companies to do something with it that's why a lot of times they ask external companies to do a campaign or something because that is not part of their organization as they outsource it basically to a different environment where the actual process does not disturb the existing process..." – J

Thus, the presence of third-party platforms enable the use of crowdsourcing to acquire new ideas, develop products and services that can satisfy their customers and ensure a competitive advantage.

In summary, the preceding sub-section has given a breakdown of the uncovered findings. Summarized in Table 6.6 are the identified enablers, barriers, their descriptive elements and underlying contexts related to crowdsourcing innovation.

Table 6.6: Breakdown of the Enablers and Barriers Influencing Crowdsourcing Innovation

Context	**Related Factors**	**Enablers**	**Barriers**
Technology	Relative advantage	• Better understanding and closeness with customers • Large pools of ideas • Opportunity to create an outside-in perspective	
	Technical compatibility	• Use of communication channels • In-built trust to prevent spamming • Forums and feedback	
	Complexity		• Complication during certain stages of the NDP process • Inadequate and incompatibility of tools with the crowd • Difficulty balancing activities • Complex and expensive approach

Organization	Top management support	• Management support in investing upcoming ideas	
	Innovativeness	• Methodology to approach and engage the crowd • The capability to refine contributions • The capability to select the right crowd members • Space for flexibility and creativity • The use of gamification and incentives	
	Financial resources	• The resources to fund experiments	• Limited resources
	Quality of human capital	• The ability to build and design the process • The ability to communicate and maintain a relationship with the crowd • Assessing input and critical thinking skills • Having empathy and social skills • Department for dealing with intellectual property • Ability to understand the motivations of the crowd	• Lack of communication skills • Unmotivated team members • Inability to retain the crowd
	Organization climate	• Openness and willingness to experiment • Open mentality and comfortable employees	• Fear of collaborating with public
	Champion	• Managers involvement during the design process • Managers belief in the crowdsourcing process	• Lack of ability to integrate outcomes into organization process

	Organization readiness	• Having a strategy • Capability to set up competitions and to develop a brief	
External task environment	Crowd readiness	• The willingness to participate • The presence of a diverse network of participants • The skillset of participants	• The insufficiency of crowds skillset
	Vendor support	• The presence of third-party platforms	

The next section would examine and discuss the identified factors related to crowdsourcing science.

6.7 Enablers and Barriers for Crowdsourcing Science Activities

Figure 6.6 gives a breakdown of the uncovered influential factors and their underlying contexts. In accordance with previous studies (Tiago et al., 2017; Turrini et al., 2018), this study finds similar factors but are grouped based on theoretical constructs. The details of the uncovered enablers and barriers for crowdsourcing science are discussed below in the preceding sub-sections.

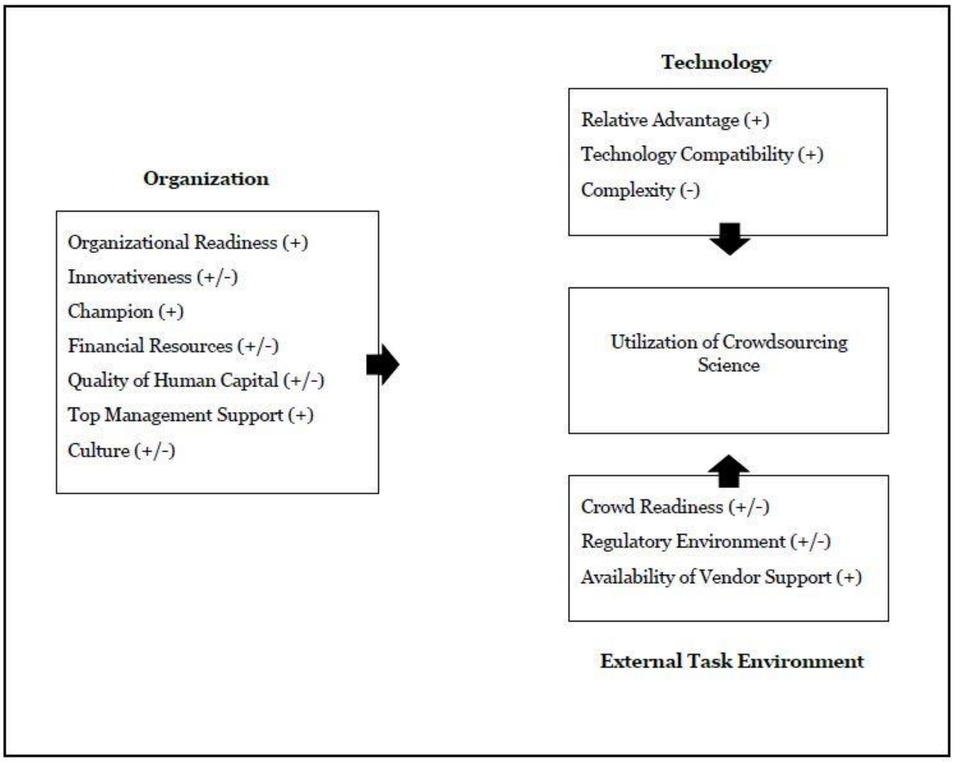

Figure 6.6. Contextual determinants, enablers (+) and barriers (-) for crowdsourcing science activities

6.7.1 Technology Context

This section covers how technologies can inhibit and enable the utilization of crowdsourcing for science activities. The findings revealed are divided into the following factors: relative advantage, technology compatibility, and complexity/simplicity.

6.7.1.1 Relative Advantage (+)

10 out of 17 participants mentioned the perceived benefits of using crowdsourcing for science activities, including access to local knowledge, availability of workforce, access to inaccessible regions, greater community outreach, opportunity to educate the crowd on science topics, and the scaling and collection of high-quality data to train software. This is supported by the findings from Cox et al. (2015), who identified contributions to science as a success factor. As described by Participant AA:

"Manpower geographically that amplifies in an enormous way. Like scientist normally are in one place but with this if you need more manpower, it helps." - AA

Therefore, relative advantage is identified as an enabling factor for crowdsourcing science activities.

6.7.1.2 Technology Compatibility (+)

The compatibility of available technologies relates to the fit of technologies with new and existing technologies. Technologies such as smartphones, GPS, internet connectivity, platform infrastructure, social media, cloud and data storage, can ease the performance of scientific tasks. The simple nature and appropriateness of these tools enable the approaching, communication and achievement of outcomes. As described by participant AL:

"I think its more about appropriateness so there are all sort of digital technologies for crowdscience tasks but it depends on what you want to achieve and whether it is appropriate to use those or not." - AL

6.7.1.3 Complexity (-)

The findings of this study revealed the complex nature of developing technologies and platform infrastructure due to high costs and lack of know-how. It was identified that tools can facilitate the performance of certain tasks, but participation and crowd accessing tools are not guaranteed. Furthermore, the lack of adequate data storage broadband and user-friendly design can inhibit the process. Tools such as GPS can be expensive to supply to every participant. Participant AB and AD said:

"*It is very difficult to develop the right technology to involve people as it is very expensive to build tools, interfaces that are attractive and usable for people. You need a lot of money to build tools for citizens to use."* - AB

"Data storage and cloud storage was a major problem at the time and also broadband speed were much slower and so we had to effectively reduce the resolution of our images." - AD

The findings show that complications in relation to technologies used, design and the process can inhibit the use of crowdsourcing for science (Fauzi et al., 2016; Minkman, Overloop & Sanden, 2015; Heiss and Matthes, 2017). The next section will cover the uncovered factors within the organizational context.

6.7.2 Organizational Context

This section covers organizational factors that can inhibit and enable the utilization of crowdsourcing for science activities. The findings revealed are divided into the following factors: financial resources, presence of a champion, top management support, culture, innovativeness (Horses for Causes), quality of human capital, and organizational readiness.

6.7.2.1 Organizational Readiness (+)

Organizational readiness is identified as a key factor. The analysis of 14 out of 17 participants revealed elements such as the need for organizations to guide and train members, the provision of cheap tools, setting up campaigns, and accommodating local knowledge, contribute to the factor. For example, providing training and guidance on how to perform tasks can immensely influence the success of projects (Feldman, Zemaite & Rushing, 2018). These elements describe the competence level of an organization to crowdsource science activities. Participant AC said,

"So there is a variety of training that can be done from project to project." - AC

Training and guiding the crowd can support the collection of high-quality data (Wiersma, 2010; Lukyanenko, Parsons & Wiersma, 2011; Worthington et al., 2012; Lewandowski & Specht, 2015). Therefore, this factor has an enabling influence on crowdsourcing science activities.

6.7.2.2 Innovativeness (+/-)

Innovativeness relates to the capability of project team members to drive the success of using this approach. Elements such as 1) assessing the skillset of crowd members 2) the capability to communicate with participants and show appreciation; 3) the capability to reward participants; 4) the capability to adapt approaches before and during projects (Horses for Causes); and 5) the use of data quality measures, 6) integrating simple task workflow, all require new techniques and constant iteration. AE weighs in:

"I think you have to be quite open and flexible. You also have to be willing to modify what your idea science experiment will be like to fit in with what is achievable for people, so really you would like for people to provide data 7 days a week so instead you have to compromise and make it 4 days." – AE

Innovativeness can also have inhibiting influence, as projects with ambiguous workflows, rigid design approaches and lack of guidance in identifying animal/plant species can have adverse effects on the process and results. Participants AI said:

"So it has been a very pioneering experience for us so we started that with one process and then we have learned from the ways the citizens respond to things and so our original workflow had a lot of questions and ambiguity and through that we found the answers we were getting were not as useful." – AI

Innovativeness is an influential factor that can inhibit and enable the use of crowdsourcing science activities.

6.7.2.3 Champion (+)

The presence of a champion relates to the drive and professional scientist belief in crowdsourcing's potential as well as utilize efforts to arrive at impactful outcomes. The findings reveal that a champion's presence has an enabling influence, as they have positively driven mind-sets and beliefs in the value of the crowd. AL said:

"Yes so thinking about from a researchers point of view, it can be really effective in delivering some of the motivations that researchers have for it. So the motivation about sharing of knowledge, democratisation science, impact of the study or work and it can be extremely beneficial in delivering impact if its designed to do that." - AL

The presence of a champion is shown to have an enabling influence on the utilization of crowdsourcing science activities.

6.7.2.4 Financial Resources (+/-)

The availability of financial support—which can either be internal or external—would have a positive influence. Professional scientists can use these funds to provide resources, rewards and manage the project more efficiently. At times, more than one citizen science project can be running, and in such cases, finance is an essential factor. Participant AH said:

"Initially, it was always that sounds like a novelty and I was funded for two years but after that it been a thing about what is the next thing after because nobody cares about major modifications to the platform that could be useful for the field." – AH

The lack of financial resources to fund projects and provide tools for participants can create difficulties. Difficulties emerge when tools are not available for the crowd to perform tasks that would lead to success in achieving knowledge discovery. Participant AO said:

"..we always trying to get funding and its hard as we have to apply to many funding sources and grant proposals which we don't get all of them and then we still have this platform that exist and grow. Its like you have to constantly bring in money to help the web development team and the management team behind the project because its not like there is an option to shut it down for a period of time. It has to be ongoing but we also have to fund the web developers or project managers." –AO

The findings in this study concur with the literature (Turrini et al., 2018; Hoover, 2016; Weathers et al., 2016). Hoover (2016) identified funding as a barrier to the implementation of citizen science. Financial resources are shown to enable and inhibit crowdsourcing scientific tasks, providing tools, and efficiently achieving outcomes.

6.7.2.5 Quality of Human Capital (+/-)

Elements such as the presence of a diverse team with skills, the ability to communicate with participants, being more open to learning from participants, planning projects and convincing academic peers, all contribute to the quality of human capital factor. The findings reveal that the quality of human capital factor has both enabling and inhibiting influences on crowdsourcing science activities. The lack of social skills, difficulty developing inclusive websites and lacking communication, can have a negative influence on participation levels during initiatives (Birkin & Goulson, 2015) The lack of time to write publications can also inhibit the use of crowdsourcing, as the impact from outputs can be delayed due to little-or-no publications (Hoover, 2016). AP and AH describe:

"you see people are very interested if they see that their data which is actually collected for fun is used by the scientist (real) and then afterwards this might be taken up by politicians because they see what results are." – AP

"I would say the biggest challenge was at the time we had no customer care experience so when things started going wrong and sociological challenges started happening with the way we will either present the research or with the way we would present change and that's was a very delicate issue." – AH

However, the presence of social skills and diverse teams that develop an environment for learning and open conversations has an enabling influence. Team members' abilities to value the crowd, have patience, and have a sense of humour, positively affect crowd member's experiences and science outcomes. Participant AO and AJ described:

"Our healthiest projects are the ones where the researchers are actively communicating with the volunteers." – AO

"....hired a coordinator and these coordinators are essential in the data collection side of things who set brochures, did interviews and set up projects on the platforms customised the mobile apps to meet the needs." – AJ

The findings correlate with previous findings that find the quality of staff capacity as a challenge (Goodchild et al., 2012; Perdana & Ostermann, 2018; Higgins & Shackleton, 2015). The quality of human capital has shown to enable and inhibit the use of crowdsourcing science.

6.7.2.6 Top Management Support (+)

The support from top management within institutions to provide guidance and funding has shown to have enabling influences. A professional scientist backed by the university or by understanding funders who believe in open, inclusive, and participatory approaches can positively influence crowdsourcing for scientific activities. The presence of an organization can also provide great awareness to attract a large mass of participants. Participant AK said:

"It is very important for you to have a well known organization already behind it such as wildlife or national history museum but if you haven't got an organization that people don't recognise already. For exposure, if you want large participation you need these big organizations."- AK

This study's findings concur with previous studies that reveal that management support benefits innovation implementation (Klein & Knight, 2005; Jansujwicz, Calhoun, & Lilieholm, 2013; Ottinger, 2010). Top management support is, therefore, an enabler for crowdsourcing science.

6.7.2.7 Culture (+/-)

Culture can also enable the use of crowdsourcing science. The atmosphere that encourages openness, transparency, and external experimentation can boost the use of crowdsourcing (Sendzimir et al., 2008). Interviews with participants revealed openness and co-creation with institutions, as well as the availability of successful projects, influenced resistance. Participant AN said:

"We had to be aware about past projects and knowing that it worked. That gave us confidence that this would work as well and because of the success of our project, other researchers in different countries would build this as well." – AN

Culture, however, can also have an inhibiting influence due to the rigid nature of peers, the inability to understand its value and distrust in data quality. As described by Participant AJ:

"Convincing peers and colleagues is also a huge challenge as there are still a lot of sceptics that don't feel the data is reliable and worthy of publishing." - AJ

The findings correlate with previous literature (Armstrong et al., 2012; Shuker et al., 2017; Jansujwicz, Calhoun & Lilieholm, 2013). The awareness of crowdsourcing as an excellent approach to scientific tasks can reduce the resistance to change of professional scientists, academics, and government institution, thereby inspiring a collaborative culture. The next section will cover the external context that can positively or negatively influence crowdsourcing for science activities.

6.7.3 External Task Environment Context

In this subsection, the external factors that influence the use of crowdsourcing for science activities are discussed. Three external environment factors act as inhibitors and enablers: availability of vendor support, crowd readiness and regulatory environment.

6.7.3.1 Crowd Readiness (+/-)

Crowd readiness was identified as an influential factor that can enable the utilization of crowdsourcing for science activities. Crowd readiness is related to the presence of diversified participation level, the presence of skilled and enthusiastic participants. Crowd readiness allows for the performance of scientific tasks such as identifying certain species, which lead to beneficial impacts from the scientific process. This is supported by the findings from Cox et al. (2015), who identified public engagement as a success factor. Participant AP said:

"what the skills are of the people who collect the data because i am working on biodiversity, all these people they have to understand or know every species. Some people are very skilled at it because they know every species which is very difficult to recognize. For example, if you

look at mosquitoes species, there are so many types of mosquitoes. I am a biologist and I only see one set of species of mosquitoes but they see lots of them." - AP

Although the crowd is beneficial to the progress of projects, however, the participation level and the capability of the crowd can also inhibit the use of crowdsourcing for science activities (Wechsler, 2014; Worthington et al., 2012; Krasny & Bonney, 2005). Crowd members that lack interest can lead to a drastic decrease in participation, thereby delaying the completion fo tasks. In conclusion, crowd readiness can have an inhibiting and enabling influence.

6.7.3.2 Regulatory Environment (+/-)

It was identified that the regulatory environment could be a barrier due to related issues, such as the lack of international funding, no avenues to publish results, weather conditions, diverse legislations and issues with local authorities during projects. The findings concur with previous literature (Perdana & Ostermann, 2018). On the topic, Participant AE said,

"There is not much funding in this field because you all competing with others such as universities." - AE

Although it is identified as a barrier, this factor can also have an enabling influence. The knowledge of local authorities (Jansujwicz, Calhoun & Lilieholm, 2013), opportunities to collaborate with government institutions, seeking legal counsel, and acceptance from universities can enable crowdsourcing science activities. AJ added,

"the reason is that the locals know a lot about the resources and can contribute in the design of the research from a local knowledge perspective." - AJ

6.7.3.3 Availability of Vendor Support (+)

Vendor support was also identified as an enabler due to the availability and use of open-source websites, as well as professionals, to assist in designing projects for academics and professional scientists. AJ describes:

"Partnering has helped us achieve this with other platforms and colleagues in the field of crowdscience such as siteside.com for recruitment, Image classification task zooniverse. So lots of partnerships, university privacy policy politics." – AJ

In summary, the identified factors have been defined and discussed according to their contexts. Summarized in Table 6.7 below are the identified enablers, barriers, their descriptive elements and underlying contexts related to crowdsourcing science.

Table 6.7: Breakdown of the Enablers and Barriers Influencing Crowdsourcing Science

Context	**Related Factors**	**Enablers**	**Barriers**
Technology	Relative advantage	• Access to knowledge, insights from local and specific regions • A faster alternative to building a database for artificial intelligence • The availability of workforce	
	Complexity	• Quick, easy and user-friendly design	• The lack of connectivity and broadband speed • Technology development and infrastructure • Expensive-to-build tools • The presence of a diverse number of species and data quality issues
	Technical compatibility	• The appropriateness of complementary technologies	

		• The availability of smartphones and apps • Building a website • Presence of experimental tools • Use of communication channels and forums	
Organization	Champion	• The positive drive of the researcher	
	Innovativeness	• Capability to adapt approaches based on the level of participants • Providing cheap and open-source tools • The use of data control measurements and procedures • The use of incentives to attract more participants • The capability to assess and co-create with participants • Ensuring workflows are less ambiguous	• Boring and less engaging projects • Lack of appropriate capabilities to ensure privacy • Lack of capability to present images in an engaging manner
	Quality of human capital	• The ability to communicate with participants • The ability to convince academic peers of its benefits • The availabilities of diversely skilled team members • The openness to learn new disciplines • Having patience and a sense of humour	• The lack of skills to develop websites and platform • The inability to communicate and engage with participants • The lack of skilled and motivated team members • Lack of time to write publications • The number and retention of participants

	Financial resources	• The availability of internal and external funding for projects	• The lack of funding and running out of money • The inability to provide tools for tasks
	Top management support	• The support of a well-known organization	
	Organizational readiness	• Provision of guides for participants • Providing training for participants	
	Culture	• The openness to partner with institutions • The availability of successful projects • Co-creating with stakeholders	• Highly competitive environment • Resistance to change and perception of citizen science
External task environment	Regulatory environment	• The knowledge and permission of local authorities • Seeking legal counsel	• Issues with authority • Language barrier due to location • Unfavourable weather conditions
	Crowd readiness	• The number of involved and motivated participants • The presence of a community • The skillset of the crowd	• Unprofessional behaviour of participants
	Vendor support	• The availability and use of open-source websites • Availability of professionals	

The next section will examine and compare the examined crowdsourcing activities to arrive at the key enablers and barriers that generally influence an organization's effective use.

6.8 Enablers and Barriers Influencing Crowdsourcing Use – Comparative Analysis

Figure 6.7 reveals a framework of the identified key factors that act as enablers and barriers, influencing the use of crowdsourcing. The findings in this study support previous studies by Sharma (2010), Troshani, Rampersad and Plewa (2011) and Ades et al. (2013), who found that top management support, culture, human capital, infrastructure and external environment are influential for the adoption and use of innovation management tools.

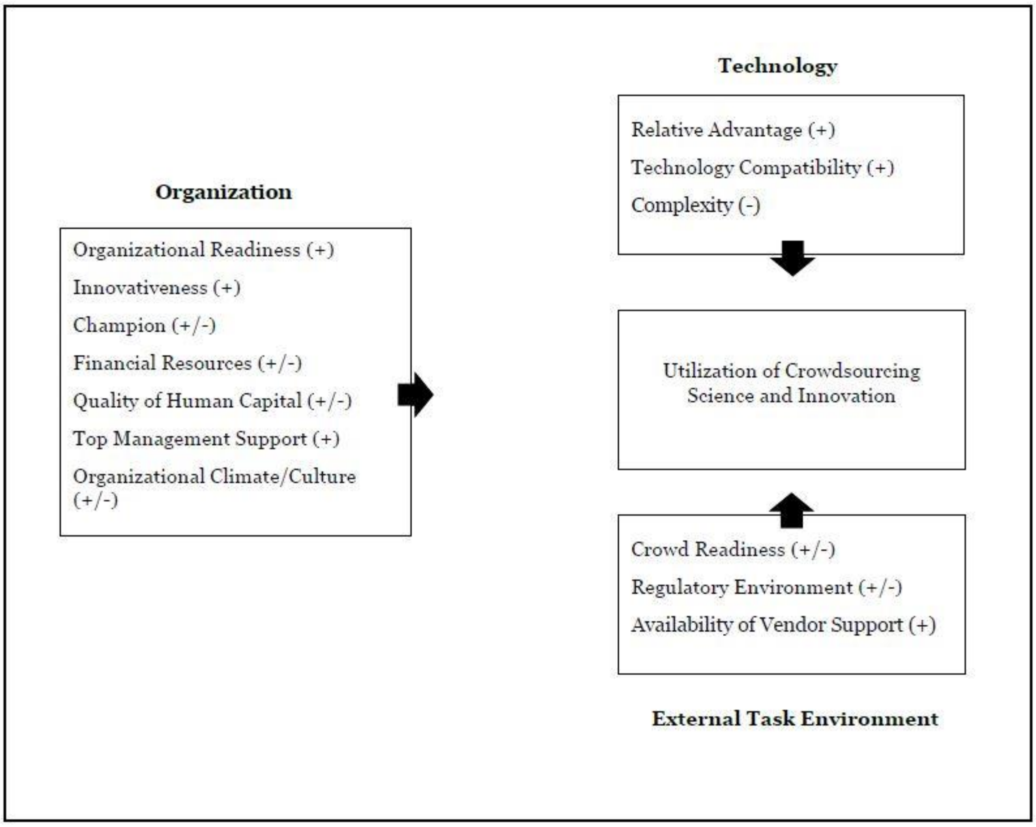

Figure 6.7. Contextual determinants and the key enablers and barriers influencing crowdsourcing

Furthermore, this research provides insight into the key factors within the TOE framework by revealing the technological, organizational, and external task environment factors influencing the utilization of crowdsourcing. It served as a functional framework for looking at the overall use of crowdsourcing, thereby giving an overview of the factors organizations should consider when contemplating crowdsourcing utilization. Specifically, it presents a thirteen-factor framework explaining the scepticism around crowdsourcing usage.

Technology contextual determinant consists of 'relative advantage', 'technical compatibility' and 'complexity'. Relative advantage and technical compatibility were found as enablers in crowdsourcing usage. Previous studies (Ven & Verelst, 2012; Tome et al., 2014; Ali, 2018) are consistent with these finding as the utilization of technologies depend on its benefits and fit between existing and new technologies. However, complexity is a barrier. Consistent with previous studies (Tome et al., 2014), the difficulty of understanding a technology can decrease its usage. Organizational contextual determinant consists of 'top management support', 'innovativeness', 'financial resources', 'quality of human capital', 'organizational readiness', 'champion' and 'culture or organizational climate'. Top management support, innovativeness, organizational readiness were found to be enablers. Previous studies find similar factors (Tome et al., 2014; Awa, Ukoha & Igwe, 2017). Financial resources, quality of human capital, champion and culture or organizational climate were found to have mixed influence as both enablers and barriers. Nevertheless the identified factors are consistent with previous studies (Tome et al., 2014; Ali, 2018; Awa, Ukoha & Emecheta, 2016). External Task Environment contextual determinant consists of 'vendor support', 'regulatory environment' and 'crowd readiness'. Vendor support was identified as an enabler (Tome et al., 2014; Ven & Verelst, 2012), while regulatory environment and crowd readiness have mixed influence (Awa, Ukoha and Emecheta, 2016). This research found that the effective use of crowdsourcing is more driven by organizational factors than technological and external task environmental factors.

Decision-makers may use these findings to serve as a benchmark in making effective usage decisions.

6.9 Organizations' Integration of Crowdsourcing Science and Innovation Activities during the Innovation Process

Based on the lens of I-P-O, this study introduces a developed model integrating two constructs that are influenced by disparate paradigms but facilitated by open mechanisms and pathways. Figure 6.8 summarizes the integrated CSCI model derived from the data analysis. Following prior research (e.g., Bagno, Salerno & Silva, 2017; Chesbrough, 2003; Ebner, Leimeister and Krcmar, 2009; Newman et al., 2012), the CSCI model details precisely how the crowdsourcing process not only leads to one outcome but rather interrelated outcomes. The model allows for the bringing together of widely distributed knowledge within and across organizational boundaries to develop research discoveries and innovations which can be used to complement future projects.

The integrated CSCI process follows 1) crowdsourcing science (CS-S) leading to crowdsourcing innovation (CS-I); and 2) crowdsourcing innovation (CS-I) leading to crowdsourcing science (CS-S), facilitated by a degree of openness and the management of activities. Although this process is aided by technology or market combinations and partnerships, it can be subject to augmentations and iterations due to the involvement of external actors and use of feedback channels.

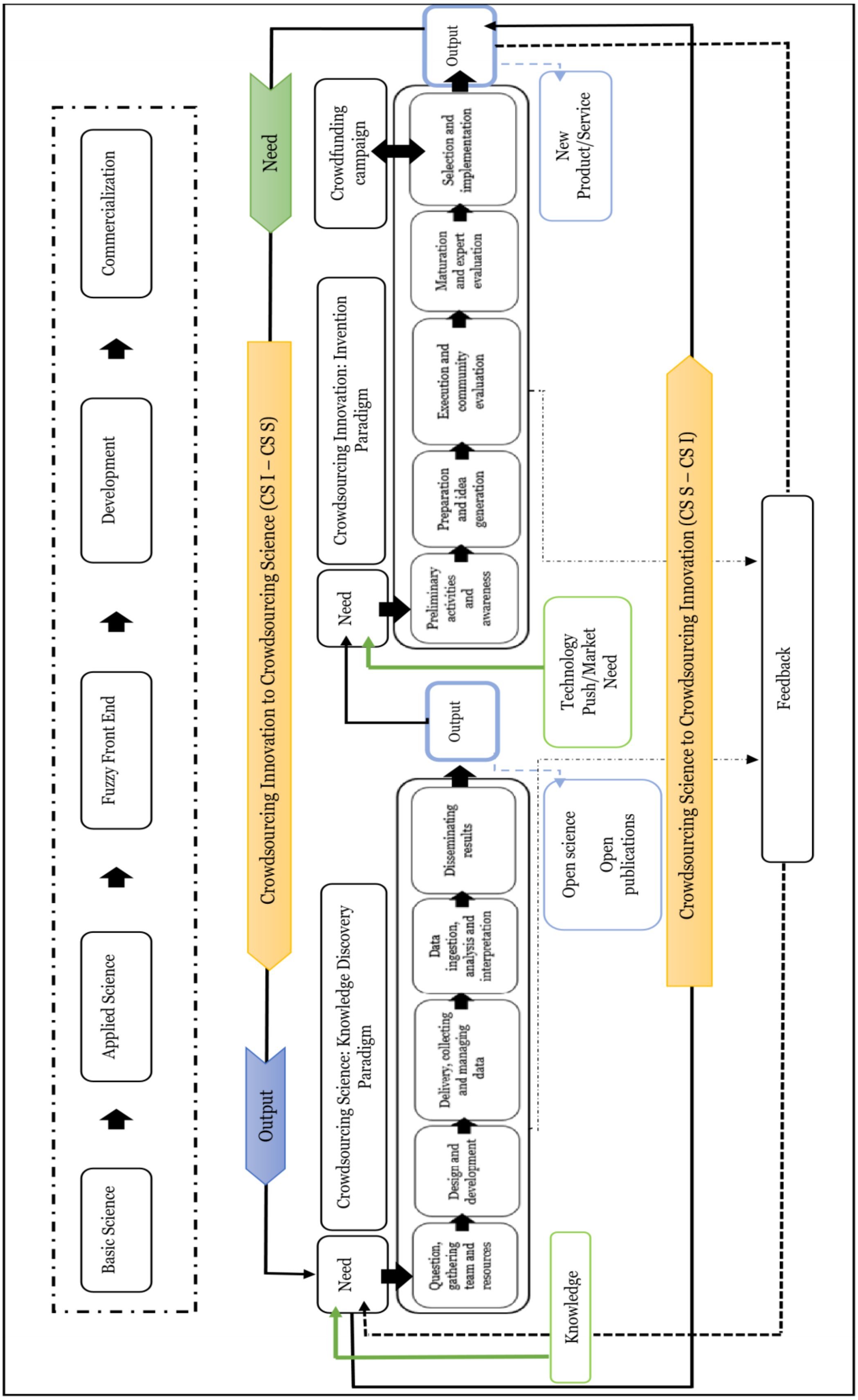

Figure 6.8. The Integrated CSCI framework

The findings show that crowdsourcing science, similar to basic research, can be a means for not just scientific knowledge discoveries but also empowerment for communities through utilizing results to improve policies and aid decision-making (Mahr et al., 2018; Hecker et al., 2018). During these activities, the involvement of all stakeholders helps aid the sustainable management of natural resources through public education and delivering knowledge (Bücheler & Sieg, 2011; McKinley, Briggs & Bartuska, 2012). Hence, collaboration with the crowd allows for a democratic consensus of decision-making. Organizations can draw from open mechanisms to in-source ideas, technology, and products from crowdsourcing science outputs through vision and strategies, thereby linking to crowdsourcing innovation. This study's findings reveal that crowdsourcing innovation is focused on applying crowdsourcing science outputs (CSO) to achieve new products, technologies or services. In this model, CSO in open mechanisms e.g. publications in open journals, IP licensing, research partnerships and so on, allow for the continuation towards crowdsourcing innovation. Organizations can then utilize CSO and collaborate with the crowd to satisfy current market needs or capture value in new markets (Afuah and Tucci, 2013). This study further finds that crowdsourcing innovation outputs (CIO) might not necessarily stop at commercialization. Instead, CIO can lead to future crowdsourcing science. Mechanisms such as technology spin-outs, management of IP, research partnerships, IP licensing, and ethical procedures enable the continuation of science and innovation involving the use of internal and external ideas, actors and pathways (Bücheler & Sieg, 2011; Perkmann & West, 2014; Fini et al., 2018).

The proposed integration of crowdsourcing activities is a continuous process requiring feedback channels, skilled team members, leadership, financial backing and top management support to ensure difficulties can be overcome in the most transparent and open manner. This means novel outputs (CSO and CIO) have more of a democratic outlook due to the collaboration with industrial actors and the combination of market and technology research (Chesbrough, 2015; Taferner, 2017; Fini et al., 2018). However, the certainty in deriving value depends on a solid linkage between outputs and effective business models. Furthermore, the framework confirms that innovation models can have varying starting points and paths driven by either the call for research, product sale or idea generation, as well as the possibility of paths having more than one ongoing activity at a time leading to new products, business and change in practice (Salerno et al., 2015; Smeilus, 2015; Taferner, 2017). The integrated CSCI model is an excellent tool for organizations to integrate science and innovation, supporting the monetization of outcomes by preventing loss in the spillover of knowledge through research partnerships, IP management and licensing.

In the next section, four key informants interviews are analysed, revealing two primary interrelated practices. These practices are 1) crowdsourcing innovation to crowdsourcing science (CS I – CS S) and 2) crowdsourcing science to crowdsourcing innovation (CS S – CS I).

6.9.1 Crowdsourcing Innovation to Crowdsourcing Science (CS I – CS S)

This section presents the findings from each of the key informants (2) that participated. A descriptive overview of each organization is first provided, followed by analysing the uncovered integrated crowd-based process leading to innovation and crowd-based science. Platoscience is a neurostimulation company with the goal of enhancing cognitive performance using technological progress and product design to give customers access to the extraordinary power of the brain. The organization utilized crowdsourcing innovation and science to develop a prototype (Helmet Simulator) which was further integrated to contribute research towards transcranial direct current stimulation (TDCS). Studies suggest it has led to improved conditions such as depression, mild cognitive impairment, memory, learning, motor skills endurance, and more (Angius et al., 2018). Signify is a world leader in creating lighting for consumers and professionals by providing energy-efficient lighting products, systems, and services, including Hue personal wireless lighting, LED lights, bulbs and luminaries. The organization involved the crowd in developing the Philip Hue lighting series was released in 2012, consisting of wireless LED bulbs, a bridge that connects to a Wi-Fi router, and an app. Furthermore, the fully commercialized product has set the base for research into developing smart cities with a system called "Interact City."

6.9.1.1 Platoscience

Figure 6.9 illustrates the process of crowdsourcing innovation leading to an outcome in which the outcome was further integrated to crowdsource research discoveries. The analysis revealed that the process started with an idea of developing a product using classical user involvement to bring customers to the lab, provide equipment, and observe how customers interacted with equipment pieces. This ensured the process to be a very product, usability and experience-oriented development, allowing development and testing with users in additions to using interviews and surveys.

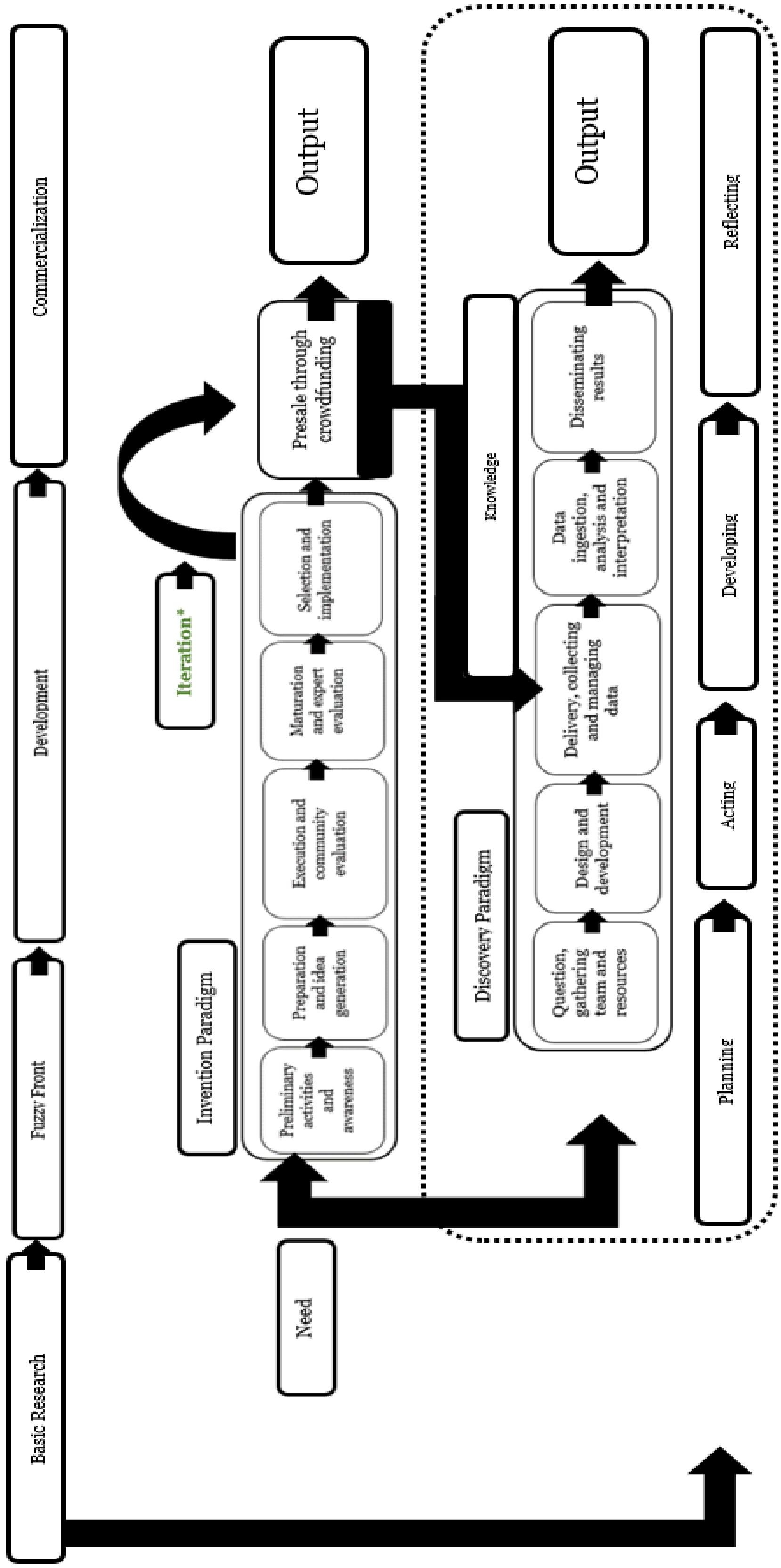

Figure 6.9. The integrated process of crowdsourcing innovation to science

The collaboration between a cross-functional team of 11 and users led the development of a functional prototype in 2017. This enabled distributed knowledge (qualitative and quantitative data) to be collected. The analysis revealed that the process was not structured, allowing for data collection before and after sessions reports in the form of 1) scales and lists to pick out factors that suit the user the most, and 2) a text field where users reflect on sessions. The key informant expresses this:

"In the beginning, it was pretty much unstructured where we would have people with headsets and we would try to speak and meet with them, bring them into the office, we invite them to a more social interaction experience just to learn more about how they would go about using the product. Trying to get more in depth because there are a lot things you don't see on a feedback form (Physical and Emotional). At the beginning, we also had 10-15 pioneers so people we worked with and now we have 100 - 150 pioneers who are distributed all over the world. It is also about which type of data you can expect because we can do personal relations sets with everyone but now we are focusing on people we know and are close to. We furthermore acquire quantitative and short qualitative from the rest of the users."

Although the product's design stage took about one year and nine months, it has never really ended (continuous). As the innovation process progressed, it was crucial having a close relationship and engagement with users (Djelassi & Decoopman, 2013; Qin et al., 2016). According to the interview, this enabled a faster iteration of the product due to the physical use of the prototype, which further enabled the company to build trust with users. During this phase, a major barrier was in relation to users fixation on ideas/concepts once a model is given to them at the start. Hence, the use of methods such as provotypes or negative brainstorming enabled the organizations to move past this difficulty. Here is a quote from the interviewee below:

"Most users have a hard time envisioning something they do not have already. If you ask people to come up with an idea based on something or model giving to them, they would be fixated on that. What we do is we give something else which doesn't mean anything and then people will criticize it and tell you why it is bad and in their expression of what they do not like, there is a lot of information on what they would like. So giving people crappy thing, they would criticize it and that's a way of brainstorming."

To measure the progress of using the crowd for developing the innovation (helmet simulator), the conversion rate of people involved in the process—such as who bought the products—was vital. As the organization did not use any rating or systematic approach due to the product innovation process stage. Most decisions around the data collected on the product were based on the decider's gut feeling of what was most relevant. Another method that was used for the integration of ideas was the frequency of things coming up. A 1-to-6 conversion rate system provided a means of detecting product features that users actually wanted, which was a good insight. The interviewee said,

"*.... if something keeps coming up, you have to take it into account and accept it.*"

The progressional process continued by obtaining market information and financial support through the presale of the prototype on crowdfunding platforms. This avenue allowed a better understanding of the user's desires before the product is launched to the market. This also supported the integration of the prototype to achieve scientific research discoveries. Figure 6.10 illustrates the helmet prototype (left) and research project (right).

Figure 6.10. Platoscience crowdsourcing innovation and science activities

The transition from crowdsourcing innovation paradigm to crowdsourcing science paradigm of knowledge discovery was assisted by the platoscience's securing of patents, ethics in management user information, and a research partnership with an institution undergoing research into transcranial direct current stimulation (TDCS) authors (Fini et al., 2018). Studies propose that the use of a similar mechanism can aid science commercialization. The organization's research partnership addressing a research question led to the crowdsourcing science involving the crowd in a home cloud-based data collection and logging. Two different approaches were designed to engage the crowd: organized and do-it-yourself crowd science along with a test platform to measure core elements of cognitive ability reasoning, attention, short-term memory and verbal ability.

The objectives of the study were in relation to 1) retention and usage patterns; and 2) simulation to measure effects on standardized cognitive tests by testing hypotheses and investigating direct current stimulation as a therapeutic tool. Interested crowd members start-off by performing a pre-training with the headset to arrive at a benchmark, followed by either a three-week training session or personalized training period. The tasks performed by the crowd are clustered in the core elements: 1) short-term memory (monkey ladder, spatial span, token search and paired associates); 2) reasoning (rotations, polygons, odd one out, and spatial planning); 3) verbal ability (digit span and grammatical reasoning); and, 4) attention (feature match and double trouble). To ensure the validity of results, each task has a set of parameters, including the number of attempts, number of correct attempts, number of error attempts, duration of time utilized, max score, average score, final score, correct score, and max level. These parameters are utilized to determine a meaningful change from the previous assessment and participants baseline. The collected results are published in journals to understand the changes and development of DCS as a therapeutic tool.

The privacy and access to the right representatives of the masses were considered a challenge. According to the discussion with the interviewee, although the product was very well consumer-oriented, its close linkage to mental illness was a private topic. Furthermore, finding the right people that would represent the needs of the masses can be difficult because of the possibility of developing a product that ends up not being acceptable, which not the case for the organization. Generally, hiring people with the right mindset, a good educational background, and experience in user involvement aided crowdsourcing success.

6.9.1.2 Signify (Philips lighting)

Figure 6.11 illustrates the process of crowdsourcing innovation leading to an outcome in which the outcome was further integrated to crowdsource research discoveries. The analysis revealed a continuous innovation process involving the crowd to develop an innovative product, as well as the science aspect in relation to understanding citizen engagement approaches. The organization generally uses the crowd for the purpose of market research, ideas input and to gain directions on product features. The organization also utilizes professional consultancies, which help in setting up campaigns in a shorter period.

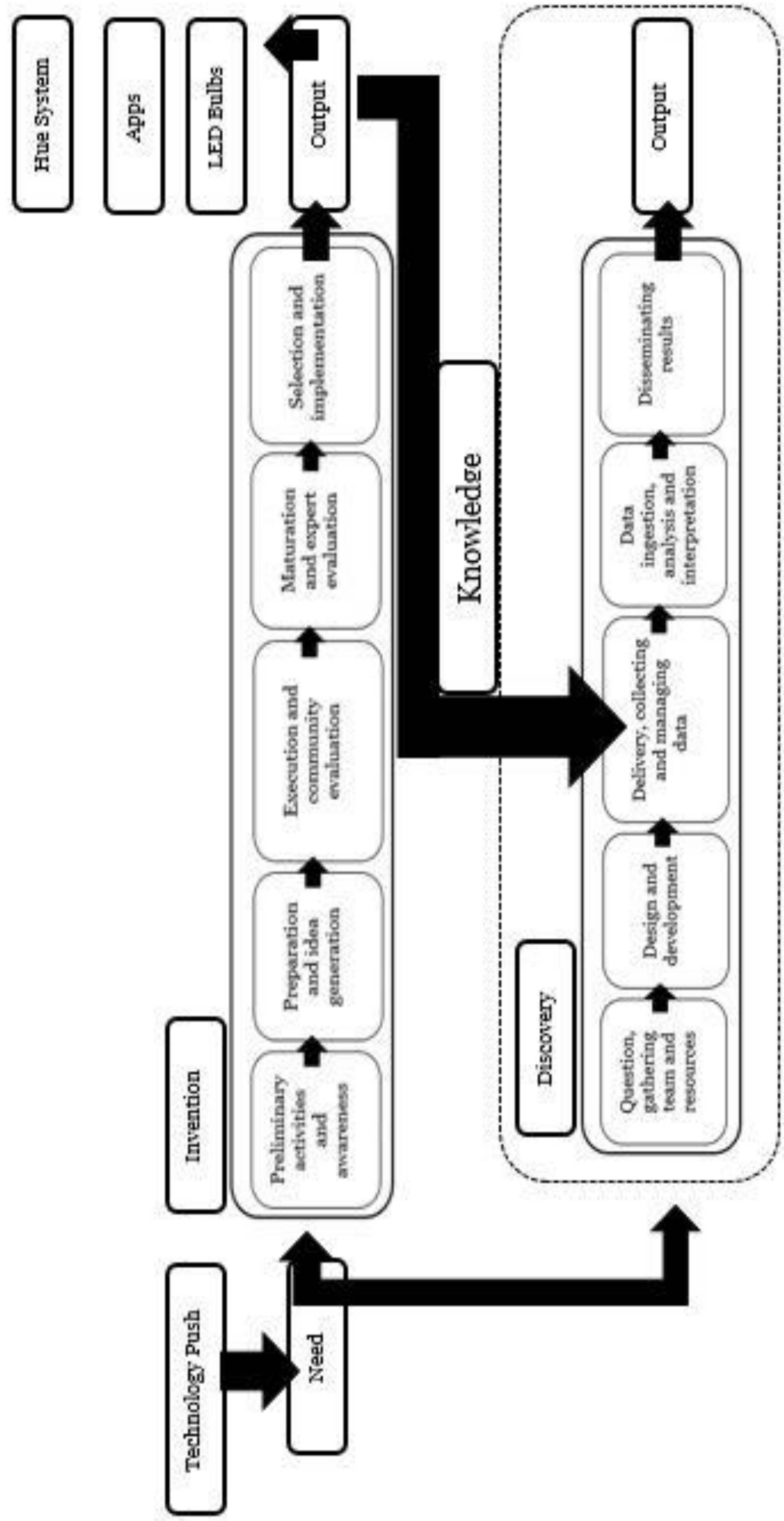

Figure 6.11. The integrated process for crowdsourcing innovation to science

Although the process is unstructured, it started with creating a challenge/question inviting crowd contributions. The internal platform "Hue environment", enabled the development of smart LED lighting, which was technology pushed into the market. The use of crowdsourcing was not necessarily for ideas but rather a guide to direct the organizations on the product conceptualization. Generally, mechanisms used to garner ideas range from surveys, beta-testing groups, expert interviews and UX (user experience) research.

"Ideally, it is something that can happen throughout the organization at any given time, of course, there are moments when you can say we are scanning the market for new opportunity, we have got an idea but we want more input for it or we already have the idea but we want people to come up with new concepts around that. It depends what you use it for, it can fit any of those."

In the concept stage, the crowd was first asked for concept starters, such as how they envisioned the product, which led to the submission of ideas as they visualised and drew things out. The analysis revealed that beta testing groups enabled inputs from multiple people to improve the concept. Visualizations were further put into words and passed on to designers to bring it to a level. Following this, the concept of the smart light bulbs was developed with prototypes, but more information was needed on "what kind of systems, applications and business models can be built around it." This is important as deriving value from innovations requires the presence of a business model to create and capture value (Chesborough 2003). To achieve this, the crowd was engaged through short future scenario stories, which generated responses on ideas that led to the development of four finished apps. As described by the informant:

"… its like how do you bring this process to a higher level which would still go back to the crowd and say this is what happened 'what do you guys think' so you try to keep them close."

Based on the product road maps and the designated management team, the organizations decide on the ideas that contribute to what was important at the time, and if they fit the process. The finished apps included Welcome Home, Go Create, and Indicator, which further was developed into the umbrella 'Hue app'. In combination with the Hue app is the Hue Lighting system, which was introduced as an open system to a developer community. This enabled beta testing before the final release in 2016. Figure 6.12 illustrate the LED lighting (left) and Interact System (right). In all, the Hue Ecosystem consists of a bulb, app, and bridge introduced in the market as an open system for continuous development. Through feedback, coding updates, and so on, the developer community assists in the debugging and creation of a "great life experience" for consumers. The findings reveal that by keeping the crowd close and engaged through continuous feedback loops, outcomes can be linked more to reality.

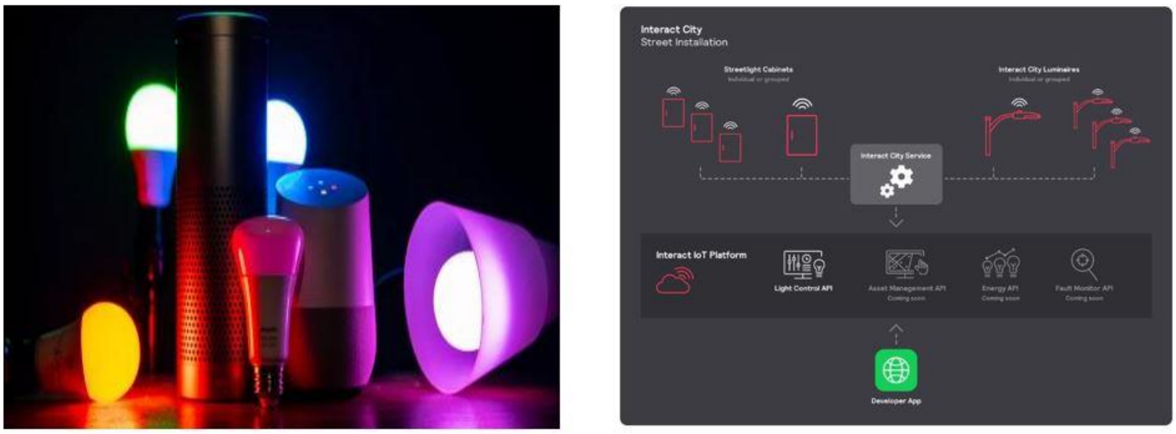

Figure 6.12. Signify crowdsourcing innovation and science activities

Following the development of LED lighting, the informant revealed a complementary IoT platform that helps with handling the growing number of data from connected light points, systems, and sensor devices. Interact City is an intelligent system that has enabled data collection from a diverse customer base in areas such as sports, retail, office, and architectural lighting. The innovative outcome (LED lighting and Platforms) was further integrated to commence crowdsourcing science activities.

Research questions centered around 'how to make cities smarter and more liveable', and how to utilize the system to generate feedback from citizens where the innovation has been implemented. Research partnerships and collaborations with public institutions allowed for areas such as Isle of Wight, Los Angeles, Eindhoven, Cardiff, and Singapore to implement LED lighting on streets, which then enabled citizens to provide feedback and increase citizen engagement. The results of this research were published in open journals and showed a high willingness of citizens wanting to be included in building smarter and more liveable cities. Furthermore, technology platforms that are open source can be a good avenue to help citizens develop applications for public and commercial uses (The Economist Intelligence Unit Limited, 2016).

The success of implementing this approach is perceived as practical, as it is determined by how much inputs are generated and the engagement of the crowd. In conclusion, the integrated crowdsourcing process can be observed as iterative and adaptable, depending on the form of crowdsourcing.

6.9.2 Crowdsourcing Science to Crowdsourcing Innovation (CS S – CS I)

This section presents the findings from each of the key informants that participated. A descriptive overview of each organization is first provided, followed by analysing the uncovered integrated crowd-based process leading to scientific discoveries, which has led to crowd-based innovation. Litterati is a citizen science project that enables the crowd to participate in cleaning up the planet, thereby creating a litter-free world one piece at a time. It is a movement that encourages participants to engage in picking up litter and share their efforts through social media. Foldit is an online 3D Jigsaw game that uses the crowd in helping biochemists understand the shapes proteins can take, which are difficult to compute automatically. By designing synthetic protein structures, it helps boost spatial ability, as well as find good structures and automated algorithms that can be used to compute protein shapes. This was more of a creative structural problem-solving project with the goal of achieving the best configuration of amino acids.

6.9.2.1 Litterati

As litter is one global pandemic that affects us in ways such as the degradation of the environment, poisoning of the food chain, etc., it is proposed that data is an approach to solving this problem. Figure 6.13 illustrates the entire integrated process of how crowdsourcing science can lead to outcomes that lead to crowdsourcing innovation.

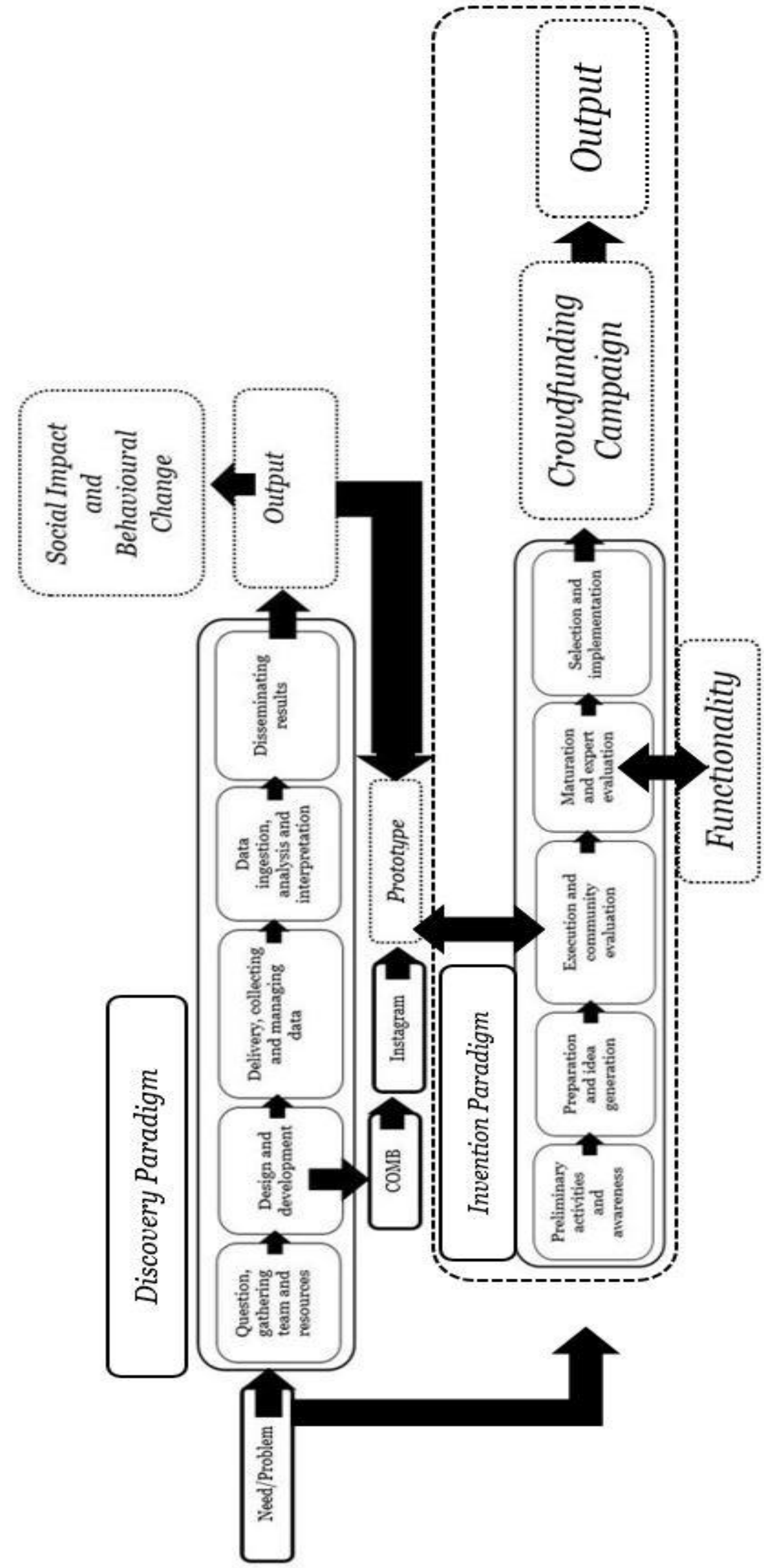

Figure 6.13. The integrated crowdsourcing process for science to innovation

The process started with the need to combat the problem of litter, such as discarded cigarette butts, wrappers, soda cans, and disposable coffee cups. The guarantee of solving litter as a major issue was not specific. Hence, a hypothesis was proposed and tested to observe if the crowd would participate in this campaign. Following this proposal, a member of the crowd decided to snap, hashtag and upload the pictures of a litter filled area on Instagram, leading to the sharing and creation of awareness. Following this effort, the idea reached new crowd members who spread the message by engaging in the same activity. It has now spread across all continents of the world, with a total number of 151,921 participants. To date, a total of 4,443 challenges have led to a total amount of 4,438,964 litter picked. As described by the informant:

"Our belief is to solve this problem, we need to use crowdsourced data to not only identify the source of the problem but also clean it up in the meantime. Through this we are able to understand where the most problematic areas are, what are the brands we are seeing most often and what are the most materials noticed."

Following the success of proving the crowdsourcing science hypothesis and the insufficiency of relying on just social media (Instagram), the team decided to improve the COMB taxonomical approach by integrating it into an app (Typhina, 2015). As the citizen science project started as a hypothesis to test the behaviour of the online community, the results from the research revealed the crowd was willing to pick up litter, thereby resulting in behavioural change based on the intrinsic desire of participants to keep the planet clean. Figure 6.14 reveals the behavioural change hypothesis project (left) and mobile phone application (right).

Figure 6.14. Litterati crowdsourcing science and innovation activities

The outcome of crowdsourcing science enabled the shift towards crowdsourcing innovation. Due to the growth of the Litterati movement and the crowdsourced research discovery, the idea of an embedded eco app allowing the crowd to provide geotagged data started the crowdsourcing innovation process. While simultaneously creating a global litter database, the technical capability of connecting the global community can also be considered an invention. As described by the informant:

"We started by proving a hypothesis such as would anyone be willing to pick up litter and once we had the idea that several people are willing to do this then we decided to build an application."

Collaboration between the research project team and crowd members around the globe aided the development of the app. The need to develop the app was due to feedback for more functionalities, a better connection, and the desire to create an impact. The functionalities required centred on understanding the combined impact of the community's efforts by community members like schools, environmentalists, and companies. Secondly, in-app maps provide the ability to search and filter litter by location, which can not be done using just social media. Thirdly, this enabled a better data collection. The informant expressed:

"*We see Litterati as building a technology not for the community, but rather with the community.*"

The design and functionality of the application were based on C.O.M.B (category, object, material and brand) taxonomy, which stands for category (food, fizzy drink, coffee), object (bottle, slipper), material (aluminium, plastic, paper), and brand (Coca-Cola, Starbucks). The process of building the app relied on the crowd's continuous engagement by supplying datasets derived from the tagged pieces of litter. The collected data allowed for improvement to the app as well as exploring trends and patterns. To measure the progress of the crowdsourcing science project, metrics—such as the total number of pieces picked up, participant level, active users, and retention of users—were utilized. In 2016, a prototype of the application was designed to enable better identification, mapping and collections of litter.

By setting up a crowdfunding campaign, the team was able to raise funds and build the application, which has continuously enabled the crowds to clean the environment. Data produced is also utilized for training machine-learning models for multiple commercialization opportunities. The project's output has resulted in providing a free downloadable app, the commercialization of data that can help improve production lines and the environment, and the creation of a delightful experience for the community.

"*We were able to automate. When you think of the data we are able to collect who, what, when and where. We are able to automate the who, the where and the when meaning the geotagging time stamps are automatically fixed to photograph when it is taken. The what is like the brand and is input by the user and right now we would say there is room for error there so we would say we started using machine learning and image analysis (software) to validate those images so we can create a data set that is golden. In the world of waste, it is a massively complex problem. These are items which are in several levels of decay…*"

"They have contributed financially (Kickstarter campaign), with product feedback, and through leveraging the data to create policy and packaging changes around the world."

The success of using crowdsourcing relates more to the attraction, retention of participants and the valid data produced. In general, the research partnership with organizations, the development of simple and easy-to-use tools, and the securing of patents reduced the barriers to integrating crowdsourcing activities.

6.9.2.2 FoldIt

Figure 6.15 illustrates the process of crowdsourcing science leading to crowdsourcing innovation. In general, the process is a repetitive approach involving the design of proteins, testing structures, generating and analyzing the data, which was used to make informed decisions on changes that can be made.

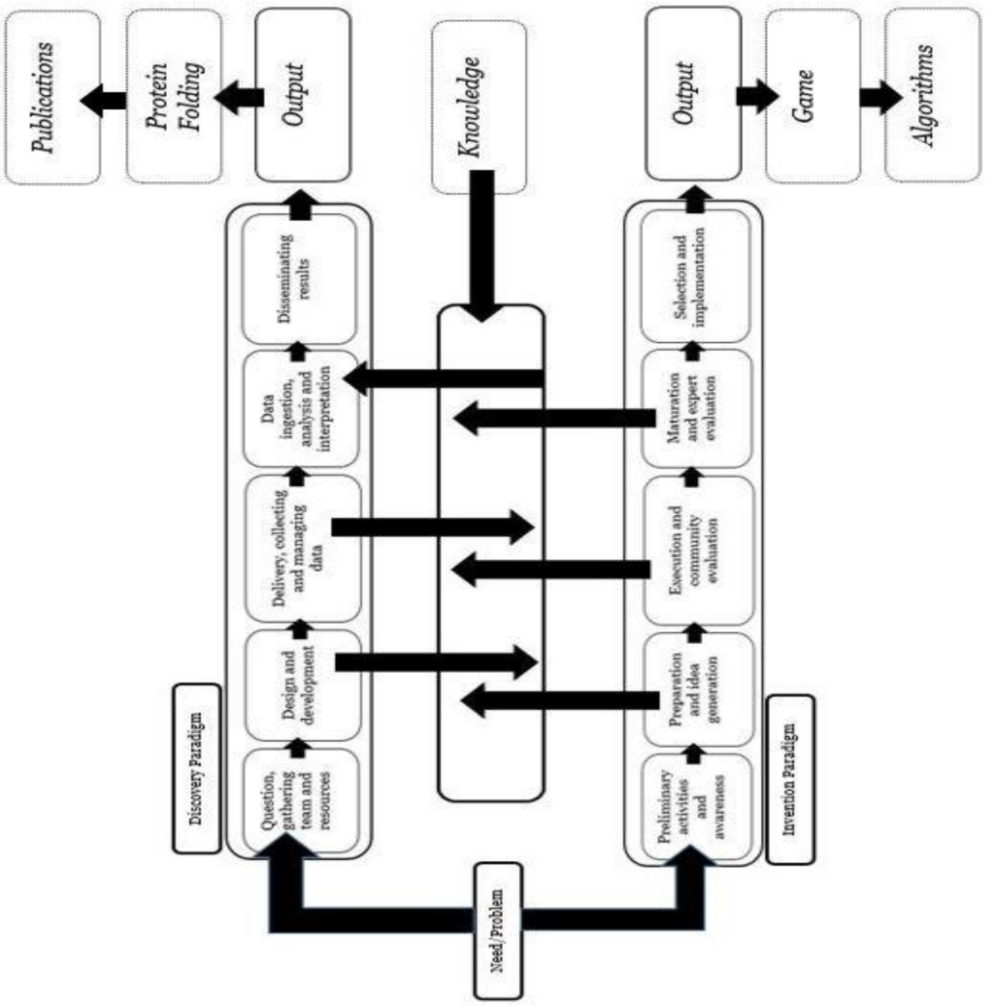

Figure 6.15. The integrated process for crowdsourcing science to innovation

The process was more of a simultaneous project whereby the start led to both crowdsourcing science (protein structures) and innovation outcomes (game architecture). The crowdsourcing science process started with presenting proteins in post-structural puzzles to the crowd, thereby generating data on the changes made and informing decisions. During the project, a Rosetta energy function model was utilized to determine well-built protein structures. The Rosetta system would prescribe a number to protein's energy, which shows how well a protein is folded. The development team of researchers examines the energy functions of protein structures as a metric to enable the organization evaluate the collected data. According to the key informant, observed structures with low energy functions are not reliable. As the project is an online game, crowds tend to discover short cuts to doing things that are not encouraged. Generally, a leader board was developed to gauge the best-formed structures amongst players to assist scientists during the project. This process led to outcomes such as publications. In addition, the number of crowd members, data set produced, as well as publications all provide information on how successful the project has become. Figure 6.16 reveals the protein structure project (left) and developed game architecture (right).

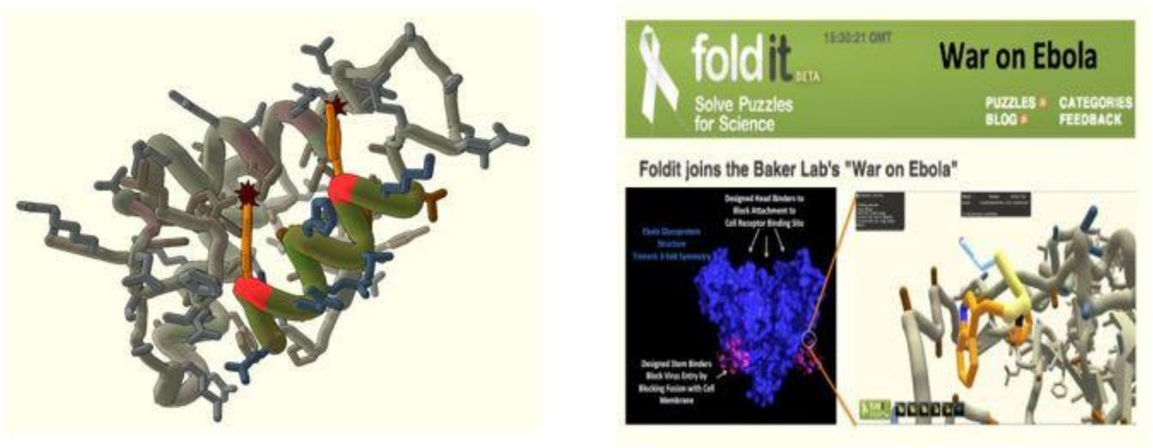

Figure 6.16. Foldit crowdsourcing science and innovation activities

Within the same process, crowdsourcing innovation involved the crowd in developing the idea of the launching of the game. The interplay between the crowd, scientific experts, and the development team, enabled the design and invention of the game. The team's initial development of the prototype started with a small group of experts, which assisted in defining the needed mechanics and desired results.

Following the development of possible prototypes with experts, a later version was released to the crowd for playtesting. According to the informant, the essence of this was to narrow the scope of the game, and understand what elements are fun and difficult. The interaction with the crowd provided loads of feedback, which helped develop the prototype further. The management of intellectual property rights and ethical procedures, allowed for the successful collaboration with more crowd members to further develop the game's architecture.

"As soon as the scientists come up with a new idea (or theory) for tackling a difficult problem, it is thoroughly discussed by the entire team at the weekly Foldit meeting. If it gets the green light, the dev team will implement a prototype for the scientists and rest of the team to try out. If, after enough iterations, it is good enough to push to the players then we present it in Foldit's developer preview for players to beta test. After player feedback leading to (usually multiple) game development improvements, the improvement is finally released to all Foldit players."

The training of the crowd ensured the playing of the game in the right manner. Training the crowd on the use of tools and promoting how proteins should be folded was vital. Furthermore, the format in which the game was presented was also important. The researchers utilized an iterative process built around successes and failures during the process facilitated by knowledge feedback channels. However, the level of crowd engagement proved to be a barrier during the process (Schläppy et al. 2017; Cox et al., 2015).

Chapter 7: Conclusion, Limitations, and Contributions

7.1 Introduction

This section would cover the discussions, findings and limitations of this study. This study aimed to examine the crowdsourcing field, compare crowdsourcing activities, and detail the integrated process of crowdsourcing from science to innovation as well as the factors that act as enablers and/or barriers to the effective use of crowdsourcing SI activities.

One of the motivations for conducting this study was related to the shift to more inclusive and participatory forms of innovation management activities, and the involvement of external sources during organization and institution processes to add value and drive the culture of openness. Another motivation for conducting this study was also related to the increasing growth of crowdsourcing and its diffusion. The main outputs of this study are in the area of innovation management, focusing on organizations' inclusion of the crowd during science and innovation activities, its management activities, the integration of both activities during the innovation process, the key factors for the effective use of crowdsourcing, application trends, and crowdsourcing clusters in terms of scientific research domains and sub-domains.

The findings of this study contribute to the literature by applying a variety of analyses to an extensive database from almost 7,059 publication articles and 33 interviews with key actors on crowdsourcing. This research proposes an integrated innovation management model, a crowdsourcing publication-retrieval framework and a holistic model of the factors influencing crowdsourcing utilization.

The findings from the qualitative analyses are particularly useful in understanding how the involvement of the crowd can lead to not just scientific discovery, but also innovations. This research offers useful insights for product managers, policymakers, and organizations. The findings from the quantitative analyses further clarify the boundaries of the crowdsourcing field, emerging trends, and applications. The findings can be helpful to a variety of practitioners such as academic, government, intermediary, and industry types of actors. The limitations of this research and future research are discussed. The following section summarizes the research study.

7.2 Findings and Contributions

Based on the evaluation of the research findings, the contributions of this study are divided into two sub-divisions based on the research methodological approaches and research objectives: 1) the qualitative, in which the key informant semi-structured interviews aided contributions to the field; and 2) the quantitative, with a focus on the boundaries, trends, and interrelationship of scientific fields, in which the scientometric analyses of publication documents aided the pictorial understanding and development of the crowdsourcing field. This section discusses the contributions, which are methodological, practical, and theoretical in nature, additionally, reporting the key findings related to the research objectives.

7.2.1 Emerging Domains and Sub-Domains of the Crowdsourcing Field

This research project is the first study to map the entire crowdsourcing research field using a scientometric approach to cluster the field into main domains and sub-domains. To achieve this, this study builds upon previous studies in the literature and the keyword analysis of almost 7,059 publication articles (Nalimov & Mulchenko, 1969; Kovacs et al., 2015; Ozcan & Islam, 2017) to arrive at three major domains and eleven sub-domains: 1) crowdsourcing and innovation (i. idea and wisdom ii. micro and macro tasks iii. donation and investment); 2) crowdsourcing and engineering (i. mapping ii. labour and knowledge iii. architecture and design); and 3) crowdsourcing and science (i. habitat monitoring ii. classification iii. public engagement iv. wildlife preservation v. marine conservation). Furthermore, similar application categories were identified, including crowdsensing, crowdtesting, crowdfunding, citizen science, micro-tasking/macro-tasking, mobile crowdsourcing, crowdsourcing systems, crowd computing, crowd creation and crowd wisdom.

The mapping of the crowdsourcing field into main, and sub-domains is a unique contribution of the present study. The existing streams of literature reviewing the field did not quantitatively examine the entire crowdsourcing field, as some studies only focus on just subset applications (citizen science), or focus on scientific disciplines such as business, innovation, and technology (Tripathi et al., 2014; Kullenberg & Kasperowski, 2016; Hossain & Kauranen, 2015). Furthermore, only one study attempted to statistically examine the field by proposing the top fifteen most frequently used words in the field (Malik, Aftab & Ali, 2019). This study correlates the top fifteen most frequently used words in the field, but further contributes by clustering the top keywords into related crowdsourcing domains C1, C2, and C3, and further sub-domains, which would be particularly relevant to future researchers, as this study presents an organized, pictorial, hierarchical, and metric mapping of the field.

This study provides a methodological contribution to examine the crowdsourcing field as a whole by developing and providing a crowdsourcing-specific search string, which can be utilized by other scholars attempting to build on this study and perform similar streams of analysis. A conceptual model is proposed, which provides details on the steps followed to arrive at the findings. This study provides a highly transparent process ensuring the reliability and validity of the study during the retrieval of data. The retrieval and final visuals were examined with the help of four experts to ensure results are reliable.

In summary, the process is not considered a linear process, but rather, an iterative process of back-and-forth verification. This study is a great example of granularity in such methods where clustering is linked to the sub-domains, and subdomains are linked to their relevant categories and applications. The mapping and methodological approach can serve as building blocks for future researchers in examining other multidisciplinary fields in relation to the aim of this study.

7.2.2 Comparative Analysis of the Process, Enablers and Barriers of Crowdsourcing Science and Innovation Activities

The present study performed a comparative analysis of two crowdsourcing activities to derive a holistic crowdsourcing process. Furthermore, there has been little attention paid to examining the crowdsourcing use from the seeker's perspective (Randhawa, Wilden & West, 2019). The holistic crowdsourcing process framework adopted gives a breakdown of the phases, as well as the stages and activities required in each stage.

Building on the perspective of input-process-output theory and in-depth semi-structured interviews with key informants from science and innovation activities revealed that a majority of seekers actively follow many iterations. The findings of this comparative analysis reveal that the holistic crowdsourcing process can be divided into three main phases and sub-phases: 1) input phase (*framing of the problem, drive, preparation and awareness, skill and capabilities needed*); 2) process phase (*technology, session management, crowd contribution management,* and *crowd management*); 3) output phase (*tasks completed, desired outcomes and utilization of crowd contributions*) and feedback channels. This study makes an important theoretical contribution as the results help in articulating the underlying processes by which managing seekers utilize crowdsourcing to achieve outcomes. In doing so, this study addresses the call of Marjanovic, Fry and Chataway (2012), Zhu, Sick, and Leker (2016) and Randhawa, Wilden & West (2019), who called for more work on the crowdsourcing process based on examining differentiated industrial partners, as well as the respective strengths and weaknesses of different crowdsourcing activities to better understand how organisations can learn to implement crowdsourcing successfully.

This study contributes by exploring the sub-components that aid the crowdsourcing process, which include the involvement of actors, a cross-functional team with skills, and capabilities. By integrating the IPO theory (Gregor, 2006; Simsek, 2009), this study expands on previous studies that have identified similar results based varying perspectives such as RBV, transaction cost or self-determination theory. This study contributes to the theory by identifying variables specific to crowdsourcing based on the IPO theory, which ultimately provides insights on the procedural and organizational requirements that foster organizational practice. As this study is based on a sample from diverse organisations in multiple countries, this would help researchers and practitioners focus their investments, time and crowdsourcing efforts better. This unique contribution of comparing two activities extends the knowledge on the crowdsourcing process. Zahay, Hajli and Sihi's (2018) focused on just B2B organizations in the United States with four participants, while this study examined both B2B and B2C organizations using a qualitative approach. This study will add cross-country organisational studies in the context of crowdsourcing.

By identifying the skills and evaluation mechanism of crowdsourcing science and innovation, this study contributes to the literature on managerial innovation by outlining those success factors which can facilitate the long term utilization of emerging organizational practices. Categorization adopted from (Podmetina et al., 2018) assisted in identifying five types of skills and capabilities. This is because most studies predominantly focused on general success factors, opportunities and benefits, neglecting the competency level of organizations (Cox et al., 2015; Ghezzi et al., 2018; Maiolini & Naggi, 2011; Lüttgens et al., 2014). The identified findings can enhance the management of the crowdsourcing process in a balanced participative style which can lead to creating and capturing value. Comparing two different crowdsourcing activities, this study identifies evaluation mechanisms which vary. The proposed evaluation mechanisms in a stage like process are included in the study based qualitative assessment. Previous studies have focused only on quantitative assessment leading to identifying a few evaluation variations (Chan, Li, & Zhu, 2018; Wu, Corney, & Grant, 2015; Chang & Chen, 2014; Link et al., 2015). This study contributes by proposing the evaluation stages, approaches and criteria specific to crowdsourcing science and innovation activities.

The findings from this study suggest that the use of crowdsourcing can be influenced by certain key factors. While some previous studies have examined the barriers or enablers particular to certain research fields to which crowdsourcing has been applied (Mergel, 2018; Turrini et al., 2018; Qin et al., 2016), there is a lack of studies that identify and unify the influential factors specific to the use of crowdsourcing as a whole (Zhao & Zhu, 2014). Building on the perspective of TOE theory and a comparative examination of two crowdsourcing activities (crowdsourcing science and crowdsourcing innovation), this study contributes to the literature by offering a unifying contextual elaboration (Tornatzky & Fleischer, 1990). This study uncovers the contextual determinants and unifies the influential factors, which are unique contributions of this study. The three main contextual determinants are technological, organizational, and external task environment with 13 factors. Six factors have both enabling and inhibiting influences, while six factors have enabling influence and one factor is a barrier to the use of crowdsourcing.

A key finding in this study is that a majority of factors influencing the use of crowdsourcing are organizational, which requires organizations to improve readiness levels. The findings in this study support previous studies by Sharma (2010), Troshani, Rampersad, and Plewa (2011), and Ades et al. (2013), who found that top management support, strategy, and culture are influential for the adoption and use of innovation management tools. The role these contextual determinants and factors play are significant in ensuring the achievement of outcomes are reached. For example, Bigliardi and Galati (2016) uncovered similar factors, but in relation to open innovation. Although open innovation and crowdsourcing are similar in terms of the models of partnerships, open innovation's difference in partnership occurs between organization-to-organization relationships, whilst crowdsourcing offers both organization-to-organization relationships and organization-to-consumer relationships during problem-solving sessions (Schenk & Guittard, 2009). This study makes a theoretical contribution by addressing Zhao and Zhu's (2014) call for studies examining the enablers and barriers that are specific to crowdsourcing. This research contributes to the emerging research body on using crowdsourcing practices by examining the seeker organizations. By proposing an initial framework to understand the enablers and barriers, the identified factors can provide fellow researchers with propositions that may guide further research.

Based on the TOE theory, this study contributes theoretically by examining crowdsourcing activities and identifying factors that are more unifying and not construct-specific. Organizations will benefit by becoming more aware of the positive and negative factors, thereby enhancing the probability of successfully implementing crowdsourcing, boosting confidence, and reducing negative results from crowdsourcing integration. This study adds to the theory by proposing new factors.

These factors are technology (*relative advantage, technology compatibility, complexity*), organization (*organizational readiness, innovativeness, champion, financial resources, quality of human capital, top management support, culture/organization climate*), and external task environment (*crowd readiness, vendor support, regulatory environment*). The contextual determinants and their underlying factors should be perceived as a starting point in answering calls for future research on understanding the enabling and inhibiting factors that influence organization's practical use. These findings are also highly relevant to industrial practice in guiding organizations in their efforts towards digital transformation.

7.2.3 Crowdsourcing as an Integration Mechanism for Science to Innovation

The present study examined the process of crowdsourcing science and innovation activities based on a theoretical approach, contributing to the literature by revealing the process of crowdsourcing's integrating science to innovation. The majority of studies have examined its use for innovation and scientific activities separately, but no studies that have examined its combined integration from science to innovation (Ebner, Leimeister & Krcmar 2009; Lauto et al., 2013; Saldanha et al., 2014; Edgeman et al., 2015; Mack & Landau 2015; Zhu, Sick & Leker 2016; Ghezzi et al., 2018; Cooper et al., 2007; Newman et al., 2012; Parrish et al., 2018). The findings of this study were based on four key informant interviews, which generally supported the integration of science and innovation in two different practices: 1) crowdsourcing science to crowdsourcing innovation (CS S – CS I); and 2) crowdsourcing innovation to crowdsourcing science (CS I – CS S). This study makes a novel contribution by integrating two different paradigms to propose how an organization can crowdsource science to achieve innovation and vice versa, thereby satisfying previous studies' call (Chesbrough, 2015; Smart et al., 2019).

Based on the IPO theory, this study shows that starting point of the process can either be driven by a call for research in a scientific discipline or idea generation leading to a new product (Salerno et al., 2015). Salerno et al. (2015) state that an innovation process does not necessarily start with generating ideas but can start with either a public call or product sale. The integrated framework is proposed illustrating that the involvement of the crowd through the use of crowdsourcing allows for an inclusive, participatory, and iterative process whereby scientific research can lead to knowledge discovery, further leading to commercial innovation (Chesbrough, 2015). In addition, the use of the crowd for innovation can transition into continuous research and science in terms of testing hypotheses and knowledge discovery, opening the possibility of applying and replicating knowledge (Chesbrough, 2015). Although leveraging crowds through crowdsourcing can play a significant role during the innovation process, the utilization of research partnerships, ethics, patents and intellectual property rights management have all become a formal part of the innovation process of enabling science commercialization (Fini et al., 2018). The study's theoretical contribution integrating the IPO theory to explain the process of how organizations can democratize science outcomes, further transforming into innovative outcomes and vice versa using crowdsourcing. The findings are important for many reasons. The integrated CSCI framework reveals a path for handling open approaches and supporting interactions, allowing for replications and realistic implementation of expertise, as well as detecting the best possible models for organizations. Furthermore, engaging stakeholders in knowledge delivering and the transferability of innovations will help organizations drive long term innovation success by tightly aligning knowledge generation processes to achieve shorter innovation cycles and reduced time to market (Enkel, Gassmann & Chesbrough, 2009; Shirk & Bonney, 2018; Redlich et al. 2015). Although the proposed framework encourages the idea of removing traditional constraints, finding the right balance between daily business and instruments can lead to long lasting success based on expertise and objectivity.

This study reveals the shift from close innovation that is based on an organization's control and self-reliance on just its idea capabilities (Chesbrough, 2003; Lakhani, 2006; Castellion & Markham, 2013) to an open-innovation approach allowing for gaining valuable information and knowledge (Taferner, 2017). This shows the value derived from an organization's new thinking and business models (Redlich et al., 2015). Furthermore, the concept of openness is practised as well through open science and open innovation (Schlagwein et al., 2017). It is argued that the coupling of open science and open-innovation processes such as crowdsourcing can have both negative and positive effects. The positive effects can aid organizations' competitive advantages in markets and improve their capabilities, and some adverse effects can be managed through improved standard technology transfer policies, top-notch ethical procedures, transparent research partnerships, and IPR.

Another crucial element is organizations' management of intellectual property, such as the key informant platoscience, which ensured the production of a commercially valuable product, further leading to science research involving the crowd to achieve knowledge discovery in neurostimulation research. Although questions to the crowd must be clear and easy to evaluate to achieve results, managers must also pay close attention to IPR for protection and create favourable conditions to overcome opportunistic behaviour problems (Bücheler & Sieg, 2011). Certain phases of the process should be private, allowing access to a selected number of members. These (private phases) can assist in controlling and paying attention to the protection of IPR and trade secrets. This study finds that the integration of crowdsourcing science to innovation creates a viable means of empowering communities through utilizing results to improve policies as well as obtaining tacit knowledge that would enable organizations to stay viable in creating new technologies (Redlich et al., 2015; Xu, Ribeiro-Soriano & Gonzalez-Garcia, 2015; Mahr et al., 2018; Hecker et al., 2018).

These empirical qualitative findings demonstrate that leveraging the crowd through crowdsourcing activities (science and innovation) contributes substantially to transforming science into innovation (Stodden, 2010; Chesbrough, 2015; Shirk & Bonney, 2018; Hecker et al., 2018). The results strongly suggest organizations' use of crowdsourcing can generate rewarding results in a faster and more community-centered perspective (Cooper et al., 2007; Blackwell et al., 2009; Devictor, Whittaker & Beltrame, 2010; Parrish et al., 2018). This study has shown the awareness of crowdsourcing approaches and their positive effects during the innovation process (Maiolini & Naggi, 2011).

This study draws a distinction and a coupling of open science and open innovation, elaborated on by authors Chesbrough (2015) and Smart et al. (2019). Organizations' vigorous use of open science data—as well as their attention to quality monitoring procedures and the usefulness of processes in recombining data, can aid in developing new products (Stodden, 2010). The findings also correlate with literature which states the need for easily sharable and reusable standard data sources such as open journals. Combining crowdsourcing science data with other data sources can lead to new open government models and innovation (Bartumeus, Oltra & Palmer, 2018).

The holistic CSCI integrated framework should be perceived as a starting point for future research on the process science activities can take to innovation through crowdsourcing approaches and other interrelated mechanisms (Stodden, 2010; Woelfle, Olliaro & Todd, 2011; Athey & Ellison 2014; Bücheler & Sieg 2011; Schildhauer & Voss 2014; Chesbrough, 2015; Smart et al., 2019). This study proposes a framework that aids in converting ideas into practice, which correlates with findings in previous studies (Carter et al., 2017). Although arriving at new ideas, or technologies can show promise, it does not guarantee value for organizations (Chesbrough, 2003). Organizations should also complement such outcomes with business models that would ensure value created can be captured.

In effect, open science can be practised by organizations to ensure scientific knowledge discoveries through crowdsourcing science are available through open channels. This study also finds that organisations can utilize crowdsourcing science to tackle basic and applied research, which leads to the development of products (Lim, 2004; Trott, 2017), but this would require organizations to be more open to research collaborations with stakeholders that have similar interests. However, this approach calls for organizations to boost their management of intellectual property rights and ethics, as mismanagement can affect the proposed model of integrating crowdsourcing science to innovation all together (West & Gallagher, 2006; Schlagwein et al., 2017). In summary, the value of discoveries, whether they enhance complementary products or enable organizations to cement their positions in markets, should inform the decision to patent or publish (Chesbrough, 2003).

7.3 Implications of Findings for Practitioners

This thesis aimed to fill a gap in mapping the crowdsourcing field as well as uncover how organizations can manage, integrate and effectively utilize crowdsourcing activities in the innovation process based on a mixed-method approach. As the existing literature on this topic is rare, this thesis provides useful indications to support the scientific discovery, R&D process, NPD and innovation management in general. Taking a process perspective and examining the interactions of seeker companies and intermediaries across the science and innovation activities, a more comprehensive and deeper understanding of the crowdsourcing process and essential factors for effective utilization are proposed.

Firstly, this research study is the first to identify the enablers and barriers for crowdsourcing by examining two different crowdsourcing activities. This research study extends to industry the TOE framework, which can be applied to uncover many factors of influence. The TOE framework elaborates on the factors from a seeker's perspective, thus providing valuable information for relevant stakeholders. The holistic exploration of the enablers and barriers can help the management teams in organizations to understand what areas drive crowdsourcing application, as well as what areas could become hidden dangers during the crowdsourcing process. This could help management teams formulating comprehensive strategies for involving the crowd to accelerate task completion and reduce the chances of failure. The identified factors are allocated along with their contexts, raising awareness of managers' potential opposition and setback.

The unveiled holistic crowdsourcing process—and the underlying skills and capabilities needed to manage the process—can help managers achieve successful crowdsourcing outcomes. Managers can benefit from this study with the awareness of what type of skilled personnel lack in teams giving the respective aims of initiatives. Project teams with a high level of engagement skills and a champion supported by incentive schemes, financial support can aid completion and its effectiveness in capturing value. Through multi-level incentives, crowd loyalty to voluntarily contribute work can be achieved as the selection of specific participants is essential. These initiatives' outcomes are democratic in nature. The data acquired through initiatives can be useful in supporting well-informed decision making.

The long-term competitiveness of any organization is based on the research and development of new products, technologies and services. The proposed integrated CSCI model supports the democratisation of science, enabling dialogue between scientists and the crowd, leading to inclusive designs, new product and solutions. Continuous implementation would require an organization's effective management of IPR and research partnerships to support the knowledge discovery and inventive process through open channels. The organization would need to cultivate ethical culture incorporating external views on data privacy, trade secrets and labour.

This research project also proposes mapping crowdsourcing research and applications holistically, considering the innovation, engineering, and science domains. The clustering of sub-domains is further linked with the relevant applications and tasks, hence, the study provides a hierarchical taxonomy for other scholars and industrial practitioners. The conceptual framework and mapping of the crowdsourcing field were developed to provide academics and managers utilizing crowdsourcing approaches with a comprehensive guide for the structure and components of crowdsourcing as a whole. The conceptual framework can help academics perform scientometric projects that require similar methodologies concerning multidisciplinary fields. The analysis of the crowdsourcing field showed that the proposed model is a significant method of grouping and organizing publications for keyword mapping and visualization. Looking at the breakdown of the crowdsourcing field, the visualization can be applied for effective identification of areas that are of interest to managers and academics. For example, the use of varying technologies such as sensors and mobile devices are an emerging area which can allow for the performance of new activities.

In summary, the implication of this study for the effective use of crowdsourcing for SI activities are:

- For managers to utilize crowdsourcing for varying activities with a willingness to experiment combined with a belief in the process being necessary;
- Organizations should complement the use of crowdsourcing activities and outcomes with supportive business models to create and capture value;
- Organizations that utilize crowdsourcing for innovation activities should also make do with customers' bad reactions and dislikes, which can be a good source of inspiration;
- Organization awareness of the factors, capabilities and activities along the phased crowdsourcing process;
- Organizations that utilize crowdsourcing for innovation should embrace openness with freedom from fear of intellectual property leakage;
- The crowdsourcing process requires the presence of a skilled and diverse team that can encourage interaction and engagement with the crowd;
- The level of participants during the crowdsourcing process can determine the success of any project; hence organizations and institutions should invest in engagement procedures;
- Participants for crowdsourcing science activities should be encouraged to be involved from the start of projects to ensure local insight can be derived before the start;
- The provision for feedback whilst running crowdsourcing activities is vital;
- Feedback channels allow for reflection on past sessions for continuous improvement;
- Organizations willing to utilize this emerging mechanism should develop complementary financial-based streams to be fully open to crowdsourcing experimentation;

- The crowdsourcing process is not entirely open. Phases should be divided into open and private.

7.4 Limitations and Future Studies

The current research's primary interest was to map the crowdsourcing field and understand the process of application and the influential factors from a seeker's perspective. The proposed mapping, the integration of science and innovation application processes, and the determinants and influential factors are unique contributions to the literature on the application of crowdsourcing. Deducing and uncovering this study's findings through methodological and theory-based approaches were deemed necessary and appropriate.

This study is limited to investigating crowdsourcing from key informants from diverse disciplines, different industry sectors, different sized organizations and different countries. Future studies can focus on a particular industrial sector within a country to validate the findings. Furthermore, a longitudinal study could provide an opportunity to investigate observations and temporal occurrences during different time-periods. Future study can look into the diffusion of crowdsourcing and examine the adopters of crowdsourcing and influential factors according to its 'early adopters', 'innovators', 'laggards', etc. Future studies can also examine aspects such as organizational learning to uncover how and which organizational structures facilitate crowdsourcing utilization. As this study examines all forms of crowdsourcing for science and innovation, future research can focus on specific types of crowdsourcing to observe if similar phases, subcomponents and procedures can be identified.

This study utilized key informants to triangulate data collection and reveal the findings. Although, the study utilized theory-based approaches, future studies can use a case study design to perform comparative analysis within a specific industry to increase generalizability. This study's use of qualitative methods to reveal the determinants and critical factors is a limitation. Future studies can use quantitative measures to validate this study's findings, as the use of interviews as a method for data collection can include some reporting and interviewer bias (Eisenhardt & Graebner, 2007). Whilst this study has outlined systematically the contextual determinants, enablers and barriers, identifying the observed interventions in other forms emerging mechanisms like open source systems or 3D printing.

This study proposed the integration of crowdsourcing activities during the innovation process. As crowdsourcing is just one of the many emerging concepts of openness, future studies can examine the organizations' coupling of science to innovation using open approaches such as open-source development, open APIs and others. Furthermore, this study takes a process analysis with less attention to the type of innovation (radical or incremental). Future studies can examine and differentiate the integrated crowdsourcing process for incremental and radical innovation to understand organizations' innovation capabilities. Future studies can also focus on understanding how crowd contributions towards SI activities enhance areas such as policy making, policy implementation and business ethics.

A scientometric approach was utilized, combining co-occurrence text mining and publication analysis to review the literature. This study used a range of keywords in our search within the abstracts, titles and full texts of publications. An expansion of keywords utilized may generate different search results. This thesis classified crowdsourcing applications into three categories and this classification are by no means exhaustive, thereby requiring other studies to consolidate the findings. The methodological approach utilized to examine the trends can be improved; as this study utilizes specific criteria for data source selection, additional criteria can improve the study. This study utilizes journals and publications in English on the topic examined; further studies can include and combine other databases, document types, and journals or publications that come in other languages, which can enrich this research study and test the mapping of the crowdsourcing field.

7.5 Final Remarks

Crowdsourcing proposes a new approach to creating value by recognizing that internal resources and external forces, are useful. This trend of bottom-up economics and ensuring growth through the bottom of the pyramid players can be essential. Despite the benefits promised, however, the integration of crowdsourcing is still considered slow and concentrated in limited areas during SI activities.

This study reveals that the research field is spread across three key areas. Furthermore, it also reveals processes, activities, capabilities and factors to integrate crowdsourcing. It is revealed that most factors are rather organizational. The process for utilizing crowdsourcing does not follow a one-size-fits-all format. Instead, it is an iterative process that requires adaptability, and openness, aiding continuous innovation and scientific discovery by leveraging the crowd.

8. References

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9. Appendices

Appendix 1: Participant Information Sheet

PhD Candidate: David A Boye
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Participants Information Sheet: Individual

Title of project: Examining the Application of Crowdsourcing during Research and Innovation Process

REC Ref NO: E472

I would like to invite you to take part in my PhD research study. Participating in this study is voluntary. I will go through this information sheet with you, to help you decide if you would like to participate and answer any questions you may have. I would suggest this would take about 5 minutes. Please feel free to discuss this with colleagues and please contact me if there are any points that are not clear.

What is the purpose of this research?

This study is concerned with identifying how crowdsourcing is used during research and innovation processes. The research aims to shine more light on why, when and how crowdsourcing is applied. Our study aims to examine the process of utilizing crowdsourcing for new projects/products? How is it utilized during different stages of new project/product development? How is it utilized during research processes? Furthermore, I would build a framework on how these processes work and add value during this process. Therefore, with the aim to be awarded a PhD degree, I am looking to answer these questions.

Why have I been invited?

You meet our sampling requirements by being an individual who applies crowdsourcing approaches for projects which are relevant for my research questions.

Do I have to take part?
It is up to you to decide if you would like to participate in this study. I will describe the study and go through the participation sheet. Participation in this research is purely voluntary. You may withdraw at any stage during the data collection. The withdrawal/exclusion from the research is not possible after data analysis has commenced. You are under no obligation to participate and there will be no negative consequences if you withdraw. If you agree to take part, I will then ask you to sign the consent form.

What will happen to individuals taking part?

You will be asked to take part in an individual interview to express your personal experience and views on this subject matter. A list of questions will be asked to you and the questions might be changed slightly from one interview to another depending on the responses. Interviews will likely last around 1 hour and there may be follow up questions afterwards once data is analyzed. These follow up questions may be emailed to you.

Individual consent forms emphasize that the information collected might be shared with authorized people for academic purposes. Collected data (recorded interviews, copies of documents) will be transferred, summarized, password-protected and notes immediately disposed of. The consent form will also include that the information collected will be saved securely as it might be needed for future academic publications (PhD thesis, journal articles, book chapters, conference presentations). The data will be stored for at least 10 years as per the University of Portsmouth Research Data Management Policy.

A short report of my results will be provided to you. You will not be identified by name or job title in this report and none of the responses you provide will be reported in a form that can be used to identify you. The same rules will apply in my PhD thesis and any other academic publications.

What will the participant have to do?

If you decide to accept this invitation and return the signed consent form, I will contact you to arrange dates and times to visit relevant facilities to conduct research. Once participants have been identified and contacted, I will arrange a convenient time and place to meet with the participant for the interview asking questions related to the subject matter.

What are the possible disadvantages and risks of taking part?

There are no significant risks of taking part in this research. Staff involved in the research will be asked to commit a small amount of time to this research study (approximately 1 hour per interview, plus additional time to help with gathering documents etc.). All interviews will be organised to minimise disruption to the work of participants. The reputation of the company and participants will be protected by ensuring the anonymity of the company and its brands in all publications. The organisation and its brands will only be identified by the company-specific report. In all other reports and academic publications, the company and its brands will not be identified. The names and job titles of all participating individuals will not be given in academic publications or in any reports supplied to the participating company. All data collected will be held securely to ensure the confidentiality of the company and its staff.

What are the possible benefits of taking part?

The possible benefits of this research are that we will have a fuller understanding of the crowdsourcing processes for new product development and research, which can help organisations engage in active collaboration with customers. This could potentially lead to reconsidering your innovation practices, increase in competitive advantage and efficient development of desirable products and services

Will your taking part in the study be kept confidential?

While taking and storing notes, the summaries of all data will be anonymised to remove reference to the individual, company names, products, locations of food and drink business facilities. All companies and individual participants will be given a specific code, which will be used in place of names, to identify transcripts. Copies of consent forms giving both codes and identifying data will be stored in separate files on the N drive from all other data to facilitate the security of companies and individuals. Care will be taken to preserve the anonymity of individual respondents when reporting back to company gatekeepers by presenting only anonymised data (removing names and job titles).

What will happen if you don't want to carry on with the study?

As a volunteer, you can stop participation in the interview at any time, without giving a reason if you do not wish to. If you do withdraw from the study after some data have been collected, you will be asked if you are content for the data collected thus far to be retained and included in the study. If you wish to withdraw before data analysis stages, all collected data would be deleted and not be used for the study. Once the research has been completed, and the data analysed, it will not be possible for you to withdraw your data from the study.

What will happen to the results of the research study?

The results of the study will be published in a PhD thesis and available at the University library via electronic resource. It is also hoped that the results will produce journal articles, book chapters and academic conference presentations. Participants will not be identifiable from the results in any document. Once the research and the publications are completed, all data collected will be deleted.

Who has reviewed this study?

Research in the University is looked at by an independent group of people, called the Research Ethics Committee, to protect your interests. This study has been reviewed and given a favourable opinion by the Faculty of Business and Law Research Ethics Committee.

Further information and contact details

If you would like to know the further details of research in the University, please follow the following link to the University of Portsmouth research website; http://www.port.ac.uk/research/

If you would like details on the research carried out in the Faculty of Business and Law, please follow the following link to the Faculty of Business and Law website; http://www.port.ac.uk/faculty-of-business-and-law/

Appendix 2: Organization Consent Form

Research Student: David A Boye
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Consent Form for Organizations

Title of project: Examining the Application of Crowdsourcing during Research and Innovation Process

1. I confirm that I have read and understood the information sheet dated 28 - 03- 2019 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that the participation of the organisation and its employees is voluntary and that organisation and its employees are free to withdraw at any time without giving any reason, up to the point where the data is being analysed. ☐
3. I agree and to being quoted using my original words, in reports of the research in anonymised form (e.g. Participant 1 said "…") ☐
4. I agree that the information collected during the study can be shared with authorised people for academic purposes. ☐
5. I agree with the data, and I contribute to being stored securely until all academic publications (PhD Thesis, Journal articles and Conference presentation) have been completed. ☐
6. I agree to take part in the above study. ☐

Name of Organisation / Participant:	Date:	Signature:
Name of Person taking Consent:	Date:	Signature:

Appendix 3: Participant Consent Form

Research Student: David A Boye
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Consent Form for Participants

Title of project: Examining the Application of Crowdsourcing during Research and Innovation Process

1. I confirm that I have read and understood the information sheet dated 28 - 03 -2019 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary, that I can choose not to participate and that I am free to withdraw at a time before data analysis without giving any reason and without being penalised in any way. ☐

3. I agree to my interview being audio recorded, and to being quoted, using my original words, in reports of the research in anonymised form (e.g. Participant 1 said "…… ") ☐

4. I understand that the information collected during this study can be shared with authorised people for academic purposes. ☐

5. I agree to the data I contribute being stored securely, until all academic publications (PhD thesis, journal articles, book chapters and conference presentations) have been completed. This will be for at least the duration of 10 years as per the University's Research Data Management Policy. ☐

6. I agree to take part in the above study. ☐

Name of Participant: Date: Signature:

Name of Person taking Consent: Date: Signature:

Appendix 4: Semi-Structured Interview for Innovation Activities

PhD Candidate: David A Boye
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Semi-Structured Interview Questions

Topic: Examining the application of crowdsourcing during the New Product Development process

Crowdsourcing is a source for the generation of ideas when considered within the context of the knowledge-based theory of the firm "by showing the effectiveness of a market mechanism to draw out knowledge from diverse external sources to solve internal problems, as well as a reliable, inexpensive source for generalizable longitudinal data. Using crowdsourcing for the NPD process facilitates customers' participation in the development of products, following their views, needs, and ideas. Understanding how to plan and execute crowdsourcing challenges of complex industrial products is crucial for receiving useful information and knowledge from crowds. The aim of this study is to build a product development framework that will be used as a standard in product development in both education, industry and the 21st century. To fulfil this, we seek answers to the following questions:

Q1	What New Product Development Process do you follow? How long have you been using crowdsourcing?
Q2	What would you define as crowdsourcing? In an example, what problem was trying to be solved and what tasks were needed to be done by the crowd during a crowdsourcing project?
Q3	What mechanisms/criteria's do you utilize to select and integrate ideas into the NPD process? What type of customer information/market research is done before new product development? What sources are used for gathering information?
Q4	How do you structure innovation problems to increase solvability, intelligibility and the participation of solvers?
Q5	How is human interaction managed on your platform to continue the engagement with customers during the NPD process? How are workflows managed with regards to tasks during the stages of the NPD process?
Q6	What skills and capabilities do you have to ensure the success of crowdsourcing sessions? What's the team size v organisation size when applying crowdsourcing?
Q7	What steps did the organisation need to take to build readiness for applying crowdsourcing during NPD process?
Q8	What tools do you use during the different stages of the NPD process (Ideation, Design and Branding of Projects)? What kind of technologies are most appropriate for which kind of people and doing what tasks?
Q9	What challenges and barriers have you faced using crowdsourcing for during NPD processes? How do you think they can be overcome?
Q10	What factors do you think is used to determine the success of applying crowdsourcing NPD process?
Q11	How can the use of crowdsourcing during NPD process be improved?
Q12	In terms of compatibility and relative advantage, would you recommend the use of crowdsourcing application during more innovation processes? How have you ensured your application meets these criteria?
Q13	What direct or indirect benefits are derived from applying crowdsourcing during NPD process?
Q14	What external factors/pressures drove the application of crowdsourcing during NPD process?
Q15	How is intellectual property managed? What rules and policies in order to manage IP rights?
Q16	What is the name of the digital platform, utilised? What are the effects of digital platforms during the NPD process?
Q17	What are the drivers that made the company utilise crowdsourcing during NPD process?

Appendix 5: Semi-Structured Interview for Science Activities

PhD Candidate: David A Boye
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Semi-Structured Interview Questions

Topic: Exploration of crowd science applications during the research process

Transdisciplinary collaborations and the use of technologies such as mobile devices has led to the shift in the relationship between science and society allowing the participation of large nexus of people (crowd) to venture into scientific research processes. With this form of research approach from traditional process stems certain issues such as data quality, crowd engagement and use of feedback. Understanding the dynamics and balance of different types of citizen activities needs to go beyond simple metrics (e.g number of participants, number of data items) to look into more quantitative and qualitative ways to evaluate projects. The success of crowd science projects are based on high scientific impact, level of public engagement and elements used to score projects are data value, project design, resource allocation, dissemination, feedback, participation and opportunities for learning (Cox et al., 2015). The aim of this study is to uncover the process, success factors and barriers in applying crowd science for research and further examine how crowd science is applied for research. To fulfil this, here are some of the interview questions shown below:

Q 1	What do you define as crowdscience?
Q2	How long have you been using crowd science for research processes and what was it used for? What project was it used for?
Q 3	How do you apply crowd science during your research process? Could you please give an example of it?
Q 4	Do you follow a method to ensure reliability and validity of the collected data in crowdscience process? If yes, please explain how do you implement it?
Q 5	How do you design your crowd science projects?
Q 6	Do you use a rewards system during crowd science application (e.g. badge, leader boards)? If yes, how do you use it?
Q 6	What mechanisms do you use to engage with the crowd/citizen during your science project?
Q 7	What are the benefits of using crowd science for your research project?
Q 8	What are the challenges of crowd science research and how did you overcome these barriers?
Q 9	What skills or capabilities as a researcher enabled you to apply and manage crowdsourcing sessions during research projects successfully?
Q 10	What type of technologies do you use to perform crowdscience tasks and utilize feedbacks?
Q 11	What do you think can be done to improve the application of crowd science during the research process?
Q12	How do you implement crowd science process at different stages of your research (e.g., data collection)? Please explain in detail how you apply crowd science from the beginning to the end.
Q13	What steps can they take to build researchers readiness for using crowdscience?
Q14	What factors do you use to determine the success of applying crowdscience for your research?

Appendix 6: Additional Interview Questions

Additional Questions CS I – CS S (CS1):

- How were the crowd utilized to arrive at scientific research outcomes, e.g. publications for the project which guided the use of the crowd to develop the headset innovation?
- What contributions did the crowd provide?
- In terms of the process of using the crowd for research, how would you breakdown the process? Please elaborate
- How were the contributions of the crowd evaluated for reliability to arrive at the research outcome that enabled the building of the headset?
- What factors determined the success of using the crowd to arrive at research outcomes?

Additional Questions CS I – CS S (CS2):

- What would you consider the research topic is in terms of LED lighting systems development?
- How is the crowd utilized for research activities? Can you assist in breaking this down into steps or phases?
- What would you consider the innovation is (guess in LED lighting systems)?
- At what point did the research process integrate with the innovation process for developing the LED systems into a commercial product?
- How have the crowd been utilized during this process?
- How are inputs of the crowd evaluated to ensure reliability and integration of ideas for both research and innovation (product)?
- Do they follow the same or different evaluation processes? Are there any other factors that
- How would you break down the use of the crowd from research to innovation (length of time)?
- What stage of the innovation process would say the LED lighting systems (fully commercialized or still a prototype)?
- Could you elaborate more on the type of feedback from the crowd? My assumption is the feedback from the crowd for research was different from the feedback for the continuous development of the LED lighting systems?
- If the answer is yes to the above question, can you also elaborate on the evaluation of the feedback used for research and the evaluation for innovation? What mechanisms or methods are used?

Additional Questions CS S – CS I (CS3):

- What would you consider the innovation of the project?
- Was the crowd involved in developing the innovation, if yes, please elaborate on how the crowd's contributions enabled you to develop the innovation into a final product/prototype?
- How would you breakdown the process of using the crowd for developing this innovation? (Idea to finished product). Please elaborate on the steps followed.
- At what point of the innovation process for the algorithm merge with a citizen science project and then back to developing the algorithm to a more commerciable product?
- Are there any other factors that contribute to ensuring the reliability and success of the final product?

Additional Questions CS S – CS I (CS4):

- What would you consider the innovation of the project?
- How was the crowd utilized in developing the innovation (idea to product/prototype)?
- Could you assist in breaking down the process in the figure above into steps followed to arrive at the innovation? Please elaborate
- At what phase of the research process does integration/iteration occur during the innovation process?
- How were the contributions from the crowd evaluated to enable decision making on what and how the innovation was developed into a finished product/prototype?

Appendix 7: Ethics Approval Form

UNIVERSITY OF PORTSMOUTH

24 April 2018

David Boye
PhD Student
Faculty of Business and Law

Dear David

Study Title:	**Examining the Application of Crowdsourcing During Research and Innovation Process**
Ethics Committee reference:	**E472**

Thank you for submitting your amendment documents for ethical review. The Ethics Committee was content to grant a favourable ethical opinion on the basis described in the application form, protocol and supporting documentation,with the following stipulation:

The favourable opinion of the EC does not grant permission or approval to undertake the research. Management permission or approval must be obtained from any host organisation, including University of Portsmouth, prior to the start of the study.

Summary of any ethical considerations:

-

Documents reviewed

The documents reviewed by Sara Hadleigh-Dun [LCM] + BaL Ethics Committee

Document	Date	Version No.
Application Form	16/08/17	1
Invitation Letter	16/08/17	1
Application Form	04/09/2017	2
Consent form	26/09/17	1
Participant information sheet	26/09/17	1
Application Form	16/10/2017	3
Consent form	16/10/2017	2
Participant information sheet	16/10/2017	2
Application Form	31/1/2018	4
Consent form	31/1/2018	3
Participant information sheet	31/1/2018	3
Invitation letter	31/1/2018	3
Application Form	26/02/2018	5
Consent form	26/02/2018	4
Participant information sheet	26/02/2018	4
Invitation letter	26/02/2018	4
Application Form	13/03/2018	6
Consent form	13/03/2018	5
Participant information sheet	13/03/2018	5
Invitation letter	13/03/2018	5
Interview Questions / Topic List	13/03/2018	5
Amendments	22/03/2018	1
Application Form	21/03/2018	7
Consent form	21/03/2018	6
Application Form	27/03/2018	8

Participant information sheet	27/03/2018	6
Application Form	04/04/2018	9
Invitation letter	04/04/2018	6
Participant information sheet	04/04/2018	7
Consent form	04/04/2018	7

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements set out by the University of Portsmouth.

After ethical review

Reporting and other requirements

The attached document acts as a reminder that research should be conducted with integrity and gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Notification of serious breaches of the protocol
- Progress reports
- Notifying the end of the study

Feedback

You are invited to give your view of the service that you have received from the Faculty Ethics Committee. If you wish to make your views known please contact the administrator, Christopher Martin.

Please quote this number on all correspondence: E472

Yours sincerely and wishing you every success in your research

Chair

Email:

Enclosures: *"After ethical review – guidance for researchers"*

Copy to: Sercan Ozcan, Paul Trott

After ethical review – guidance for researchers

This document sets out important guidance for researchers with a favourable opinion from a University of Portsmouth Ethics Committee. Please read the guidance carefully. A failure to follow the guidance could lead to the committee reviewing and possibly revoking its opinion on the research.

It is assumed that the research will commence within 3 months of the date of the favourable ethical opinion or the start date stated in the application, whichever is the latest.

The research must not commence until the researcher has obtained any necessary management permissions or approvals – this is particularly pertinent in cases of research hosted by external organisations. The appropriate head of department should be aware of a member of staff's research plans.

If it is proposed to extend the duration of the study beyond that stated in the application, the Ethics Committee must be informed.

If the research extends beyond a year then an annual progress report must be submitted to the Ethics Committee.

When the study has been completed the Ethics Committee must be notified.

Any proposed substantial amendments must be submitted to the Ethics Committee for review. A substantial amendment is any amendment to the terms of the application for ethical review, or to the protocol or other supporting documentation approved by the Committee that is likely to affect to a significant degree:

(a) the safety or physical or mental integrity of participants

(b) the scientific value of the study

(c) the conduct or management of the study.

A substantial amendment should not be implemented until a favourable ethical opinion has been given by the Committee.

Researchers are reminded of the University's commitments as stated in the Concordat to Support Research Integrity viz:

- maintaining the highest standards of rigour and integrity in all aspects of research
- ensuring that research is conducted according to appropriate ethical, legal and professional frameworks, obligations and standards
- supporting a research environment that is underpinned by a culture of integrity and based on good governance, best practice and support for the development of researchers
- using transparent, robust and fair processes to deal with allegations of research misconduct should they arise
- working together to strengthen the integrity of research and to reviewing progress regularly and openly

In ensuring that it meets these commitments the University has adopted the UKRIO Code of Practice for Research. Any breach of this code may be considered as misconduct and may be investigated following the University Procedure for the Investigation of Allegations of Misconduct in Research.

Researchers are advised to use the UKRIO checklist as a simple guide to integrity.

Appendix 8: Conference Attendance and Publication Output at CiNet Conference, Potsdam, (2017)

This is to confirm that the paper

A BIBLIOMETRIC REVIEW OF CROWDSOURCING ACTIVITIES AND APPLICATIONS

written by

Paul Trott, Sercan Ozcan, David Boye

University of Portsmouth, United Kingdom

is accepted for presentation at and will be included in the program* of the

18th International CINet Conference

which will be held on 10-12 September 2017 in Potsdam, Germany

On behalf of the CINet board,

Jeannette Visser-Groeneveld

Appendix 9: Conference Paper presented at CINET Potsdam (2017)

THE BIBLIOMETRIC MAPPING OF CROWDSOURCING FIELD: UNCOVERING NEW DOMAINS

David Boye[1], Sercan Ozcan [2], Paul Trott [3] and Jbid Arsenyan[4]

[123]University of Portsmouth, Portsmouth, UK

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ABSTRACT

In order to track the evolution of the multidisciplinary research area that is crowdsourcing, a bibliometric analysis is conducted to assess the rate of publications. The aim is to provide valuable information about changes in the trends within the area. Crowdsourcing literature was classified into 50 research areas with an emphasis in research in computer science and business economics. Findings suggest that the number of publications in this field have substantially increased over the last four years (2013-2017), compared to the time period 2006 – 2012. The distribution of publications between countries is skewed, with the USA and China conducting 60% of the research. Data analysis shows that the literature trends towards new models including spatial crowdsourcing and crowd sensing, and an increase in mobile crowdsourcing applications is observed. Our study provides a series of indicators to map the development of crowdsourcing research.

Keywords: *Crowdsourcing, Bibliometrics, Co-occurrence, Text-mining, New Domains*

Appendix 10: Conference Paper presented at GTM, Netherlands (2018)

Examining Consumer Oriented Innovations: A Crowdfunding Text Mining Approach

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University of Portsmouth
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Portsmouth Business School, University of Portsmouth
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University of Portsmouth

Keywords: Crowdfunding, Emerging Areas, Bibliometrics, Text-mining, Technological Mapping

ABSTRACT

INTRODUCTION

Majority of text mining analysis focus on patent (Ozcan and Islam, 2017; Wang et al, 2018), publication (Rafols et al, 2014; Li, Porter and Suominen, 2017; Ebrahim and Bong, 2018) and recently social media (He, Zha and Li, 2013; Zhuravleva, Bot and Hilton, 2016; Mehrazar et al, 2018) as data sources. However these data sources with exception of social media, show just large organisation oriented activities such as publication scientific output and patents illustrating R&D centre outputs and organisation interests when examined using bibliometric or scientometric analysis.

Appendix 11: Crowdsourcing Science Nvivo Analysis

Nodes

Search Project

Name	Files	References
Interview Questions	0	0
A1. Tasks Breakdown and Structure	17	28
A3. Evaluation data quality	16	21
A4. Process Crowdsourcing science activities	17	37
A5. Enablers	17	122
A1. T	6	7
A2. O	8	17
A3. E	9	17
A6. Barriers	17	26
Skills and Capabilities	17	68

Appendix 12: Crowdsourcing Innovation Nvivo Analysis

Nodes

Name	Files	References
Interview Questions	0	0
A Crowdsourcing Process Innovation	17	38
A. Tasks and Structure	16	40
A2. Evaluation Integration Ideas	16	25
A3. Enablers	17	140
A1. T	7	10
A2. O	8	9
A3. E	6	9
overcoming challenges	3	4
A4. Barriers	12	19
Skills and Capabilities	17	84

Appendix 13: UPR16 Ethics Form

FORM UPR16
Research Ethics Review Checklist

Please include this completed form as an appendix to your thesis (see the Research Degrees Operational Handbook for more information

Postgraduate Research Student (PGRS) Information		**Student ID:**	772107
PGRS Name:	David Adjetey Boye		
Department:	Strategy, Enterprise and Innovation	**First Supervisor:**	Dr Sercan Ozcan
Start Date: (or progression date for Prof Doc students)	October, 2015		

Study Mode and Route:						
	Part-time	☐	MPhil	☐	MD	☐
	Full-time	☒	PhD	☒	Professional Doctorate	☐

Title of Thesis:	An Integrative Perspective and Analysis for Crowdsourcing Science and Innovation
Thesis Word Count: (excluding ancillary data)	71,236

If you are unsure about any of the following, please contact the local representative on your Faculty Ethics Committee for advice. Please note that it is your responsibility to follow the University's Ethics Policy and any relevant University, academic or professional guidelines in the conduct of your study

Although the Ethics Committee may have given your study a favourable opinion, the final responsibility for the ethical conduct of this work lies with the researcher(s).

UKRIO Finished Research Checklist:
(If you would like to know more about the checklist, please see your Faculty or Departmental Ethics Committee rep or see the online version of the full checklist at: http://www.ukrio.org/what-we-do/code-of-practice-for-research/)

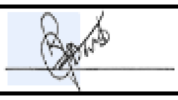
a) Have all of your research and findings been reported accurately, honestly and within a reasonable time frame?	YES NO	☒ ☐
b) Have all contributions to knowledge been acknowledged?	YES NO	☒ ☐
c) Have you complied with all agreements relating to intellectual property, publication and authorship?	YES NO	☒ ☐
d) Has your research data been retained in a secure and accessible form and will it remain so for the required duration?	YES NO	☒ ☐
e) Does your research comply with all legal, ethical, and contractual requirements?	YES NO	☒ ☐

Candidate Statement:

I have considered the ethical dimensions of the above named research project, and have successfully obtained the necessary ethical approval(s)

Ethical review number(s) from Faculty Ethics Committee (or from NRES/SCREC):	E472

If you have *not* submitted your work for ethical review, and/or you have answered 'No' to one or more of questions a) to e), please explain below why this is so:

Signed *(PGRS)*:		**Date:** 31- 03- 2021

UPR16 – April 2018