Theory-Based Problem Formulation and Ideation in mHealth: Analysis and Recommendations

Coquessa Jones, Curtin University, Australia
John R. Venable, Curtin University, Australia

ABSTRACT

This article reports on an investigation into how to improve problem formulation and ideation in design science research (DSR) within the mHealth domain. A systematic literature review of problem formulation in published mHealth DSR papers found that problem formulation is often only weakly performed, with shortcomings in stakeholder analysis, patient-centricity, clinical input, use of kernel theory, and problem analysis. The study proposes using coloured cognitive mapping for DSR (CCM4DSR) as a tool to improve problem formulation in mHealth DSR. A case study using CCM4DSR found that using CCM4DSR provided a more comprehensive problem formulation and analysis, highlighting aspects that, until CCM4DSR was used, weren’t apparent to the research team and which served as a better basis for mHealth feature ideation.

KEYWORDS
Action Design Research, ADR, Causal Mapping, CCM, Coloured Cognitive Mapping, Design Science Research, Design Theory, DSR, Ideation, Melanoma, mHealth, Problem Formulation, Skin Cancer, Theory

INTRODUCTION

The background context of the research reported in this paper is that melanoma has become the third most prevalent cancer in Australia (Welfare, 2019) and is a significant cancer worldwide. As global warming and sun strength continue to advance, melanoma rates may rise both in Australia and worldwide. Although progress in treatment in recent years has led to increased survival (Moser & Meunier, 2014), survivors still have a high risk of recurrence, which remains constant regardless of the length of time from initial diagnosis (Jones et al., 2016). This necessitates a life-long vigilance of the patient’s skin, through self-checks and clinical based monitoring (Shead et al., 2018). However, several studies (Bowen et al., 2012; Glenn et al., 2017; Mujumdar et al., 2009) have found that only approximately a third of survivors tend to regularly carry out this preventative after-care.

mHealth is the utilisation of a mobile device to provide support within the healthcare domain (Hallberg & Salimi, 2020). mHealth is being applied to several domains, including chronic disease management and improving fitness, with the latter being the most common mHealth app (Korzh et
mHealth research largely works to solve problems in the problem domain of healthcare such as accessibility to information and disease management (Jupp et al., 2018).

mHealth research, which aims to solve health-related problems through developing a new mHealth app, clearly fits within the Design Science Research (DSR) paradigm. DSR “requires the creation of an innovative, purposeful artifact for a specified problem domain” (A. R. Hevner et al., 2004); a new mHealth solution is such a purposeful artefact. While the objective of the project reported in this paper is to improve skin check adherence, provide patient empowerment through education, and support chronic disease management, the specific scope of this article is to report on a novel approach for the problem formulation and ideation stages of the broader mHealth research project.

The overall mHealth project follows the Action Design Research (ADR) methodology (Sein et al., 2011). Like most DSR, the ADR methodology (Sein et al., 2011) requires the researcher to undertake problem formulation, to understand the problem, set the scope of the research, and ideate features for the solution to be developed. Comprehensive problem formulation must be undertaken to ensure that a DSR mHealth project has a solid foundation. It is this initial stage upon which the rest of the project will be built and, if done without proper rigor, risks compromising the success of the final outcomes. ADR’s explicit problem formulation stage articulates both principles and tasks to be performed. However, it is a problem that stating activities and principles does not necessarily equate to them being performed and followed faithfully. It is a problem in the design of a DSR methodology (in this case, ADR) that guidance may be insufficient or omit aspects of problem formulation, which can potentially compromise success.

In accordance with ADR, the overall project aims to develop and evaluate a “theory-ingrained artifact” i.e., an mHealth mobile application whose design is based on or informed by extant theory. However, the problem formulation must also account for knowledge not yet incorporated into theory, including aspects of the problem discovered during the research and the needs of stakeholders, especially the often rich and complex needs of mHealth users. It is within this context that the authors have been conducting the first stage of ADR: Problem Formulation, and the tasks associated with it (Sein et al., 2011), which prompts questions about how to effectively undertake problem formulation in ADR and other DSR methodologies.

This paper addresses two research questions:

RQ1: “How are problem formulation and ideation currently performed in published DSR/ADR mHealth projects?”

RQ2: “How can problem formulation and ideation be performed better (more rigorously and with better ideation outcomes) in DSR/ADR mHealth projects?”

In answering these questions, the paper assesses potential weaknesses in extant approaches reported in the literature and suggests directions for improvement. By developing an effective means to formulate problems well in mHealth and DSR more generally, this research is important to improving mHealth and DSR success, effectively using DSR and mHealth research resources, and improving outcomes for mHealth and other designed artefact users.

To answer the research questions, the researchers perform a systematic literature review of the problem formulation and requirements/functionality elicitation and analysis methods used in DSR (including ADR) mHealth research projects. Based on this review, the article identifies some potential issues and suggests the use of causal mapping. In particular, the article recommends using the approach of Coloured Cognitive Mapping for Design Science Research (CCM4DSR, Venable 2014, 2019) for improving problem analysis, formulation, and ideation in DSR projects aimed at developing mHealth applications. The paper further demonstrates the use of CCM4DSR in deriving key design features for an mHealth app for supporting melanoma survivors.
The paper is organised as follows: (1) background, (2) research methodology, (3) findings and discussion of the systematic literature review to address RQ1, (4) findings and discussion of the case study to address RQ2, and (5) conclusion. The next section briefly summarises relevant literature.

**BACKGROUND**

**mHealth**

Health-related mobile applications, or ‘mHealth’ apps (Vo et al., 2019), offer “possibilities for optimizing health systems, improving care, promoting health, and reducing health disparities” (Vo et al., 2019).

To ensure broader uptake and continued use of mHealth solutions, stakeholder input is a key consideration. A Stanford review of cancer specific mHealth evaluations showed that little thought was given to user experience/user interface (UX/UI) practices, patient testing or clinician input (Davis & Oakley-Girvan, 2017). These findings confirm previous reviews, which also determined that future mHealth solutions need to include patients and clinical experts throughout the development, testing, implementation and evaluation stages (Barello et al., 2016; Darlow & Wen, 2016).

**Design Science Research**

Venable and Baskerville (J. Venable & Baskerville, 2012) provide a concise definition of DSR as “Research that invents a new purposeful artefact to address a generalised type of problem and evaluates its utility for solving problems of that type” (p. 142). In their earlier, seminal work on DSR, Hevner et al. (A. R. Hevner et al., 2004) provided seven guidelines for DSR. Guideline 2 outlines the need to ensure that problems are “important and relevant” (A. R. Hevner et al., 2004). Working on solving a generalised problem and rigorously evaluating how well the purposeful artefact works to solve the problem are what differentiate DSR (i.e. research) from everyday design (i.e. practice). While careful and thorough consideration and understanding of the problem is important to effective design practice, it is essential to DSR. The problem understanding and formulation guide both the purposeful artefact design (by identifying requirements) and the subsequent purposeful artefact evaluation (by establishing the evaluation criteria). Importantly, getting the problem wrong can lead to what Mitroff and Featheringham (Mitroff & Featheringham, 1974) call an error of the third kind: solving the wrong problem or choosing the wrong problem representation. Virtually all DSR methodologies start with a problem, but few take steps to analyse and formulate the problem. Action Design Research (ADR), discussed in the next section, is one of the exceptions.

**Action Design Research**

ADR (Sein et al., 2011) is a methodology for performing DSR. It emphasises collaboration with one or more (typically organisational) stakeholders (which is one of the main reasons why the authors have chosen to adopt it). There are four main phases to ADR: (1) problem formulation (the topic of this paper), as well as (2) cycles of Building, Intervention, and Evaluation (also known as the BIE cycle), (3) Reflection and Learning, and (4) Formalisation of Learning. Repeating stages 1, 2, and 3 is common.

ADR identifies six tasks and two principles for Problem Formulation. Table 1 shows the six tasks of problem formulation in ADR. The two principles of problem formulation in ADR are: Principle 1: Practice-Inspired Research (i.e. working with practitioners to meet practitioner needs) and Principle 2: Theory-Ingrained Artefact (i.e. the artefact choice and design are informed by theory). Engaging with stakeholders (principle 1) throughout the research helps ensure problem understanding as well as problem relevance (and hence practical research significance). Following principle 2 helps ensure theoretical significance of the research by relating the artefact design to extant theory and the
development of design theories or design principles as theoretical outcomes. According to Sein et al., a theory-ingrained artefact is one that uses theories to inform development. The theoretical bases for artefact designs may include “Gregor’s theories of Type IV (explanation and prediction theories) or Type V (design theories)” (Sein et al., 2011).

The use of DSR and particularly ADR as a methodology adds structure to the process for mHealth research projects. Providing an iterative framework that calls for the inclusion of users/stakeholders, ADR (Sein et al., 2011) outlines a patient-centric approach to artefact design that seems to be lacking in mHealth cancer solutions (Darlow & Wen, 2016).

Importantly, however, ADR (Sein et al., 2011) provides little support and advice for how to incorporate identified theoretical bases (activity 4 in table 1) into a suitable problem formulation or ideation for artefact design (principle 2). The main objective of this paper is to address this issue.

Problem Formulation

Nielsen’s paper on problem formulation in DSR (Nielsen, 2020) examines the shortcomings of problematisation within DSR as compared to other areas. Nielsen’s (2020) hypothesis centres around three key aspects that are lacking: problematisation analysis, empirical grounding, and problem-setting perspective. Problematisation analysis refers to the exploration of the underlying issue and provision of contextual information from varied perspectives (i.e. stakeholder, researcher). DSR problem identification often occurs through literature analysis and omits an empirical justification, but empirically grounding the problem understanding in DSR leads to richer understanding of the problem and helps to prevent errors of the third kind. Problem-setting recognises that the situation is being addressed through a particular lens, which ‘frames’ what will be solved and how it will be done. Any DSR project must determine a problem scope that is suitable for a successful research project.

Nielsen (2020) recognises the work of Venable as one of the few examples of how problematisation can be undertaken in DSR. The views and the findings outlined in this article align well with those of Nielsen (2020). The remainder of this paper focuses on assessing problem formulation deficiencies within DSR/ADR mHealth research projects and exploring directions for improvement.

Summary

The introduction to this paper posited two research questions. While the paper asserts that there is little support in DSR for problem formulation and ideation (supported by Nielsen, 2020), a good empirical basis for that assertion is needed, hence the first research question: “How are problem formulation and ideation currently performed in published DSR/ADR mHealth projects?” If there is indeed a weak basis for problem formulation in DSR mHealth projects, then a second research question needs to consider what can be done about that situation: “How can problem formulation and ideation be performed better (more rigorously and with better ideation outcomes) in DSR/ADR mHealth projects?”

The next section discusses the research methodologies used for addressing these two research questions.
RESEARCH METHODOLOGY

Research Question 1: Systematic Literature Review

To answer the first research question, confirm the existence, nature, and extent of the problem that the research addresses, and begin formulating the problem, the researchers conducted a systematic literature review (SLR) (Jennex, 2015; vom Brocke et al., 2015; Webster & Watson, 2002) to determine what strategies, methodologies and tools have been used by other mHealth DSR researchers to elicit functionality and analyse requirements for their artefacts. In conducting a SLR, the first step is to formulate a specific set of parameters that define literature that is of relevance, so that the results will show a high level of relevance to the broader research project. Papers were included if they met the following criteria:

- Research must utilise DSR;
- The artefact must be in the mHealth domain;
- The mobile app must have a patient-facing component (not just an internally focused clinical artefact);
- The artefact must be disease or disease prevention specific;
- The paper refers to how functionality and/or requirements were determined.

The second step is to conduct the actual search across relevant databases. This paper’s SLR literature search process was iterative and performed across the following portals, databases and journals:

- AIS eLibrary
- Springer Link
- ACM
- ProQuest
- NCIB
- Google Scholar
- Curtin University Online Library

A keyword search technique was used, which combined the phrases shown in Table 2.

The number of publications that were identified were of a manageable quantity (18, with three pairs being written as a continuation of a larger research project) and were therefore explored by performing manual qualitative thematic coding within the native PDFs. In the third step, the results were categorised using code terms, allowing for analysis of relevant content.

The code terms included:

- Health concern addressed

Table 2. Keyword search phrases

| Methodology                  | Mobile/Health          |
|------------------------------|------------------------|
| Design Science Research      | mHealth Mobile Health  |
| Action Design Research       | Health Mobile App      |
| DSR                          |                         |
| ADR                          |                         |
• How functionality/requirements determined:
  ◦ Literature review
  ◦ Clinicians consulted
  ◦ Patients consulted
  ◦ Quantitative method used
  ◦ Qualitative method used
  ◦ Iterative prototyping leading to refined requirements
• Analysis of functionality/requirements determinants (was/how was it done)
• Use of DSR
• Use of ADR
• Use of kernel theory
• Theory-ingrained artefact
• Patients consulted prior to prototype development
• Patients consulted to test prototype (but not engaged in determining prototype requirements)
• Year published
• Problem formulation
• Causal analysis
• Stakeholder analysis
• Deep understanding of users

The literature search, coding and analysis were conducted by one of the researchers. In the fourth and last step, the resultant spreadsheet and analysis notes were reviewed, queried and discussed by both authors.

Research Question 2: Case Study
To address the second research question, the authors evaluated the suitability of the Coloured Cognitive Mapping for Design Science Research (CCM4DSR) technique (Schilling et al., 2017; J. R. Venable, 2019, 2014) by applying it to the problem formulation and ideation parts of the ADR project to develop an mHealth app to improve skin monitoring behaviours in melanoma survivors. Doing so constitutes a DSR evaluation using a case study (Alpi & Evans, 2019; Yin & Campbell, 2018) research methodology to examine the application of the research technique (CCM4DSR) to the particular problem domain within mHealth. The focus of the case study/application was on modelling the causes and consequences of poor behaviours according to the literature and then transitioning to ideation of relevant mHealth app features. While CCM4DSR can also be used to model stakeholder understandings of the problem (and integrate them with the literature), that is not the focus of this paper.

The next section describes the findings of the structured literature review to examine how problem formulation has been performed in published mHealth DSR projects, especially those few mHealth DSR projects that used the ADR methodology.

SYSTEMATIC LITERATURE REVIEW FINDINGS
Only 18 papers met the criteria as previously outlined. Only two of the papers applied the ADR research methodology. Tables 3a and b provide the detailed results of the analysis of those 18 papers. 17 of the 18 papers (almost 95%) use a literature review to determine at least some aspects of app functionality and requirements, as well as to inform the artefact development. This result shows strong adherence to the DSR Rigour Cycle (A. Hevner & Chatterjee, 2010), which requires “researchers to thoroughly research and reference the knowledge base in order to guarantee that the designs produced are research contributions and not routine designs” (A. Hevner & Chatterjee, 2010). It also shows the
same commitment to ADR’s ‘Principle 2; theory-ingrained artifact’ (Sein et al., 2011), which states that an artefact must be built on a theoretical underpinning.

The majority of researchers reviewed literature from a variety of disciplines, which avoided a myopic approach and strengthened problem formulation. Conversely, just 60% of papers refer to the use of a kernel theory, limiting the researcher’s ability to develop an artefact in a way that is “disciplined, rigorous, and transparent” (Iivari, 2010).

A third of the research projects relied solely on literature reviews to determine functionality and requirements with only 66% consulting with clinicians and a mere 27% engaging with patients/potential users prior to artefact development. However, over 77% of papers detail sought feedback and evaluation by users once a prototype had been developed. Half of those that sought user input detailed that an iterative design process was undertaken. The inclusion of patients/clinicians allowed for further refinement of functional requirements during the project’s development stages.

On the whole, less than 40% of DSR/ADR projects included in this review incorporated end users as part of their iterative prototyping process. Only one of the two ADR papers reported following the ‘Building, Intervention and Evaluation (BIE)’ cycle schema as proposed by Sein et al. (2011) in the second stage of ADR. More generally, the DSR design cycle asks for artefacts to “be rigorously and

| Author/Year | Health Concern Addressed | Literature Review | Clinicians Consulted | Before Prototyping | After Prototyping | Quantitative Methods | Qualitative Methods | Iterative Prototyping |
|-------------|--------------------------|-------------------|----------------------|-------------------|------------------|---------------------|--------------------|---------------------|
| Elgayar et al., 2013 | Diabetes | Yes | Yes | No | No | No | Yes | Yes |
| Hermano & Stewart, 2014 | Mental health | No | No | No | Yes | Yes | Yes | No |
| Schnall et al., 2014 | HIV | Yes | Yes | Yes | Yes | No | Yes | No |
| Schnall et al., 2016 | HIV | Yes | Yes | Yes | Yes | No | Yes | No |
| Aljaroodi et al., 2017 | Stroke | Yes | Yes | Yes | Yes | No | Yes | Yes |
| Ainosayan et al., 2017 | Heart failure | Yes | Yes | No | Yes | No | Yes | No |
| Lamhard & Legner, 2017 | Age-related macular degeneration | Yes | Yes | No | Yes | No | No | Yes |
| Nguyen et al., 2017 | Coronary heart disease | Yes | No | No | Yes | No | No | No |
| Arige 2018 | Diabetes | Yes | Yes | No | Yes | No | Yes | Yes |
| Kao 2018 | Telehealth - in home chronic disease monitoring | Yes | Yes | No | No | No | Yes | No |
| Alharby & Chatterjee, 2019 | Chronic obstructive pulmonary disease | Yes | Yes | No | Yes | Yes | Yes | Yes |
| Gimpel et al, 2015 | Stress | Yes | No | Yes | Yes | No | Yes | No |
| Djamasbi et al., 2016 | Sleep | Yes | No | No | Yes | No | No | Yes |
| Wilson et al., 2017 | Sleep | Yes | No | No | Yes | No | Yes | Yes |
| Greve et al., 2020 | Non-communicable disease education/counselling | Yes | Yes | No | Yes | No | Yes | No |

- **Table 3a. Condensed version of literature review findings (part 1)**

The same commitment to ADR’s ‘Principle 2: theory-ingrained artifact’ (Sein et al., 2011), which states that an artefact must be built on a theoretical underpinning.

The majority of researchers reviewed literature from a variety of disciplines, which avoided a myopic approach and strengthened problem formulation. Conversely, just 60% of papers refer to the use of a kernel theory, limiting the researcher’s ability to develop an artefact in a way that is “disciplined, rigorous, and transparent” (Iivari, 2010).

A third of the research projects relied solely on literature reviews to determine functionality and requirements with only 66% consulting with clinicians and a mere 27% engaging with patients/potential users prior to artefact development. However, over 77% of papers detail sought feedback and evaluation by users once a prototype had been developed. Half of those that sought user input detailed that an iterative design process was undertaken. The inclusion of patients/clinicians allowed for further refinement of functional requirements during the project’s development stages.

On the whole, less than 40% of DSR/ADR projects included in this review incorporated end users as part of their iterative prototyping process. Only one of the two ADR papers reported following the ‘Building, Intervention and Evaluation (BIE)’ cycle schema as proposed by Sein et al. (2011) in the second stage of ADR. More generally, the DSR design cycle asks for artefacts to “be rigorously and

| Author/Year | Health Concern Addressed | Literature Review | Clinicians Consulted | Before Prototyping | After Prototyping | Quantitative Methods | Qualitative Methods | Iterative Prototyping |
|-------------|--------------------------|-------------------|----------------------|-------------------|------------------|---------------------|--------------------|---------------------|
| Elgayar et al., 2013 | Diabetes | Yes | Yes | No | No | No | Yes | Yes |
| Hermano & Stewart, 2014 | Mental health | No | No | No | Yes | Yes | Yes | No |
| Schnall et al., 2014 | HIV | Yes | Yes | Yes | Yes | No | Yes | No |
| Schnall et al., 2016 | HIV | Yes | Yes | Yes | Yes | No | Yes | No |
| Aljaroodi et al., 2017 | Stroke | Yes | Yes | Yes | Yes | No | Yes | Yes |
| Ainosayan et al., 2017 | Heart failure | Yes | Yes | No | Yes | No | Yes | No |
| Lamhard & Legner, 2017 | Age-related macular degeneration | Yes | Yes | No | Yes | No | No | Yes |
| Nguyen et al., 2017 | Coronary heart disease | Yes | No | No | Yes | No | No | No |
| Arige 2018 | Diabetes | Yes | Yes | No | Yes | No | Yes | Yes |
| Kao 2018 | Telehealth - in home chronic disease monitoring | Yes | Yes | No | No | No | Yes | No |
| Alharby & Chatterjee, 2019 | Chronic obstructive pulmonary disease | Yes | Yes | No | Yes | Yes | Yes | Yes |
| Gimpel et al, 2015 | Stress | Yes | No | Yes | Yes | No | Yes | No |
| Djamasbi et al., 2016 | Sleep | Yes | No | No | Yes | No | No | Yes |
| Wilson et al., 2017 | Sleep | Yes | No | No | Yes | No | Yes | Yes |
| Greve et al., 2020 | Non-communicable disease education/counselling | Yes | Yes | No | Yes | No | Yes | No |

- **Table 3a. Condensed version of literature review findings (part 1)**

same commitment to ADR’s ‘Principle 2: theory-ingrained artifact’ (Sein et al., 2011), which states that an artefact must be built on a theoretical underpinning.

The majority of researchers reviewed literature from a variety of disciplines, which avoided a myopic approach and strengthened problem formulation. Conversely, just 60% of papers refer to the use of a kernel theory, limiting the researcher’s ability to develop an artefact in a way that is “disciplined, rigorous, and transparent” (Iivari, 2010).

A third of the research projects relied solely on literature reviews to determine functionality and requirements with only 66% consulting with clinicians and a mere 27% engaging with patients/potential users prior to artefact development. However, over 77% of papers detail sought feedback and evaluation by users once a prototype had been developed. Half of those that sought user input detailed that an iterative design process was undertaken. The inclusion of patients/clinicians allowed for further refinement of functional requirements during the project’s development stages.

On the whole, less than 40% of DSR/ADR projects included in this review incorporated end users as part of their iterative prototyping process. Only one of the two ADR papers reported following the ‘Building, Intervention and Evaluation (BIE)’ cycle schema as proposed by Sein et al. (2011) in the second stage of ADR. More generally, the DSR design cycle asks for artefacts to “be rigorously and
thoroughly tested in laboratory and experimental situations before releasing them into field testing” (A. Hevner & Chatterjee, 2010). This aspect was not reported by a large number of the reviewed projects.

Both quantitative and qualitative methods were used to elicit requirements. Over 77% specified the method, with only 14% using quantitative and the remainder using qualitative methods. Table 4 outlines the methods used.

Table 3b. Condensed version of literature review findings (part2)

| Author/Years          | Kernel Theory                  | Theory engrained | Analysis/Performed After Consultation | Problem Formulation | Root Causes of Problems | Stakeholder Identification | Deep Understanding of Users |
|-----------------------|--------------------------------|------------------|---------------------------------------|---------------------|-------------------------|---------------------------|-----------------------------|
| Eligay et al., 2013   | Yes - positive psychology      | No               | No                                    | No                  | Met                     | Met                       | Partially Met               |
| Hermanto & Stewart, 2014 | Yes - behaviour change theory     | Yes          | Yes                                    | Met                  | Met                     | Met                       | Partially Met               |
| Schnall et al., 2014  | Yes - self-care theory & behavior change model | Yes | No                                    | No                  | Met                     | Met                       | Partially Met               |
| Lienhard & Legner, 2017 | Yes - activity theory     | No               | No                                    | No                  | Met                     | Met                       | Partially Met               |
| Aljarige 2018         | Yes - theory of interpersonal behavior | Yes | Yes                                    | Met                  | Met                     | Met                       | Partially Met               |
| Kao 2018              | Yes - health belief model      | Yes              | No                                    | No                  | Met                     | Met                       | Partially Met               |
| Gimpel et al, 2015    | Yes - transactional model of stress | Yes | No                                    | Partially Met       | Partially Met           | Partially Met             | Partially Met               |
| Djamasabi et al., 2016 | Yes - behavioral change theory | Yes          | No                                    | Partially Met       | Not Met                 | Not Met                   | Not Met                     |
| Wilson et al., 2017   | Yes - persuasive system design & behavior change support systems | Yes | No                                    | Partially Met       | Partially Met           | Partially Met             | Not Met                     |
| Greve et al., 2020    | No                             | No               | No                                    | No                  | Met                     | Met                       | Met                         |
| Volland et al., 2013  | Yes - information, motivation, and strategy (IMS) model | Yes | Yes                                    | Met                  | Partially Met           | Met                       | Partially Met               |
| Singh & Vanshney, 2014 | No                             | No               | No                                    | Partially Met       | Met                     | Not Met                   | Not Met                     |
| Volland & Eurlich, 2014 | Yes - information, motivation, and strategy (IMS) model | Yes | No                                    | Met                  | Met                     | Met                       | Partially Met               |

Table 4. Quantitative and qualitative methods used

| Quantitative          | Qualitative                      |
|-----------------------|-----------------------------------|
| Survey/Questionnaire  | Discussions/Consultations          |
|                       | Workshops                          |
|                       | App Reviews                        |
|                       | Interviews                          |
|                       | Focus Groups                        |
|                       | Questionnaire                        |
Only four of the papers identified that an analysis was performed on the outputs of the requirement elicitation methods. Schnall et al and Volland et al. (2014) used thematic and coding analysis (Schnall et al., 2014; Volland et al., 2014) and Kao et al. (2018) employed the Unified Modelling Language (Rumbaugh et al., 1999) to model the findings from interviews, as well as to represent processes (Kao et al., 2018). After a literature review and discussions with domain experts, Alrige (2018) developed initial design principles which she then mapped to design features (Alrige, 2018).

With only 20% of papers performing analysis, there is a missed opportunity by the others to gain more in-depth insights from stakeholder engagements.

The last four columns in table 3b use ‘met’, ‘partially met’ and ‘not met’ to denote the level at which researchers undertook the activities of (1) Problem Formulation, (2) Root Cause Analysis of Problems, (3) Stakeholder Identification and (4) Deep Understanding of Users. While carefully undertaken, making this interpretation is somewhat subjective.

Just over 60% of papers detailed a multi-faceted type of problem formulation. Techniques included a disease-specific systematic review of mHealth apps and articles (El-gayar et al., 2013), a literature and app review combined with multiple user-centric focus groups and clinicians as authors utilising their first-hand experience and knowledge (Schnall et al., 2014, 2016), literature reviews in addition to consultations with clinicians (Alnosayan et al., 2017; Alrige, 2018; Volland et al., 2013, 2014), and literature reviews supplemented by experience in practice (Kao et al., 2018; Lienhard & Legner, 2017).

Greve et al.’s (2020) problem formulation was the most detailed and thorough of the papers. They performed a cross-discipline literature review and determined a practice-based problem. This was then followed by discussions with the government of a developing African country and public health researchers. They worked to understand the “contextual background regarding the country, the health system within the country and the general non-communicable disease health status in the area”. Interactions with these stakeholders from the onset proved to be an important key to understanding the true nature of the problem.

The remaining 40% of papers derived their problem formulation from a literature review.

Almost 80% of research projects referenced the root causes of problems at some level of detail, three papers mentioned causes in a more indirect manner, and one neglected to address the causes of the research problem.

67% of papers identified stakeholder groups important to their research in the form of end-user or patient, outlining demographics, disease specific attributes and specific needs/considerations. This same selection of papers also addressed the involvement of a clinical or domain expert stakeholder group. Three papers identified patient user groups but omitted clinicians, while the remaining two papers contained little to no mention of stakeholder specifics.

A smaller percentage (22%) of the research projects provided a deeper understanding of their user groups, leaving the remainder with a more superficial view and a portion of that with an even more diminished comprehension of those that should be participating and collaborating with them.

DISCUSSION OF SYSTEMATIC LITERATURE REVIEW FINDINGS

This section discusses the findings, noting potential weaknesses in the existing DSR mHealth literature and makes some suggestions for how to deal with aspects arising from the discussion.

Potential Weaknesses of DSR in mHealth

The systematic literature review uncovered several areas of opportunity to enrich problem formulation in the application of DSR for mHealth.

While the majority of papers refer, at least superficially, to the causes of problems, they lack a more comprehensive and prescribed causal analysis. (A definition of causal modelling and its benefits can be found in the section on the case study findings for research question 2 further below.) These
papers missed the opportunity to gain a better understanding of the problem environment and to develop a more informed solution.

The review also reveals a lack of considered stakeholder analysis. The lack of identification and in-depth consideration of user/stakeholder groups in a structured form left a large portion of the research projects without direction and understanding from those who experience the problem or hold the practical knowledge.

Following on from this, less than a third of projects employed participation from users (patients) before prototyping. This outcome accentuates the lack of patient-centricity in the problem formulation and initial requirements determination stages.

Djamasbi et al. (2016) in particular experienced the adverse effects of not including end users and clinicians in the problem formulation and requirements elicitation stage. The omission led to users experiencing two challenging prototype testing studies (Djamasbi et al., 2016). This difficulty was acknowledged by the research team and addressed in a subsequent publication (Wilson et al., 2017), recognising the need for clinician and user input as a way forward.

**Suggestions for Improvement**

Suggestions for improvement come in many forms, which include different ways of identifying aspects and understandings of the problem, as well as different ways of modelling or representing the problem. These address both aspects of type 3 errors (solving the wrong problem or using the wrong representation) identified by Mitroff and Featheringham (1974). This section identifies five different ways for improving problem formulation in mHealth DSR projects.

First, conducting stakeholder analysis in a well-structured way can be a fruitful approach to improving problem analysis in DSR. For example, Venable (2009) examines the place of users/stakeholders in DSR, the ways that the groups are identified and how they can be analysed (J. R. Venable, 2009). He details how the use of Ulrich’s Critical Systems Heuristics (CSH) framework (Ulrich, 1983) appropriately suits stakeholder analysis needs in DSR. Identifying stakeholders for each DSR project, based on the CSH roles of client, decision maker, professional and witness (see Table 5) as part of the problem formulation process will give a better comprehension of those involved and which groups should be consulted.

Second, effective use of established human-computer interface (HCI) development practices can further add to the understanding of stakeholders/users. Once stakeholders and their roles have been established, a list of characteristics for each group can be made (Shneiderman & Plaisant, 2010). This

| Role          | Issues                                                                 |
|---------------|------------------------------------------------------------------------|
| Client        | Purpose, measure of improvement                                         |
| Decision Maker| Resources, decision environment                                        |
| Professional  | Expertise, what guarantees success in the intervention                  |
| Witness       | Emancipation of affected parties, legitimacy and appropriateness of the worldview(s) governing the intervention |
includes demographic information such as age, gender, ethnicity and other ‘personal characteristics’ (Kujala & Kauppinen, 2004) as well as other task, social and geographic characteristics (Kujala & Kauppinen, 2004).

These characteristics can then be used to create an abstract representation of each group in the form of a persona (Miaskiewicz & Kozar, 2011). Each representation acts as a reminder of user perspectives throughout the design process. This technique has been increasingly used in mHealth research projects (Haldane et al., 2019) and adds to the patient-centred/experience design approach.

Third, obtaining a clinical perspective is an important consideration when pursuing a mHealth project. There are an abundance of patient focused apps available that do not contain accurate scientific data (Berkowitz et al., 2017), leading, in some cases, to increased patient risk (Hanrahan et al., 2014). The inclusion of clinicians throughout the process will aid in mitigating these factors and lend validity and credibility to the final artefact (Pandey et al., 2013).

Fourth, making effective use of kernel theories (or justificatory knowledge) from the literature is another approach. Walls et al. (1992), Markus et al. (2002) and Gregor and Jones (2006) advocate for the use of kernel theory (or justificatory knowledge) from natural and/or behavioural sciences as part of the DSR process. Indeed, this is formalised in principle 2 of ADR: Theory-ingrained artefact. While not a necessity, kernel theories can be applied to understand the problem to be solved, inform artefact design, determine requirements and to develop a design theory (J. Venable, 2006).

Fifth and finally, causal modelling can be used to structure a problem understanding and agree upon a formulation. Causal modelling is a heuristic, analytical tool (Asher, 1983) used to illustrate complex cause and effect relationships (Youngblut, 1994). Various forms of causal modelling tools include the Ishikawa or fishbone diagram, the interrelationship diagram and current reality tree (Doggett, 2005), cognitive mapping (Eden & Ackermann, 2001) and coloured cognitive mapping (J. R. Venable, 2005). As discussed earlier, CCM4DSR was the approach investigated in this paper. The next section presents findings from the case study of the application of CCM4DSR to problem formulation for a melanoma survivor mHealth app.

**CASE STUDY FINDINGS: CCM4DSR EXPERIENCE IN USE**

As discussed in the introduction and the research methodology section, to assist in the problem formulation, the researchers chose to use Coloured Cognitive Mapping (CCM) for DSR (CCM4DSR) because it was designed for use in DSR (J. R. Venable, 2019). CCM4DSR has five steps: (1) Problem Diagnosis, Formulation, and Shared Understanding (model the “problem as difficulties”, i.e. relevant aspects of the undesirable current situation, as a CCM), (2) General Requirements Derivation (invert the CCM into an initial CCM of the “problem as opportunities”, i.e. what would be desirable outcomes), (3) General Design Ideation (identify actions and strategies to achieve desired outcomes and add them to the CCM), (4) Artefact and Design Theory Evaluation (based on the CCM), and (5) Design Theory Formulation (accomplished in parallel with the other stages/activities. As with ADR, looping back to prior stages/activities is normal (Venable, 2019).

Contell et al’s ‘DScaffolding’, or Design Science Scaffolding (Contell et al., 2017), template was used to support the cognitive mapping activity. The tool provides a guide to problem formulation and includes a section based on Ulrich’s CSH framework (Ulrich, 1983) to capture stakeholder information in the same location.

Through a literature review, a number of ‘problems as difficulties’ were uncovered and represented as part of a CCM. The negative framing of the problem as difficulties works to identify the current (as is) state. When the exercise is inverted, to present ‘problems as opportunities’ the result is a pathway to an improved future state.

It is this proposed future state that is then translated into functional and non-functional requirements.
The authors conducted an extensive, multi-discipline literature review at the onset of the melanoma focused mHealth research project. The outcome highlighted the gaps felt by melanoma survivors and the numerous problems and challenges they face. But distilling the vast amount of information into a comprehensible problem formulation was difficult.

Conducting CCM4DSR (see figures 1-4) enabled the authors to structure and analyse what had previously seemed like an unmanageable amount of material. Note: In CCM, nodes that represent something undesirable are coloured red while nodes that represent something desirable are coloured green. As figures in this journal cannot include colour, undesirable nodes are shown as hexagons and desirable nodes are shown as ovals.

The authors went through multiple iterations of CCMs, as one author was familiar with the method and the other was familiar with the mHealth and other health literature. Discussion helped to clarify meaning and precision of the wording of each node in the diagrams, as well as clarifying and understanding the causal links. With one author (a PhD student) studying part-time while learning the method and the other author (the supervisor) teaching full-time, the process took several weeks. Figures 1 and 2 show the result of analysing the ‘problems as difficulties’, which focus on the undesirable, “as is” situation. Figure 1 shows the consequences of the central problem, “Poor … [as opposed to] good melanoma survivor health behaviours. The consequences demonstrate the problem importance. Figure 2 shows a subset (due to space limitations, see Figure 6 in the Appendix for the full figure) of the causes of the central problem.

Inverting each node in the CCMs in figures 1 and 2 leads to CCMs (figures 3 and 4 respectively) of the “problem as opportunities”, which focus on a desirable future state, in which the problem is solved or at least reduced. Note that the nodes in figure 3 correspond one-for-one to the nodes in figure 1. Similarly, many (but not all) of the nodes in figure 4 correspond directly to nodes in figure 2.

Figures 1 and 2 integrated the literature, which provided many different perspectives. Figure 3 and especially figure 4 enabled contemplating the ‘opportunities’ as solutions holistically. Discussions undertaken resulted in many realisations such as solutions that hadn’t previously been thought of and also aided in expanding on many of the one-dimensional ideas (Jones & Venable, 2020).

During the development of the initial CCMs (see figures 1-4), the authors identified several demographic groups (see the left-hand side of figure 2) with different specialised issues as melanoma survivors. The rich understanding of users’ issues led to identifying a suggested requirement node stating, “Improve relevance and access to health information for people from disadvantaged groups (disability, poor, minorities, uneducated) … don’t” (on the left of figure 4). When reaching the ideation stage, a CCM (figure 5) extracted and used these different demographic groups and ideated features to tailor (customise or configure) each instance of the app based on the user’s demographic characteristics.

Figure 1. CCM of consequences of the problem as difficulties (as is)
Importantly, this CCM will also form the basis of subsequent user personas that will be created during the rest of the ideation stage of the project. This information will further assist in shaping the features and functionality required from the mHealth solution for encouraging good melanoma survivor health behaviours.

**DISCUSSION OF CASE STUDY FINDINGS**

Prior to using CCM4DSR, the authors were at risk of missing whole areas of interest that may have not even been uncovered when consultation with stakeholders occurs. They wouldn’t be aware of the missed opportunities.

This contemplation resulted in a more comprehensive first set of functional requirements than if the authors not undergone the process (Jones & Venable, 2020). The results can now be presented to clinical partners, providing a visual representation that gives an overview of the project direction in an easily digestible format.
CCMs or similar casual analysis strategies are not currently being utilised in the extant literature reviewed. There is potential for the CCM4DSR process to be used for other mHealth related research projects and for any DSR or ADR research endeavour.

CONCLUSION

The research reported in this paper was conducted as part of a larger mHealth project aiming to develop an mHealth app to improve health behaviours in melanoma survivors to help prevent and
detect melanoma recurrence. The objective of this particular paper was to identify a means to improve problem analysis in mHealth DSR projects.

In answering the first research question, the analysis in this paper highlighted several potential weaknesses in the problem formulation activities reported in extant DSR mHealth publications. Potential weaknesses included a noticeable lack of engagement with end-users (typically patients) at the problem formulation stage. While causal analysis was usually present, it was also usually somewhat superficial, lacking both depth and precision. Stakeholder analyses also typically lacked depth and consideration of the problem environment and ecology. Finally, kernel theory from the literature was only used in about half of the publications, highlighting a lack of a theoretical basis for problem understanding and subsequent artefact ideation and design.

The above potential weaknesses can possibly cause significant problems in DSR mHealth projects. It is possible that they can lead to what has been termed an error of the third kind: solving the wrong problem (type I is false positive and type II is false negative). Moreover, without a rich understanding of the problem and user needs and constraints, significant opportunities for more effective and efficacious means to improve upon the problem may be missed. As mHealth apps are concerned with health and health improvement, the differences between the effectiveness and efficacy of different designed solutions may be highly significant.

In answering the second research question, this paper suggests that (1) earlier and deeper engagement with patients/users, (2) explicitly conducting and using causal analysis and (3) stakeholder analysis techniques, and (4) searches for kernel theory that explains problems (or barriers to their solution) may yield better understanding and lead to better design interventions in mHealth applications and, ultimately, better health outcomes. The example use of CCM4DSR in the case study answering the second research question provides some evidence of the richer problem understanding and the increased possibilities identified for problem solving.

We did not identify any prior health or mHealth research that uses formal causal models, such as CCMs, or conducts formal stakeholder analyses; our suggestions are novel within the health domain. It is likely that following the suggestions made and illustrated in this paper can improve the understanding of problems in the health domain and lead to better and more appropriate (and therefore likely more effective) health and mHealth solutions, with attendant improvement in health outcomes and less wasteful health expenditures.

While the single case study described in this paper does provide some evidence of the utility of the CCM4DSR technique for conducting DSR in mHealth, further research is needed to apply and empirically and critically examine whether (and how well) the suggested improvements do indeed yield the benefits asserted in this research.
REFERENCES

Alnosayan, N., Chatterjee, S., Alluhaidan, A., Lee, E., & Houston Feenstra, L. (2017). Design and Usability of a Heart Failure mHealth System: A Pilot Study. *JMIR Human Factors*, 4(1), e9. doi:10.2196/humanfactors.6481 PMID:28341615

Alpi, K. M., & Evans, J. J. (2019). Distinguishing case study as a research method from case reports as a publication type. *Journal of the Medical Library Association: JMLA*, 107(1), 1–5. doi:10.5195/JMLA.2019.615 PMID:30598643

Alrige, M. (2018). *A Nutrient-Profiling Inspired Mobile-Based Application for Type-2 Diabetics to Increase Knowledge about Nutrition and Improve Dietary Behavior*. Academic Press.

Asher, H. (1983). *Causal Modeling* (2nd ed.). doi:10.4135/9781412983600

Barello, S., Triberti, S., Graffigna, G., Libreri, C., Serino, S., Hibbard, J., & Riva, G. (2016). eHealth for Patient Engagement: A Systematic Review. *Frontiers in Psychology*, 6. 10.3389/fpsyg.2015.02013

Berkowitz, C. M., Zullig, L. L., Koontz, B. F., & Smith, S. K. (2017). Prescribing an App? Oncology Providers’ Views on Mobile Health Apps for Cancer Care. *JCO Clinical Cancer Informatics*, 1, 1–7. 10.1200/CCI.17.00107

Bowen, D., Jabson, J., Haddock, N., Hay, J., & Edwards, K. (2012). Skin care behaviors among melanoma survivors. *Psycho-Oncology*, 21(12), 1285–1291. https://doi.org/10.1002/pon.2017

Contell, J. P., Diaz, O., & Venable, J. R. (2017). DScaffolding: A Tool to Support Learning and Conducting Design Science Research. *Proceedings of the 12th International Conference on Design Science Research in Information Systems and Technology (DESРИST 2017) Karlsruhe, Germany*, 441–446.

Darlow, S., & Wen, K.-Y. (2016). Development testing of mobile health interventions for cancer patient self-management: A review. *Health Informatics Journal*, 22(3), 633–650. https://doi.org/10.1177/1460458215577994

Davis, S. W., & Oakley-Girvan, I. (2017). Achieving value in mobile health applications for cancer survivors. *Journal of Cancer Survivorship: Research and Practice*, 11(4), 498–504. https://doi.org/10.1007/s11764-017-0608-1

Djamasbi, S., Strong, D. M., Wilson, E. V., & Ruiz, C. (2016). Applying both User Experience and Design Science Research Twenty-second Americas Conference on Information Systems. Academic Press.

Doggett, A. M. (2005). Root Cause Analysis: A Framework for Tool Selection. *The Quality Management Journal*, 12(4), 34–45. https://doi.org/10.1080/10686967.2005.11919269

Eden, C., & Ackermann, F. (2001). SODA - The Principles. In Rational Analysis for a Problematic World Revisited. Academic Press.

El-gayar, O., Timsina, P., & Nawar, N. (2013). A mHealth Architecture for Diabetes Self-Management System. *AMCIS 2013 Proceedings*. https://aisel.aisnet.org/amcis2013/HealthInformation/RoundTablePresentations/5

Glenn, B. A., Chen, K. L., Chang, L. C., Lin, T., & Bastani, R. (2017). Skin Examination Practices Among Melanoma Survivors and Their Children. *Journal of Cancer Education*, 32(2), 335–343. https://doi.org/10.1007/s13187-016-0998-1

Haldane, V., Koh, J. J. K., Srivastava, A., Teo, K. W. Q., Tan, Y. G., Cheng, R. X., Yap, Y. C., Ong, P.-S., Van Dam, R. M., Foo, J. M., Müller-Riemenschneider, F., Koh, G. C.-H., Foong, P. S., Perel, P., & Legido-Quigley, H. (2019). User Preferences and Persona Design for an mHealth Intervention to Support Adherence to Cardiovascular Disease Medication in Singapore: A Multi-Method Study. *JMIR mHealth and uHealth*, 7(5), e10465. https://doi.org/10.2196/10465

Hallberg, D., & Salimi, N. (2020). Qualitative and quantitative analysis of definitions of e-health and m-health. *Healthcare Informatics Research*, 26(2), 119–128. https://doi.org/10.4258/hir.2020.26.2.119

Hanrahan, C., Aungst, T. D., & Cole, S. (2014). *Evaluating Mobile Medical Applications*. https://www.ashp.org/-/media/store/files/mobile-medical-apps.pdf

Hevner, A., & Chatterjee, S. (2010). *Design Research in Information Systems* (Vol. 22). Springer US. 10.1007/978-1-4419-5653-8

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *Management Information Systems Quarterly*, 28(1), 75–105. https://dl.acm.org/citation.cfm?id=2017212.2017217
Iivari, J. (2010). Twelve Theses on Design Science Research in Information Systems. Springer. https://doi.org/10.1007/978-1-4419-5653-8_5.

Jennex, M. E. (2015). Literature reviews and the review process: An editor-in-chiefs perspective. *Communications of the Association for Information Systems*, 36(8), 139–146. https://doi.org/10.17705/1cais.03608

Jones, C., & Venable, J. R. (2020). Integrating CCM4DSR into ADR to Improve Problem Formulation. In *Proceedings of the 15th International Conference on Design Science Research in Information Systems and Technology - (DESRIST 2020)* (pp. 247-258). Springer International Publishing. https://doi.org/10.1007/978-3-030-64823-7

Jones, M. S., Torisu-Itakura, H., Flaherty, D. C., Schoellhammer, H. F., Lee, J., Sim, M. S., & Faries, M. B. (2016). Second primary melanoma: Risk factors, histopathologic features, survival, and implications for follow-up. *American Surgeon*, 82(10), 1009–1013. /pmc/articles/PMC5555365/?report=abstract

Jupp, J. C. Y., Sultani, H., Cooper, C. A., Peterson, K. A., & Truong, T. H. (2018). Evaluation of mobile phone applications to support medication adherence and symptom management in oncology patients. *Pediatric Blood & Cancer*, 65(11), e27278. https://doi.org/10.1002/pbc.27278

Kao, H. Y., Wei, C. W., Yu, M. C., Liang, T. Y., Wu, W. H., & Wu, Y. J. (2018). Integrating a mobile health applications for self-management to enhance Telecare system. *Telematics and Informatics*, 35(4), 815–825. https://doi.org/10.1016/j.tele.2017.12.011

Kujala, S., & Kauppinen, M. (2004). Identifying and selecting users for user-centered design. *ACM International Conference Proceeding Series*. 10.1145/1028014.1028060

Lienhard, K., & Legner, C. (2017). Principles in the Design of Mobile Medical Apps: Guidance for Those who Care. *Wirtschaftsinformatik*, 2017.

Miaskiewicz, T., & Kozar, K. A. (2011). Personas and user-centered design: How can personas benefit product design processes? *Design Studies*. 10.1016/j.destud.2011.03.003

Mitroff, I. I., & Featheringham, T. R. (1974). On systemic problem solving and the error of the third kind. *Behavioral Science*, 19(6), 383–393. https://doi.org/10.1002/bs.3830190605

Moser, E. C., & Meunier, F. (2014). Cancer survivorship: A positive side-effect of more successful cancer treatment. *EJC Supplements*, 12(1), 1–4. 10.1016/j.ejcsup.2014.03.001

Mujumdar, U. J., Hay, J. L., Monroe-Hinds, Y. C., Hummer, A. J., Begg, C. B., Wilcox, H. B., Oliveira, S. A., & Berwick, M. (2009). Sun protection and skin self-examination in melanoma survivors. *Psycho-Oncology*, 18(10), 1106–1115. https://doi.org/10.1002/pon.1510

Nielsen, P. A. (2020). *Problematizing in IS Design Research*. Springer. https://doi.org/10.1007/978-3-030-64823-7_24

Pandey, A., Hasan, S., Dubey, D., & Sarangi, S. (2013). Smartphone Apps as a Source of Cancer Information: Changing Trends in Health Information-Seeking Behavior. *Journal of Cancer Education, 28*(1), 138–142. https://doi.org/10.1007/s13187-012-0446-9

Rumbaugh, J., Jacobson, I., & Booch, G. (1999). *The UML reference manual* (Vol. 1). Addison-Wesley.

Schilling, R. D., Aier, S., Brosius, M., Haki, M. K., & Winter, R. (2017). Extending CCM4DSR for collaborative diagnosis of socio-technical problems. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 10243 LNCS, 247–263. 10.1007/978-3-319-59144-5_15

Schnall, R., Rojas, M., Bakken, S., Brown, W., Carballo-Dieguez, A., Carry, M., Gelaude, D., Mosley, J. P., & Travers, J. (2016). A user-centered model for designing consumer mobile health (mHealth) applications (apps). *Journal of Biomedical Informatics*, 60, 243–251. https://doi.org/10.1016/j.jbi.2016.02.002

Schnall, R., Rojas, M., Travers, J., Brown, W., & Bakken, S. (2014). Use of Design Science for Informing the Development of a Mobile App for Persons Living with HIV. *AMIA Symposium*, 2014, 1037–1045.

Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research 1. Action Design Research, 35(1).

Shead, D. A., Hanish, L. J., Clarke, R., & Corrigan, A. (2018). *NCCN Guidelines for Patients® | Melanoma*. National Comprehensive Cancer Network., https://www.nccn.org/patients/guidelines/melanoma/
Shneiderman, B., & Plaisant, C. (2010). *Designing the User Interface: Strategies for Effective Human-computer Interaction*. Addison-Wesley. https://books.google.com.au/books?id=pddxRQAACAAJ

Ulrich, W. (1983). *Critical Heuristics of Social Planning: A New Approach to Practical Philosophy*. P. Haupt. https://books.google.com.au/books?id=7PdDPgAACAAJ

Venable, J. (2006). The role of theory and theorising in design science research. *Proceedings of the 1st International Conference on Design Science Research in Information Systems and Technology*. https://www.academia.edu/download/44379893/The_role_of_theory_and_theorising_in_des20160404-841-mz753q.pdf

Venable, J., & Baskerville, R. (2012). Eating our own cooking: Toward a more rigorous design science of research methods. *Electronic Journal of Business Research Methods*, 10(2), 141–153. https://search-proquest.com.dbgw.lis.curtin.edu.au/docview/1318921958?rfr_id=info%3Axri%2Fsid%3Aprimo

Venable, J. R. (2005). Coloured Cognitive Maps for Modelling Decision Contexts. In T. Bui & A. Gachet (Eds.), CEUR Workshop Proceedings (Vol. 144). http://ftp.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-144/03_venable.pdf

Venable, J. R. (2009). Identifying and addressing stakeholder interests in design science research: An analysis using critical systems heuristics. *IFIP Advances in Information and Communication Technology*. 10.1007/978-3-642-02388-0_7

Venable, J. R. (2014). Using Coloured Cognitive Mapping (CCM) for design science research. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 8463 LNCS, 345–359. 10.1007/978-3-319-06701-8_25

Venable, J. R. (2019). *Coloured Cognitive Mapping for Design Science Research (CCM4DSR)*. Academic Press.

Vo, V., Auroy, L., & Sarradon-Eck, A. (2019). Patients’ perceptions of mhealth apps: Meta-ethnographic review of qualitative studies. *Journal of Medical Internet Research*, 21(7).

Volland, D., Korak, K., Brückner, D., & Kowatsch, T. (2013). Towards design principles for pharmacist-patient health information systems. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 7939 LNCS, 519–526. 10.1007/978-3-642-38827-9_45

Volland, D., Korak, K., & Kowatsch, T. (2014). Emerging patterns of communication in a pharmacist-patient health information system. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 8463 LNCS, 378–382. 10.1007/978-3-319-06701-8_29

von Brocke, J., Simons, A., Riemer, K., Niehaves, B., Plattfaut, R., & Cleven, A. (2015). Standing on the shoulders of giants: Challenges and recommendations of literature search in information systems research. *Communications of the Association for Information Systems*, 37, 205–224. https://doi.org/10.17705/1crais.03709

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review Reproduced with permission of the copyright owner. Further reproduction prohibited without permission. *Management Information Systems Quarterly*, 26(2), xiii–xxiii. https://doi.org/10.2307/4132319

Welfare. (2019). *Cancer in Australia 2019*. https://www.aihw.gov.au/getmedia/8e9cf52-0055-41a0-96d9-f81b0fe98cf/aihw-can-123.pdf.aspx?inline=true

Wilson, E. V., Djamasi, S., Strong, D., & Ruiz, C. (2017). Using a Key Informant Focus Group, Formative User Testing, and Theory to Guide Design of a Sleep Health BCSS. *Hawaii International Conference on System Sciences 2017 (HICSS-50)*. https://aisel.aisnet.org/hicss-50/1c/health_behavior/5

Yin, R. K., & Campbell, D. T. (2018). *Case study research and applications : design and methods*.

Youngblut, J. A. M. (1994). A consumer’s guide to causal modeling: Part I. *Journal of Pediatric Nursing*, 10.5555/uri:pii:0882596394900574

ENDNOTE

1 The British/Australian spelling of artefact is used throughout this article, with the exception of quoted instances that use American spelling.
APPENDIX

Figure 6. CCM of the causes of the problem as difficulties (as is)
Figure 7. CCM of actions to reduce causes of the problem (problem as solutions)
Coquessa Jones completed her undergraduate studies in design at Curtin University and continued on to obtain a Master’s in Communication Design at RMIT University. It was during that period that she discovered her passion for design thinking and user-centric design approaches. She has shared this enthusiasm while lecturing students at North Metropolitan TAFE and Swinburne Online, teaching them the fundamentals of user experience/user interface (UX/UI) design. Coquessa is currently working in the Western Australian health department, tackling COVID-19 ICT problems with design thinking solutions. This includes state-wide contact tracing, venue check-in and vaccination inventory and administration solutions. Her industry work and current PhD research project intersect while trying to bring meaningful improvements to the lives of Australian melanoma survivors.

John Venable is an Adjunct Research Fellow, Business Information Systems in the School of Management and Marketing at Curtin University, Perth, Western Australia. He has held academic positions in Information Systems and Computer Science in the USA, Denmark, New Zealand, and Australia. He has published in international conferences and journals including The European Journal of Information Systems, Journal of Information Technology, Information & Management, The Information Systems Journal, Information Technology & People, Communications of the Association for Information Systems, The Scandinavian Journal of Information Systems, The Journal of Community Informatics, Wirtschaftsinformatik, and the Electronic Journal of Business Research Methods. Concerning Design Science Research (DSR), Dr Venable has published over 50 refereed papers about or using DSR, is the section editor for DSR of the Australasian Journal of Information Systems, co-organised the 2010 IFIP Working Groups 8.2 and 8.6 Joint International Working Conference on “Human Benefit through the Diffusion of Information Systems Design Science Research”, and co-edited a special issue of Information Technology and People on “Design and Diffusion of Systems for Human Benefit”. Dr Venable’s other research interests include IS development and planning methods and practice; organisational, IS and data modelling; problem solving methods; qualitative and critical research; research methods; organisational culture and change management; knowledge management and organisational learning; Group Support Systems and collaborative work; digital library systems; and application and management of IS and IT to support not-for-profit organisations.