Extending the framework for Mobile Health Information Systems Research: A Content Analysis

Extending the framework for Mobile Health Information Systems Research: A Content Analysis

Shah Jahan Miah , John Gammack , Najmul Hasan

PII: S0306-4379(17)30163-1
DOI: 10.1016/j.is.2017.04.001
Reference: IS 1213

To appear in: *Information Systems*

Received date: 15 March 2017
Revised date: 12 April 2017
Accepted date: 12 April 2017

Please cite this article as: Shah Jahan Miah , John Gammack , Najmul Hasan , Extending the framework for Mobile Health Information Systems Research: A Content Analysis, *Information Systems* (2017), doi: 10.1016/j.is.2017.04.001

Highlights

- This paper describes findings of a comprehensive content analysis on the current state of m-health research for IS researchers and professionals.
- The paper identifies eight application categories (themes), ten design issues (security, privacy, literacy, accessibility, acceptability, reliability, usability, confidentiality, integrity, knowledge-sharing and system flexibility) as well as the stakeholders and development techniques involved.
- It is anticipated that the findings that reinforce use of design science research, theoretically motivate the central role of M-health IS design

Extending the framework for Mobile Health Information Systems Research: A Content Analysis

Shah Jahan Miah

Information Systems Discipline, College of Business, Victoria University, Footscray Park Campus, Melbourne, Australia

John Gammack

College of Technological Innovation, Zayed University, Abu Dhabi, United Arab Emirates

Najmul Hasan

MRC Bangladesh Ltd, Dhaka, Bangladesh

Abstract

Whilst researchers and professionals recognize that mobile health (m-health) systems offer unprecedented opportunities, most existing work has comprised individual project-based developments in specialised areas. Existing review articles generally utilise medical literature and categories: none investigates m-health from an information systems (IS) design point of view. Identifying application areas, design issues and IS research techniques will demonstrate models, issues, approaches and gaps to inform future research. A comprehensive analysis of the literature from this viewpoint is thus valuable, both for theoretical progression and for guiding real-world innovative system developments.

Drawing from key IS and healthcare multidisciplinary journals we analyse recent (2010-2016) articles concerning m-health application developments and their associated design or development issues, with particular focus on the use of contemporary research methods. Our analysis suggests that m-health is an emerging field to which, although underused, contemporary approaches such as design science research are particularly appropriate. We identify eight application categories, eleven design issues (security, privacy, literacy, accessibility, acceptability, reliability, usability, confidentiality, integrity, knowledge sharing and flexibility) as well as the stakeholders and development techniques involved. This goes beyond previous frameworks, and theoretically integrates the central role of IS design within the sub-field.

Keywords: m-health, design science, mobile-based innovations, content analysis, information systems design methodologies.

Corresponding Author: *Dr Shah Miah, College of Business, Victoria University, Melbourne, Australia, Phone:+61 3 99199835, email: shah.miah@vu.edu.au*

1 Introduction

Research on healthcare applications design for mobile devices (M-health) has gained increasing attention over the past decade. M-health broadly refers to a service or mobile application for providing healthcare support to anyone, anytime, and anywhere [10]. M-health aims to provide health professionals, patients, clinicians and other relevant users with information support services to manage, disseminate, collect, administer, control and monitor healthcare information and improve health service delivery and quality of care support. The service provided by various m-health information systems (IS), eliminates geographical and temporal constraints while enhancing the coverage, quality, cost savings and other user provisions of healthcare [15, 51, 76].

M-health IS provide information services that facilitate, *inter alia*, onsite patient care, community wellbeing and self-care, clinician decision making, administrative mobility and personalization support provision both for service receivers and service providers. Various innovative M-health IS have been proposed and many forms of m-health applications have thus been developed as fully functional system solutions. Currently M-health IS offers not only personalized access to applications through mobile devices, but also provides associated data from various sensors, automatic trackers and relevant stakeholders, for real-time actions. Through Internet enabled wireless networks, and/or other forms of connectivity such as Bluetooth, m-health innovations allow acquisition, monitoring, forecasting, sharing and control of various health conditions. Such provisions are designed for healthcare personnel and patients with disparate needs to make decisions regarding treatments and care support, and serves administration requirements for developing anytime-anywhere service support. Illustrative examples include: M-health systems for remote patient monitoring [4], disease prevention and wellbeing [78], knowledge exchange [59] and medication management [39]. To date many such initiatives have been developer-driven and theoretically piecemeal, and inconsistent or lacking in their generalisabilty either to knowledge or theory. The continuing flow of such M-health studies indicates a need for a contemporary research framework that may help better to formalize this sub-field within IS research.

Within the IS literature Varshney [76] analysed 129 selected articles from IS, biomedical informatics and health informatics outlets up to 2012 and identified four major areas of M-health with associated research challenges. The areas are: expanding healthcare coverage, improving decision making, managing chronic conditions and providing suitable healthcare in emergencies. The defined challenges are grouped as being related to (a) patients, (b) healthcare professionals, (c) IT and (d) applications. The aim of this effort was to suggest further research directions within the four categories but also acknowledged that other categories would be required for this proposed M-health framework to become comprehensive. Hussein et al. [27] reviewed 133 articles on smartphone medical apps across medical and technical repositories and found most articles described apps for specific diseases or subfields, or were general reviews. Only 5 addressed general frameworks and only one addressed the developer's perspective, a classification of 200 IOS apps, by Liu et al. [41]. Both Zein et al. [82] and Sahinoglu et al. [63] note the absence of systematic reviews on testing and verification of mobile apps, including M-health apps. Zein at al's observation that "there are currently no available comprehensive systematic review studies in the area of mobile and smartphone application testing" [82, p.334] motivated their own study in this area.

Most of the other literature reviews in the M-health field have used top down approaches with extant or adapted medical categories to conduct their document analysis. Where new categories are induced from the articles

selected these are often ad hoc properties of a sample chosen purposively. When a field is still emerging at a rapid rate, it is unlikely that any categorisation induced from its earliest articles will have general utility beyond the classification purpose or provide enactment and long-term stability. The paper by Kallander et al. [36], for example, cited various numbers of thematic categories that had been suggested in the M-health literature, from which they chose a 6 items typology (see [82]).

Naturally, all systematic literature reviews are limited by the articles available at the time of sampling, as Fiordelli et al. [20] note with regard to their own review. Fiordelli et al. [20] actually split the decade to 2012 into two halves, noting a sudden exponential growth with the advent of smartphones around 2008, with distinctive patterns in each half.

In the various existing review articles on M-health , other than Varshney [76], who identifies IT and application areas of research challenge, IS considerations are far removed from their primary focus. Although there are several conference papers represented, IS journals provide only 16 M-health articles in his sample and his analysis shows that only about 11% of all M-health articles address application design, development and testing: well behind the other three areas. However, understanding what types of application development methodologies are used for M-health and their design issues is imperative to offer better understanding to M-health designers, IS researchers and industry practitioners in their further innovative developments of M-health applications. Whilst the reviews to date find no shortage of developed apps and pilot studies towards medical outcomes [75] these provide little contribution to research knowledge and there remains little specific contribution that can guide IS development in this field. As a contemporary IS method, Design Science Research (DSR) [25] provides explicit approaches by reinforcing - not only IS design innovation (e.g. product and process perspectives) but also methodological innovation [24]. DSR requires both a rigorous contribution to knowledge, and a development of knowledge relevant to stakeholders' practices. Nevertheless, to date very few studies seemed explicitly to apply the DSR approach in M-health. We therefore wished to explore in more systematic detail how M-health innovations are being developed, and the role of design science approaches within that.

To formalize the M-health design sub-field and extend the current frameworks and understanding, we used a bottom-up approach to conduct an IS focused literature review and analysis through the use of a qualitative content analysis method [12]. We aim to identify the scope and prospect for potential use of DSR in M-health design. Prior to conducting the analysis we chose an IS design lens that both encompasses identifying the range of human user roles, and also the design issues and methods used for developing and evaluating M-health artefacts: areas lacking in the previous M-health studies reviewed. This responds to the more recent calls for design collaboration and IS focus in M-health app development that are now becoming evident [9, 35].

Under this approach, we set two main objectives for our literature analysis. The first objective was to attain better understanding on M-health research emerging themes, stakeholders and key design issues and solution technologies (hardware, software and networking). The second objective was to find the forms of replicable methodology used, if any, to design M-health applications. In particular, we aimed to identify aspects of DSR in the existing research of M-health app development. This assessment will indicate the extent to which DSR methodologies both are used, and have further potential to apply, in M-health app design.

The paper is structured as follows. The next section gives an overview of the historical progression of M-health studies and the aspects of particular significance for further investigation, including an illustrative case to show

an application of DSR in M-health app design. The section after that provides methodological details followed by the findings of the study. The discussion section describes the overall contributions of the research followed by a conclusion section in which we summarise and discuss limitations and further directions of the research.

2 STUDY BACKGROUND

2.1 M-health innovations

Although today's M-health studies effectively began with the invention of the smart cell phone, in 1949, AT&T invented a program called "Mobile Telephone Service", for providing health services to 100 towns and 5,000 customers in the US. However, the service experienced major technological issues as they used only three radio channels to provide only three customers at a particular time [60]. Laxminarayan and Istepanian [29] described M-health for the first time as "unwired e-med" and in 2003, as mobile communications technologies were further developed for healthcare systems, the term 'M-health' was redefined as 'emerging mobile communications and network technologies for healthcare' [29]. Mobile technologies are now rapidly growing due to popular uptake along with emerging capacity in hardware and software as well as powerful cellular technologies, and companies such as Apple and Samsung have developed features in their mobile devices (e.g. tablets, i-pads, portable computers, mobile phones and personal digital assistants-PDAs), for health services which offer potential general provision of mobile health apps. This has engendered innovations in the ways healthy lifestyles and well-being can be supported, while linking technologies for health, health professional and individuals in social care systems [28].

An increasing number of apps, especially among the most used, are being linked to social media [31]. Social media allows people to be active participants in their health maintenance: virtually connected communities are enabling people to become more educated, supported, and more knowledgably to control and self-regulate their wellness in health- and lifestyle-related decision making [72]. Emerging technologies, responsive to individual profiles combined with Internet-based analytics, realise opportunities for new types of consumer-oriented innovations and enable new forms of community-based provision. A recent count found over 165,000 mobile healthcare apps, but cautioned on the lack of evidence for the safety and efficacy of many, as well as the non-adoption and the confusion entailed by the sheer amount of apps available [72]. Many healthcare providers are now "prescribing" apps, implying a need for objective quality vetting, regulation and perhaps certification, along with future integration into electronic health records and monitoring systems, all currently under-researched areas.

2.2 Previous reviews of the M-health literature

As M-health research has matured it has gained increasing attention by IS researchers and healthcare system professionals alike. This is due to its practical relevance to patients, healthcare professionals, application developers, service providers and other agents aided by the ubiquity of mobile devices and apps. Although the benefits are clear for target agents/groups such as patients and the elderly (e.g. for receiving emergency care, and assistance to manage their daily activities in independent living), health professionals (e.g. improving decision making and providing care support to patients), and healthcare organizations or service providers (e.g. for expanding healthcare coverage, providing suitable healthcare in emergencies, and offering awareness on prevention), M-health has not been previously assessed and conceptualized as a distinct and vital sub-field of IS research.

Although new research designs and app rating or certifying mechanisms have begun to emerge, much of the literature describes individual, project-based application developments which do not offer generalised knowledge contributions, mostly being clinical trials or pilot studies [20]. Previous reviews of the M-health literature have also typically used top-down categorisations from the medical literature to identify research directions for specific areas of health, and their focus is largely that of medical journals' interests. From the viewpoint of IS, understanding related to the solution themes, the development methods of M-health application and the associated design issues are poorly developed and lacking a theoretical framework. Although emerging as an "autonomous field of study" [20], studies in the area of M-health are rarely discussed in terms of the concerns and opportunities within the realm of IS design research. Previous meta-analyses of the M-health literature are summarised in table 1 and briefly discussed below.

Existing studies	*Literature review methodologies*	*Outcomes of the analysis*
Conserve et al. [13]	7 articles; Narrative analysis	M-health interventions for increasing HIV testing
Jennings and Gagliardi, [32]	173 articles; iterative thematic analysis	M-health to find influence of gender relations
Free et al [19]	Three-part search strategy was implemented on several databases; narrative synthesis	Provided evidence of effectiveness of mobile computing and communication technologies to improve healthcare and health service
Payne et al. [56]	24 articles; qualitative synthesis	M-health studies that are informed by behavioral theories or strategies
Nhavoto and Grönlund [51]	271 articles; 220 M-health technologies, 51 GIS, Narrative analysis	Captured existing understanding on how mobile technologies and GIS applications have been used for improving health care
Mobasheri et al. [35]	185 mobile apps; Narrative analysis	Identified the current barrier and potential use of M-health apps related in the field of breast disease
Betjeman et al. [7]	109 articles; Thematic analysis	Identified major issues and challenges of M-health for future research.
Kallander et al. [36]	Several project documents, Two stage process, a thematic overview, the study only focused on 6 major thematic areas	The potential challenges and opportunities for integration of community M-health applications
Martinez-Pérez et al. [44]	371 papers and 557 apps related to the leading causes of death; comparison study	Identified top 10 causes by comparing the amount of M-health research and the number of mobile apps dedicated to the diseases and conditions that led to human death.
Catalani et al. [8]	62 articles; qualitative data synthesis	Relevance of M-health interventions for HIV treatment and its prevention
Silva et al. [69]	35 articles; content survey	M-health technologies growth, its regulation, and legislation issues
Varshney [76]	129 articles; structured survey out of 16 IS journals	Findings major themes, research issues, and a framework to describe M-health

Table 1: Previous M-health literature review studies

The typical emphasis of these reviews is instrumental: focusing on emerging directions in M-health associated with medical or social categories. The review by Jennings and Gagliani [32] for example selected only articles related to developing countries, and whose findings concerned gender dynamics. Kallander et al. [36] used predefined M-health themes from the literature to assess how low-middle income countries were approaching the intersection of mobile technology and public health and identified the key challenge of moving from "pilot projects to national scalable programs".

Although IT and apps are centrally involved, the reviews rarely consider IS issues. Indeed this is an explicitly acknowledged delimitation of the otherwise comprehensive review by Fiordelli et al. [20] who excluded technology-oriented databases in favour of medical and socially focused sources of articles. Fiordelli et al. [20] reviewed the decade of M-health research from 2002-12 to assess the impact of mobile phones, describing the field's monotonic and at times exponential growth and categorising articles by medical conditions, usually chronic. Whilst acknowledging they had not considered articles from technology databases, they noted the numerous health apps available on app stores, together with the lack of systematic research on these. More recent research by Silva et al. [69] aimed to identify M-health potential and challenges, and focused on classifying the 37 most significant apps proposed by industry by therapy area. These were drawn from the iTunes store, and

cited evidence that the US store alone had more than 40000 healthcare apps as of 2013, whilst Varshney [76] claimed there were over 100000 M-health apps available across various devices at the time his research was done. The research based 165,000 figure of IMS [31] and the 259 000 figure of research2guidance (2016)[1] indicates the current trajectory and scale of development of healthcare related apps. Payne et al.'s [56] literature review identified 24 articles on mobile apps for M-health behaviour interventions, but these were found to be mainly pilot or feasibility studies. Although review articles of M-health apps are beginning to emerge, (e.g. [64]; [50]) these also tend to have outcomes relevant to specialised medical practitioner audiences. Despite several apps being available, both of these recent articles conclude that functionality is lacking and that there is a need for more relevant app development for the areas reviewed (iatrogenic infection and gout respectively). Like others (e.g. [35]), Schnall and Iribarren [64] specifically call for collaboration between medical specialists and IS developers.

2.3 Major methodologies for M-health innovations

The proliferation of apps indicated earlier, with wearable or implantable monitors indicates the demand potential, but development is generally not research-led, and untested or ill-informed apps can be actively dangerous. Diagnostic inaccuracy, unreliable, (or reliable but invalid) measures, inappropriate treatment recommendations and data breaches or misrepresentation are just some of the recognized outcomes from improperly designed solutions [28].

Many current M-health innovations are, however, designed through the use of traditional development system methodologies that encompass steps or iterations for identifying and analysing requirements, designing or implementing a system solution and testing the system within the problem domain. For instance, Radzuweit and Lechner [61] utilised prototyping for designing a consultation service that supported effective interaction between individuals and health professionals. Milošević et al. [47] used a basic software engineering methodology for designing an M-health application for community well-being by monitoring individuals' health conditions such as physical activity, weight and heart activity. The methodology consisted of common phases such as problem definition, architecture (mobile computing) design and implementation. Chatzipavlou et al [9] stressed the "executive role of developers" and their specific need to understand legal and financial aspects to gain user confidence with the apps they develop: embodying a traditional developer-centric perspective.

Many of the M-health innovations designs, however, do not evaluate the solution directly or indirectly with the target user groups. For instance, Oluwafemi et al. [53] proposed a patient communication solution through messaging but, although the study used phases such as design, development and evaluation, the authors did not evaluate the solution with the target user patient group. Moreover, Zein et al [82] have identified a lack of systematic testing in mobile app developments and specify several areas where gaps exist. Although the later phases are neglected, many M-health developments display a traditional methodology of system design starting with requirement identification and analysis then software design and development continuing through to testing, implementation and maintenance. The Scandinavian, socio-technical and user-centred traditions have all variously argued for the continuing participation of stakeholders in this process, and designing for relevance to

[1] Research2guidance (2016). mHealth App Developer Economics 2016, The current status and trends of the mHealth app market, URL: http://research2guidance.com/r2g/r2g-mHealth-App-Developer-Economics-2016.pdf

the realities of the operational environment, which itself may require redesign and change management, values recognized within the newer development models and methods of DSR.

2.4 **Design Science Research** methodologies

Design Science Research (DSR) represents development, implementation, evaluation, and adaptation of artefacts for contextually relevant problem solving [25] and its traditional focus on the design and construction of solution artefacts suggest its utility for M-health applications. Because badly designed health applications can be dangerous, it is therefore important to emphasise the use of an appropriate design methodology for quality innovation design in the M-health sector.

DSR offers improvements over traditional methodologies in designing IS artefacts, so understanding DSR is of significance for M-health design. DSR provides methodologies that have roots in engineering and the artificial sciences [71]. DSR "seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished" [25, p. 76]. DSR is particularly relevant for innovative solution designs for M-health applications because it better supports designers/researchers in establishing grounded knowledge and in embedding behavioral or human aspects into the design of artifacts to solve real world problems [65].

Hevner et al's [25] guidelines are intended to be supportive to designing IS artefacts in form of constructs, models, methods, and instantiations [42]. M-health solutions are composed of mutable and adaptable hardware, software, and human interfaces and presents unique and challenging design problems that call for new and creative methodological ideas, to which DSR is relevant. However, although the design steps commonly used for developing and evaluating M-health innovations in many IS solutions may be similar to design guidance of DSR methodologies, none of the M-health design studies reviewed previously explicitly utilised DSR. Previous literature reviews have not inventorised the design methodologies nor assessed their current status in the literature.

2.4.1 An illustrative case of Design Science Research in M-heath app design

Before beginning our content analysis we describe a case study to illustrate the development of an M-health solution app developed using Design Science Research to show how the various constructs and guidelines used apply in the context of a representative M-health study.

Healthcare consultation provision is a crucial issue in public healthcare. Yet citizens in remote or rural areas often receive poor or inadequate treatment and preventative care due to the lack of effective service delivery options for facilitating medical consultation and treatment information care support. Despite technological advances such as smartphone penetration transforming society, rural citizens, particularly in developing countries have suffered from "digital divide" in healthcare support due to limited access to electronic information systems for their individual healthcare decision making. To address this gap, a mobile based clinical decision support system solution approach called Bhalo-Achi (*I am Fine*) was designed and evaluated for providing general healthcare decision support and medical information dissemination to rural citizens [46].

Using DSR methodological guidelines the M-health application was designed through engaging medical professionals and citizen groups – outlining the basic user demand for general practice services. Cognizant of the increasing pervasiveness of mobile phones and social media usage, the solution targets the demand of Bangladeshi rural citizens, who do not have adequate access to healthcare support in general practice, but who do have mobile phones and capable telecommunication infrastructure. In the adopted approach, Hevner et al's [25] seven guidelines were grouped into three broad activities (identifying target problems and solution types; artifact creation and evaluation and finally research contribution and communication of research). The three project phases represent design and development guidance for M-health apps as illustrated below.

Prior to producing the artifact (***Hevner et al's guideline one*****)** we used *guideline two* to identify the specific problem of relevance. Our project identified a target population within the problem domain of general practice healthcare and produced a mobile decision support artefact designed to support healthcare decisions for rural patients in Bangladesh.

Second, for artifact evaluation (*guideline three***)**, the utility of the initial artifact was demonstrated to obtain feedback from target users (representative stakeholders). Evolutionary prototyping development in consultation with doctors (representative knowledge sources) ensured ongoing evaluation of quality and relevance during development. Following *guideline five* for ensuring research and artifact construction rigor, iterative prototyping is standard practice, and a social media based doctor rating technique was used to validate the artefact following generally accepted research procedures (observational and descriptive methods). Using *guideline six* (design as a search process), valid healthcare knowledge was established through iterative development and evaluation in order to cope with much of the uncertainty inherent in the problem space (e.g. patients' concerns relevant to general practices and emergencies were separated from the primary medical and healthcare requirements) to allow progressive and incremental solution development at a level that would fit the usage context.

Finally, the third activity phase identifies the research contribution and communicates the outcome to a professional community in order to express its value within the relevant body of knowledge. Using *guideline four* the study used experimental and focus group methods and analysis showed clear benefits to the target populations in rural areas of Bangladesh. The approach connects citizens to doctors based on the queries and information provided by the patients. Available doctors evaluate a patient's condition and provide answers for diagnosis or treatment. Using *guideline seven*, the study presented detail relevant to academic, management and industry professionals, and was verbally presented to such audiences in workshops and presentations during its development and evaluation.

Following Gregor and Hevner [24], the study further ensured the principles of form and functions incorporating underlying constructs were described, including scope of artifact design, mutability of artifact, testable properties, new knowledge justification, kernel theories, principles of implementation and the expository instantiation.

Although the case described above illustrates how DSR may be specifically used, (see Schnall et al. [65] for another example) a comprehensive content analysis on the current literature of M-health innovation design and associated issues remains of importance, not only for theoretical progression but also importantly for more real-world application developments in future. There remains a need to assess the methods used in M-health app design and how DSR may better address future application design. Our first aim is therefore to identify major

recent work in M-health, their contributions, and the methods used by the developers, with particular focus on design approaches.

2.5 Research Questions

Nunamaker et al. [52] stated that a body of knowledge comprises of research domains and research methodologies, and that, "A research process involves both understanding the research domains, asking meaningful research questions, and applying valid research methodologies to address these questions. Results from a good research project contribute to the body of knowledge by expanding knowledge in a given domain" (p. 91). IS design is a broad, varied and evolving research domain with many sub-fields and application areas. An objective of this study is to conceptualise M-health research as a distinct sub-field of IS research, through analysis of prior literature and design approaches taken. Very few previous M-health studies have attempted to reflect on their chosen methods, or on the relation of their work in the context of a body of knowledge. Our work therefore addresses the following research questions (RQs):

RQ1: What are the themes and associated design issues in published M-health literature?

RQ2: What are the design details of M-health applications reported in previous M-health designs?

RQ3: How do these studies relate to design science research knowledge?

The answers to RQ1 and RQ2 are generated through a systematic content analysis, RQ3 is then considered separately against this background to extend our understanding of M-health research in IS.

3 Method

3.1 Target area of interest

The main aim of the study is to identify and analyse recent M-health studies, to classify emerging themes and to explore solution designs and methodologies used in M-health applications design. This extends and updates Varshney's work [76] where the aim, based on literature prior to 2012, was to develop knowledge around M-health IS design themes to inform future research agendas. Secondly, to detail the use of IS methodologies in existing M-health app design which had not been a focus of previous reviews. In the Design Science Research (DSR) literature, Hevner et al. [25] defined four types of IS solutions (artifacts), namely constructs, models, methods, and instantiations. Gregor and Hevner [24] extended this by adding design theory as a fifth type of IS artifact, marking an essential difference from traditional reporting of a specific development by an explicit consideration of its relationship to a body of knowledge. We accordingly aim to investigate the recent M-health design literature using this typology, identifying both literature analyses, and specifically relevant M-health conference and journal articles. We distinguish these by primary concern, whether focusing on design or development issues, application developments, or design theories (figure 1), selected as described below.

Two main types of sample articles are targeted. The first set is those primarily with a focus on IS *issues* in designing for M-health (e.g. research methods, IT deployed, key themes, adoption, relationships among studies). The other articles primarily concern M-health theory and *application design* per se (e.g. describing a particular type of solution artifact, relevant design theory and approaches used, and development or evaluation methods).

3.2 Sample articles and their sources

We used a bottom-up approach for collecting our sample articles. That is, we didn't initially select the specific outlets for selecting the sample articles but rather conducted an independent search using keywords across various databases such as Sciencedirect, NCBI, and Google scholar. Keywords both represent the essence of articles and indicates new literature to examine, and their choice is critical. Although we were most interested in recent literature, we filtered from 2004, since this was a landmark date in DSR conceptualisation. Using the terms "design science (research)" and "{mobile,m} health" as initial filters on the ACM digital library, Sciencedirect and Proquest databases we however identified only a handful of peer reviewed articles since 2004, with only 4 articles (conferences or journals) before 2011. We therefore expanded the terms used (e-health and apps or applications) and the databases used to ensure better coverage of relevant articles.

Following the proposal of Dieste et al. [14] for developing an optimum search strategy, "mobile health" was initially searched in Google scholar to find relevant multidisciplinary journals in various databases yielding around 100 results related to "mobile health". Then we used specific terms (e.g. "applications", "applications design", "design research"), in Boolean searches [58]. Depending on the search syntax for each database, the full text of the journal articles and conference proceedings published in English were also searched using the following search strings:

(mobile health OR mHealth) AND (apps OR apps design OR design research OR design issues)

Telemedicine AND (apps OR apps design OR design research OR design issues)

(Healthcare OR mhealth) AND (mobile OR decision framework OR applications OR technology OR information systems)

This also expanded the journal base beyond IS journals to relevant multidisciplinary journals. The databases searched were as follows: Springer Link, Science Direct, ProQuest Central, EBSCO online database, Wiley Online Library, NCBI database, IEEE Xplore and the ACM Digital library.

From 2010 to 2016 (December), for issues focused articles, we identified 55 articles and for those with more design focus, 36 articles. The articles are from published journals and leading IS conference proceedings (i.e. excluding book chapters and other working papers that are published on online repositories). We also manually excluded those papers that mainly concerned web-based applications but where the only relevance was on access using mobile devices and thus we separated e-health and telemedicine from M-health studies proper.

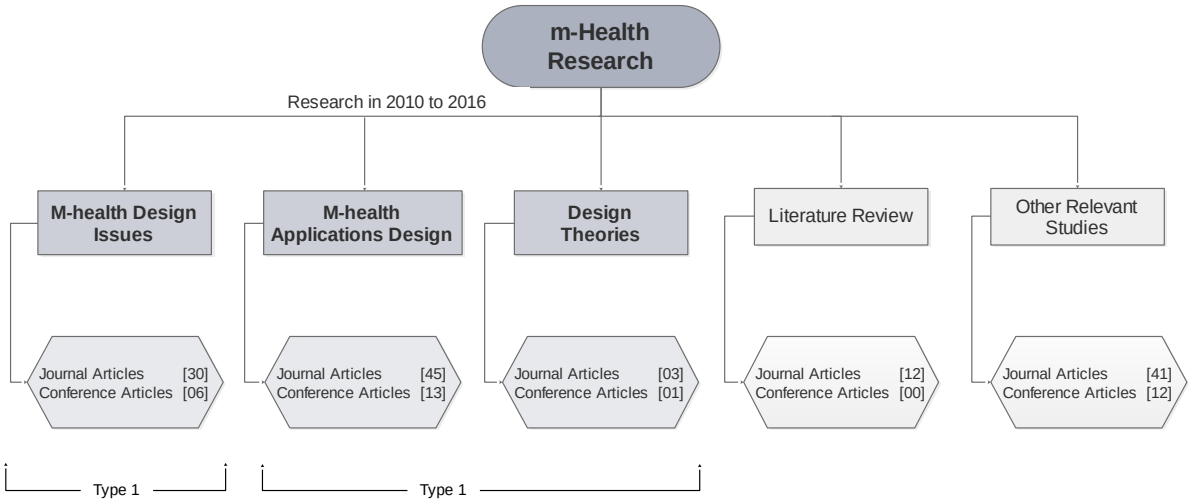

Figure 1: M-health areas of focus in existing studies

We classified the journals into two groups: top high-impact journals (such as DSS, EJIS, JAIS, MISQ, JIT, ISR, ISJ and JMIS, (ranked as top eight IS journals by ACPHIS) and lower impact or domain-specific journals (e.g. the multidisciplinary journals publishing M-health papers, such as *Journal of Medical Internet Research, (JMIR), mHealth and uHealth, Diabetes technology & therapeutics* etc). The process used to identify and select articles is shown in figure 2. Tables 2 and 3 show the pattern of results from our search and with a modal number of articles of 1, shows there is a wide range but no dominant or central outlets. It also indicates there is no particular upward trend in the number of publications. With small numbers, this is not significant, but is consistent with a nascent field of study. Note that the "Journal of mHealth" has operated since 2014 but is a professional, rather than an academic journal. For further sample details please see Appendix A: we now look more specifically at the content of the identified articles.

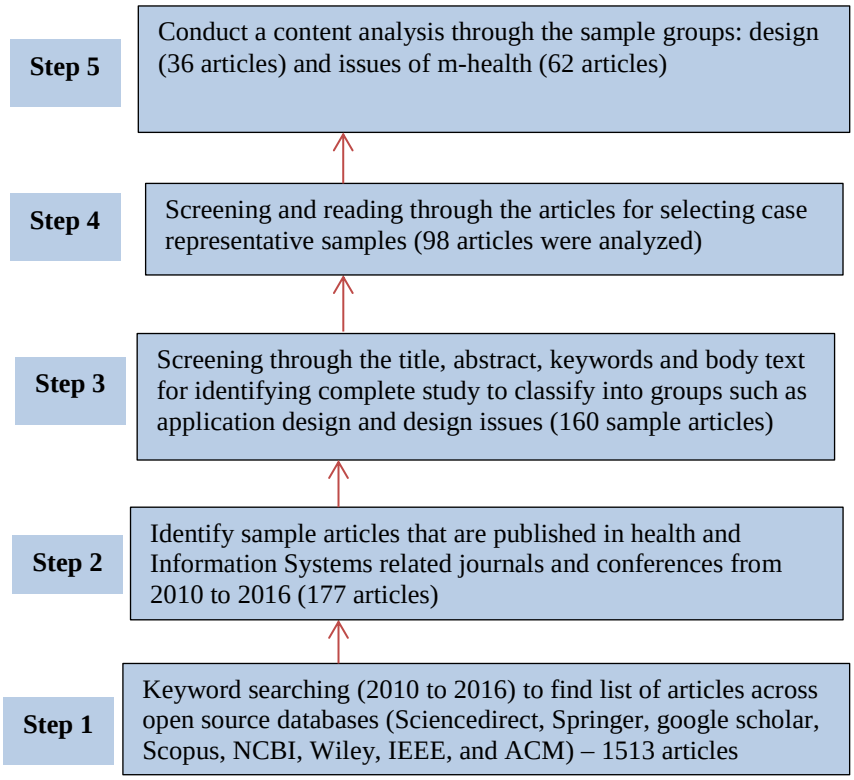

Figure 2: Five-step methodology for sample collection

3.3 Content analysis

Content analysis is an analysis method that can variously use qualitative and quantitative research techniques. The method can be applied for exploring and analyzing data or content directly obtained from written documents, as well as from human interaction processes [21]. Using qualitative methods, the method is useful to enhance the ability of researchers to exploit documents as important sources of information to identify new phenomena. Many IS researchers have applied the content analysis method both for qualitative and quantitative analysis in different IS research domains. For example, Al-Debei and Avison [1] used content analysis in their analysis of business model concepts using IS literature while Arnott and Pervan [2] explored previous articles of DSR in relation to decision support systems (DSS) design research. Indulska and Recker [30] also conducted qualitative content analysis on DSR articles to establish the claims of these articles' usage of DSR methods in IS research. In our research, we followed the approach of Arnott and Pervan [2] to analyse both types of articles, as the approach guided to produce useful insights and current state of the DSS research.

The result of a qualitative content analysis provides a summary of the original information and can be presented in the form of concepts and/or categories that express the investigated phenomenon. For conducting effective content analysis inductive analysis is appropriate when "there are no previous studies dealing with the phenomenon or when it is fragmented" [17, p.107]. We analyzed both types of articles using the inductive method, for classification and categorisation of the attributes. The articles were collected to gain insights on their

issues, themes and methodologies utilised in designing M-health, and also to reveal the extent of use of methods related to DSR.

We were guided by the three phases of *preparing*, *organising* and *reporting* described by Elo and Kyngäs [17]. The preparing phase aims to form a categorization based on related and common characteristics from a collection of grouped codings or headings. This includes an interpretation process that helps identify categories that describe the phenomenon that has been analysed [17]. The first concern is to determine what to analyse: in this case we *prepared* 98 articles retrieved from databases using research-relevant terms. In the *organising* phase we manually went through each article to identify the issues, key themes and how the design was conducted. Although a small total, we believe it is sufficient to represent the issues. We separated issues focused papers from M-health design focused articles where we identified their design process description, evaluation methodologies and rigorous processes employed. These enact existing IS design methodologies and can be loosly mapped to the explicit DSR guidelines of Hevner et al. [25]. Finally, for *reporting* purposes (to summarize the outcome of the content analysis) we have represented our findings using the structures of Varshney [76] for issues and of Hevner et al. [25] for design. The next section will describe the findings of our analysis.

4 Findings

The section describes the findings revealed in two separate analyses. First we briefly describe the issues emerging, and indicate some areas from recent papers not identified in the earlier studies reviewed, which had been based on an earlier sampling period. We then focus in more detail on the techniques and technologies used.

4.1 Issues of M-health IS design

Our content analysis of the articles identified as having a primary focus on M-health issues per se identified 20 areas of innovative M-health apps for stakeholders including patients, healthcare givers, doctors and healthcare professionals. The areas are patient monitoring, self-management, disease prevention, adherence improvement dietary control, evidence based practices, early intervention in childhood, medication compliance for elderly populations, therapeutic support, treatment support, interaction support between doctor and patients, home monitoring, healthcare data collection, clinical decision making, and public healthcare service etc. We found the majority of apps were designed for patient support (such as self-care and remote monitoring) with fewer apps for healthcare professional and care-givers. The most common target audience for the apps developer was those with chronic diseases or older adults. It was evident that majority of the app developers came from technological backgrounds rather than having domain specific or medical knowledge.

Varshney [76] described four emerging themes of M-health, namely healthcare coverage, improving decision making, managing chronic conditions and providing suitable healthcare in emergencies. His survey covered the years up to 2012, and he acknowledged this classification would be expanded as research matured. Our classification extends this to a total of eight relevant themes, shown in figure 3. Each theme is discussed further below, identifying the IS-relevant aspects of indicative studies.

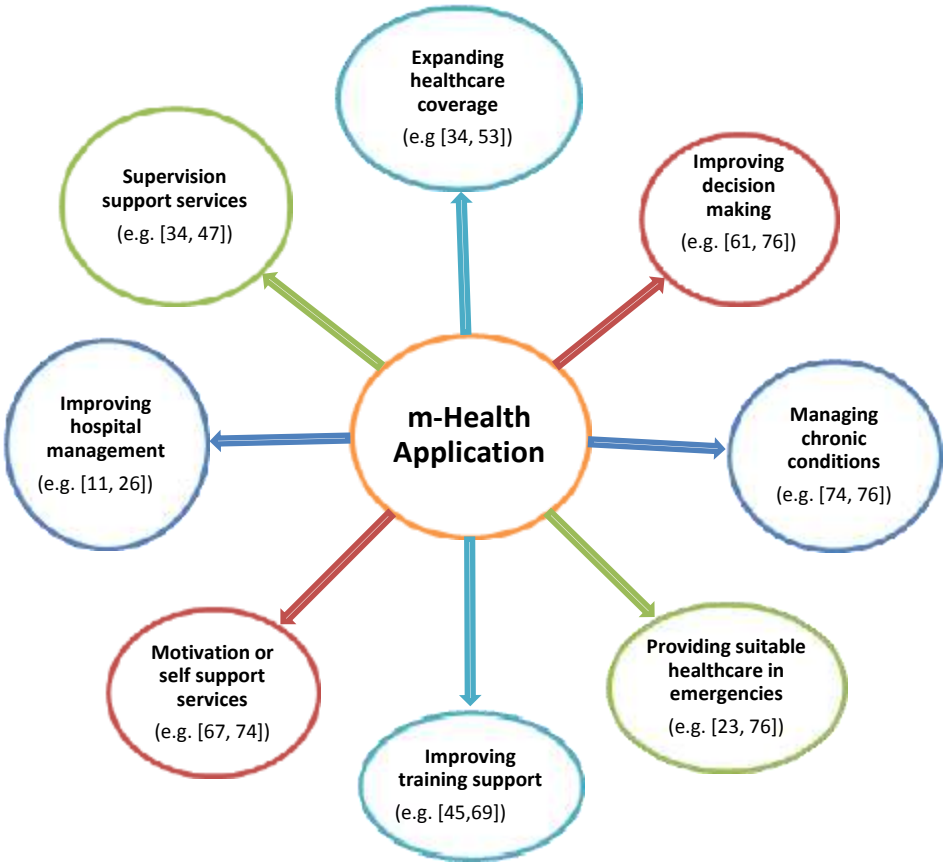

Figure 3: Eight emerging themes (innovation areas) of M-health IS research

The themes are defined as follows:

Theme 1: Expanding healthcare coverage

M-health allows provision across the different locations of patients and healthcare professionals. Service to remote or otherwise underserved regions is enabled. Real time support via low-cost short message service (SMS) based remote monitoring is gaining popularity (e.g. [67]). Likewise sensor based monitoring applications can be linked and transmissions recorded as usability and feasibility of collected sensor data expands [18, 26, 37]. Through networks of sensor nodes, and network cameras with image processing, P/T/Z operation, TCP/IP management for mobile healthcare service remote monitoring, diagnostics and treatment interventions become enabled. Involving healthcare professionals in app design augments the technological potential. In the weight loss program of Shaw et al. [67] for example, Rothman's Behaviour Change Process [62] was considered during application development. In areas where patients are underserved, such as the developing nations, remote or rural areas, or where there is a shortage of physicians or long waiting times, further research using such technologies within effective information systems is needed.

Theme 2: Improving decision making

Due to increased mobility in support services decision making in healthcare industries has been improved in relation to prevention, diagnosis, data collection, treatment, adherence monitoring and surveillance using mobile networks [5]. Appropriate decision-making depends on the validity and reliability of the data collection, error

checking and observation. Through remote and timeous data collection over wireless networks appropriate and necessary actions can be taken promptly. Using M-health protocols like color coding, symbolic presentations and use of alternate screens it is easy to develop clinical strategy and improve usability [76] in diverse aspects of clinical decision making, at both healthcare professional and patient level.

Various strategies have been developed to provide decision support to healthcare industries both for disease assessment and treatment provision. Radzuweit and Lechner [61] developed a hybrid IT-artefact using common Web technologies like HTML, CSS and JavaScript, from which healthcare management improved their reasoning strategy and changed their knowledge and skill to develop their decision making. Wireless based systems using GSM/GPRS can provide real time disease diagnostics and give quick decisions, which are also cost effective. For example, ECG signals through Bluetooth devices can be transmitted using *AliveECG* software [38]. Banos et al. [5] described a sensor-based application named *Shimmer2* supported by the M-health Droid Communication Manager that successfully provided an open framework for taking instant decisions in healthcare management. Many chronic patients like diabetics or asthma patients are also now used to M-health applications and are able to improve self-efficacy. Researchers have found that patient healthcare behaviour has changed using self-reported electronic diaries. Wolf et al. [80] for example found significant benefits from patients using a mobile/web e-health diary and symptom tracking tool compared to traditional care. Clinical DSS are likely to remain an important area of M-health IS research.

Theme 3: Managing chronic conditions

M-health technologies can foster greater commitment for better managing chronic disease. A design research approach by Radzuweit and Lechner [61] suggested shared tablet computers could enhance the relationship between patients and healthcare providers for managing chronic conditions. If web apps are not available, researcher(s) have readily found mobile alternatives, e.g. Android supported apps using java script. In Wolf et al's [80] study the mobile app was preferred to the equivalent web app. In the development phase many developers have used PHP due to its logical approach and created the supporting databases using *MySql*. But HTML technology combined with JavaScript is very well-suited to developing apps that helps elderly people or chronic patients self-manage and report in a user friendly environment. Wearable sensor and portable biomedical systems also improve the condition of chronic diseases. Tools like mobile adapters, smart watch adapters, bracelet adapters and belt adapters help to improve care of chronic conditions in self-care management. For example M-healthDroid, an open framework for building M-health apps [5] can be used to build apps that investigate and visualise human behaviour or make knowledge-based inferences and give quick feedback. Wireless technologies like WiFi, 3G connection, Bluetooth, geo-positioning technologies (GPS), are configured to mobile apps means (e.g. elderly) people's activities can send feedback to the professional enabling alert generating, providing notifications and self-guidelines and likewise for controlling eating disorders as patients self-monitor meals, emotions, behaviours, and their thoughts. Reliability and acceptability of wearables, adoption and usability are all areas to which IS research can contribute.

Theme 4: Providing suitable healthcare in emergencies

Emergencies in healthcare can be described as disruptive care provided by the healthcare centre with increasing demand on service. Standard communication systems can be overridden during an emergency period as healthcare providers attempt to give proper service. On the other hand, emergencies may occur for the individual

patient e.g. elderly people who may not get proper care at specific periods. In this situation, M-health applications can provide better emergency service like reminders to take medicine [23]. With telemedicine systems emergency services are easier to provide as well as enabling remote monitoring. Accordingly, self-management procedures at emergency times are increasing. For example, even the electrocardiogram (ECG) can be cost-effectively done from the patient's home during an emergency period. Transmitting ECG signals and lab reports can be done using a wireless telemedicine system with mobile network technologies like GSM/GPRS as an alternative to cabled network, and PHP and MySql were used for developing the apps where standard bandwidth in the control system is sufficient to record the ECG [38].

Expert involvement however, both technical and psychological, is critical to such system design and development. Apart from accurate detail measurement, there is emphasis on security issues of the application especially on data transmission [40]. Goyal et al. [23] considered social cognitive theory (SCT) in designing and developing apps for remote and emergency services. Both socially and technically focussed IS/IT are applicable research lines in emergency healthcare.

Theme 5: Improving training support

A healthcare provider is an individual, group or organization who provides observation facilities, preventive attitude, curative advice as well as rehabilitation in healthcare service in a systematic way to the patients. With M-health technology a patient's roles begin to overlap those of a healthcare provider. Provider strategy nowadays is changing towards patient training using (effectively ubiquitous) portable and mobile devices. On the other hand physicians are becoming used to mobile technology for supplying training to patients and also for collecting medical data using self-trained mobile apps.

Some mobile games with learning activities can also help patients share the healthcare provider burden. For example a mobile phone "dice/chess" game helps rehabilitate neuro-damaged hand movements [81]. Barbosa et al's [6] interdisciplinary team used mobile games to support a "normalized" schooling experience for young oncological patients. Some mobile app development environments e.g. *"iBuildApp"* has led to apps developed by medical students, who are non-professional in apps development [45]. Education and training to replace or supplement professional care is available for mental health issues such as general anxiety disorder and post-traumatic stress disorder. Without the help of psychiatrists, apps developers have developed many such mobile apps for mental health but these have often proved ineffective or even risky [3], and a Collaboratory for Psychiatric App Development, stressing clinician involvement has be formed in response [79]. Especially when science, policy and regulation are lagging, such examples simultaneously reinforce the need for informed medical input, and for ensuring effective IS design for patient-relevant contexts. Evaluating end-user or participatory app development methods, and game-based or other protocols for effective training, education and rehabilitation as IS aspects relevant in this sector.

Theme 6: Motivation support services

Modifiable lifestyle behaviours such as dietary control, and timely physical exercise can help to control many health problems. Traditionally healthcare providers counsel their patients to determine their understanding and to change their behavior taking measures at regular intervals. M-health provides more flexible support

opportunities in this regard, including motivating "forgetful" patients through SMS. Shaw et al.'s [67] study indicated a increased acceptance of the SMS in delivering health service, and led to development of a web based SMS provider protocol.

Mobile apps can focus on target behaviours that benefit a patient's health. For example one M-health application, SapoFitness [66], helps to keep a personal health record, enables an auto alarm service and can share information in social networks. Mobile apps, linked to wireless medical peripheral devices can assist self-control for various types of chronic disease patients. The Bent II mobile app for example was integrated with TELUS Health Space (Microsoft HealthVault) for self-monitoring for diabetics [23]. Social-cognitive theories provide models widely used in applied health for behavioural change [66], and encompass control of psychological determinants, observational learning, and self-regulation; all supportable by mobile apps, often free on app stores. Motivation is managed in the Mobile *RehApp*™ game, developed for ankle sprain rehabilitation using augmented reality technology [22], since traditional rehabilitation exercises are "boring".

On the other hand, there are medical conditions which patients are embarrassed to disclose face to face with a doctor. Oluwafemi and Olanrewaju [53] discussed this situation where patients use mobile health apps to describe problems and receive diagnosis within a secure and confidential network environment. The data are secured through biometric verification of the patient and at the other end, the software verifies authorized login. Security, usability, gamification and the role of social media are all relevant research areas relevant to this segment.

Theme 7: Improving hospital management

Hospitals are organizations providing medical services, increasingly based on technology. Hospital management can be defined as the process, technical functions and activities, organized towards the goal of effective service provision. With mobile and wireless technology professional services can be provided both accurately and efficiently, and with proper design, securely and confidentially. Developing apps for portable devices can also enhance hospital management. For example, Jeong et al. [33] suggested personalized chronic disease care linked to mobile Electronic Medical Record (EMR) applications can provide significant change in healthcare service. As well as EMR linked apps, Choi et al. [11] also considered laboratory information systems (LIS), picture archiving and communication systems (PACS), and nurse information systems (NIS) all of which can improve hospital management. Typically, Android, java, C, C++, PHP and MySql are used to develop such apps for hospital use [47]. As well as continuing app development and testing, integration of systems and medical records suggests further lines of research.

Theme 8: Supervision support services

Administrative case management provides ongoing, real time support to patients. This acts primarily as the bridge between patients and healthcare provider and is known as supervision in healthcare management.

Although supervisors provide effective supervision, technology can often give a better service. With the help of mobile apps (diabetics) are able to measure their (blood glucose level) independently at home or hospital without requiring a doctor or nurse at regular intervals, and can receive appropriate health advice as required. In general, smartphones enable multimedia communication, with vital and real-time data [11, 53]. Data collection from integrating various sensors and other mobile apps synthesizes health monitoring and wellness management, and

enhances case management through capturing e-records or providing e-prescriptions [53]. Similarly cancer pain management and emergency healthcare service in remote area are supported through apps related to maintaining daily lives of patients [34, 54].

In the design phase of such types of apps attention must be paid to user validation, registration of the patients, doctors and laboratory scientists for security and confidentiality. On the other hand, usability issues are critical. This includes touch screen interfaces, which can improve interactive logging system accuracy and speed. Correspondingly, evaluation of the designed apps should be tested from the user perspective. Panou et al. [54] tested their *Guardian Angel* app for the elderly with 30 users and five experts after design and development to identify usability issues and future redesign proposals. Usability in general is a relevant line for further IS research into this aspect.

Our analysis of the sample found 11 IS issues that are regularly discussed in M-health studies, ranging from security to system flexibility. Figure 4 illustrates the number of studies that are related to each of these issues, though this analysis must meantime remain descriptive due to small numbers.

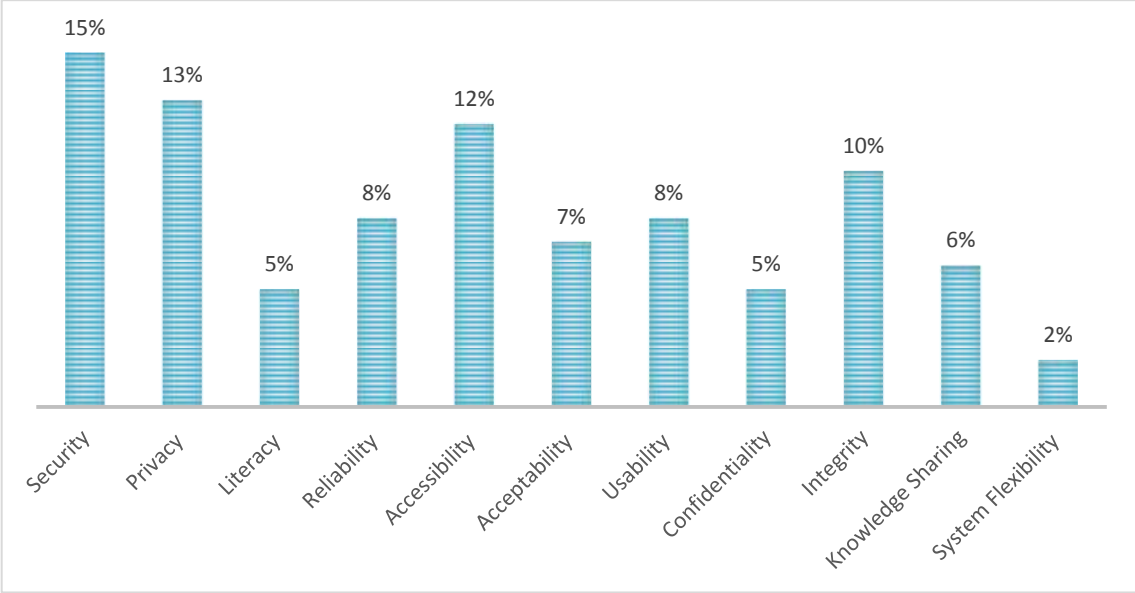

Figure 4: IS Issues identified in different M-health innovation studies

We then looked at the specific IT involved in the various studies, summarised in table 2.

Table 2: Key IT choices used in M-health application design

Key software technique (service providers and service receivers side)	Network technologies	Special Hardware details
PHP and MYSQL database, Java [11, 53, 61] **SQLite** [61] **Unity 3D engine** [6, 22] **C, C++, Microsoft Visual C++ 2010 compiler, HTTPS** [11, 67] **HTML code (investigated various mobile apps)** [45, and many others] **Autodesk Maya for 3D modelling, 3D Studio Max** [59 and many others] **Android SDK (Software Development Kit)** [22, 70 and many others] **Signal quality index (SQI) algorithm, Blowfish algorithm** [16] **Triple Data Encryption Standard (3DES)** [40, 70] **Froyo (Android 2.2 operating system) and Gambit Scheme programming Language**[57]	**Wireless and GPS technology** [5, 11, 38 and many others] **wireless sensor network (WSN)** [26, 37, 81 and many others] **Mobile Augmented Reality (MAR) Technology** [22, 79] **Near-field communication (NFC) technology** [49] **Mobile Node** [70] **IEEE 802.15.4/ZigBee, Bluetooth Low Energy, IEEE 802.15.6, ANT/ANT+, Sensium, Z-Wave, RuBee, Zarlink** [43, 81 and many others] **Bluetooth wireless communication** [77]	**Touch sensitive monitor** [11] **Jawbone UP24** [23] **7-lead ECG device** [10, 26 and many others] **Bluetooth** [5, 23 and many others] **Blood pressure meterUA-767** [49] **Electronic pen and PIC24microcontroller** [68, 77]

Whilst particular technologies are not of primary interest in the present study, mainstream network technologies, including Bluetooth, along with standard programming languages, form the platform for most of the applications described in the articles, with relatively few individual cases using specialized hardware or software techniques. Further details are given in Appendix B.

4.2 Findings for M-health studies focussed on application design

Our main concern was to examine the extent of M-health design insights and use of IS design methodologies, whether piecemeal or thoroughgoing, in app development. Although DSR is formulated for methodological rigour, it draws upon a long history of system development practice and theory. As such, research contributions can be approximately mapped against the primary outputs recognized through design research components (e.g. Design Science artefacts can be constructs, models, methods, instantiations and design theories). For each article we classified, inductively generated from the articles themselves, we identified which of these outputs was the main contribution of the research, and mapped them to the established categories in Design Science, to allow an assessment of the extent of DSR relevance in this field. Figure 6 shows the DSR themes for the second set of articles analysed in our study, showing that most work produced an instantiation or implementation (e.g. an app

or a prototype), with relatively little contribution to conceptualization of the M-health research field. Very few studies indicated requirements for developing new design theories so they can be reusable as new knowledge (as shown in figure 5).

We also analysed this set of M-health articles using the thematic components of DSR. Appendix C summarizes the detailed analysis in a table showing the contribution type and relating each study to design science features. Although most papers were not expressed using DSR terms the categories could be approximately mapped to the list in figure 6. The papers described respectively: *artefact types and purposes*; *problem relevance; problem definitions and design themes; design steps and components; methods and approaches used*, (which indicated the rigour of the process and its replicability) and finally details related to *evaluation*, as is common with system development projects. The M-health contribution is *communicated* to its target audience through the research report itself, and as applicable to its professional audiences and users. As a norm of peer reviewed papers, the contribution of a study is a standard requirement. However, as most papers were conducted as projects, usually developing an app and describing that, few conformed fully to the requirements for design science as outlined by Gregor and Hevner [24].

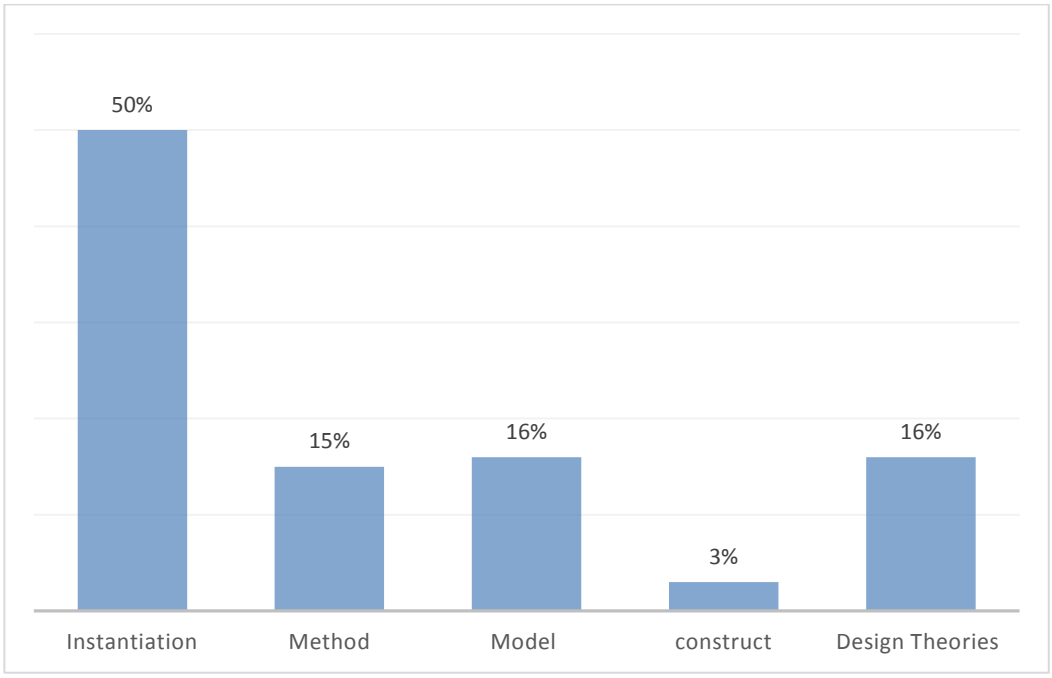

Figure 5: M-health artefact types

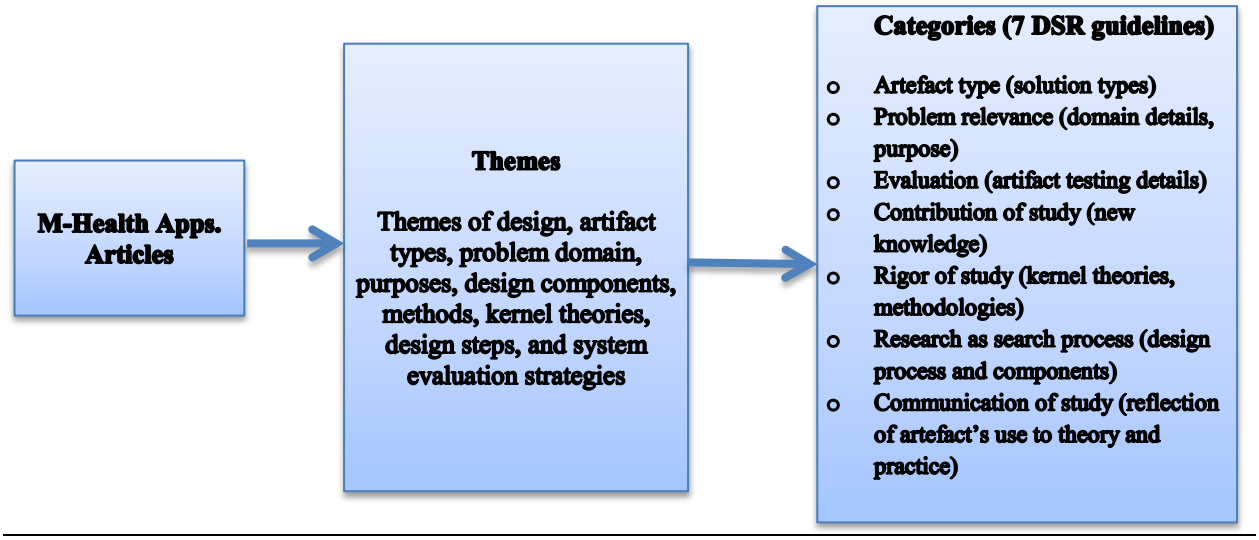

Figure 6: Design science categories and themes

5 Discussion and conclusions

Our analysis of the recent literature on M-health information systems has highlighted several issues not evident from previous reviews of this emerging field, which has often been undertaken from a primarily healthcare or medical perspective. Like Varshney [76], who surveyed the literature up to 2012, we emphasize categories relevant to IS research neglected in previous reviews.

Our first finding shows that M-health has grown to encompass new issues and application categories beyond those identified in earlier reviews. The initial M-health categories that Varshney [76] identified, namely *expanding healthcare coverage, improving decision making, managing chronic conditions* and *providing suitable healthcare in emergencies* have been both validated and extended to *include supporting training, patient motivation, supervision support* and *improving hospital management*.

As well as finding more areas of M-health per se, we identified eleven specific IS/IT areas represented in the recent literature (*Security, Privacy, Literacy, Reliability, Accessibility, Acceptability, Usability, Confidentiality, Integrity, Knowledge Sharing* and *System Flexibility*), which follows Varshney's [76] hope that his framework for M-health research would be extended to include more research categories and help identify new associated research problems. Both IT and application design related IS research challenges apply in M-health. Within the eight themes there are examples of different research approaches taken, such as prototyping and traditional lifecycle development, and the recent studies described also serve to suggest further lines of IS/IT research, including usability, security, testing, gamification and decision support. Our analysis also identified various ICTs (e.g. Bluetooth devices, digital cameras, PHP, Java, C++, MySQL, SQI, Unity 3D engine etc.) and network technologies (e.g. Mobile Augmented Reality, cellular and sensor networks, and 3G/4G wireless networks etc.). Network security and integration also suggests further research relating these to M-health provision.

Although the field is expanding rapidly, this is not, however, reflected proportionally in academic studies, with relatively few journal and conference papers (154) compared to the number of apps available (259 000). This comports with Thibaut's [73] observation that despite thousands of psychiatry apps, a search using the keywords "mobile technology" and "psychiatry," retrieved only 35 articles from the PubMed database, and indicates the huge potential for research as the field emerges. While there is a continuing stream of research papers, this is fragmented across multidisciplinary as well as IS journals, with no dominant or central outlets. The dedicated *Journal of mhealth* is a practitioner, not an academic, journal, and most academic journals and conferences typically had only one M-health paper in the seven-year sampling period. Figure 7 illustrates the growth of M-health conference and journal articles published from 2010 to 2016 Figure 8 summarises the conference and journals articles in five different aspects of M-health research.

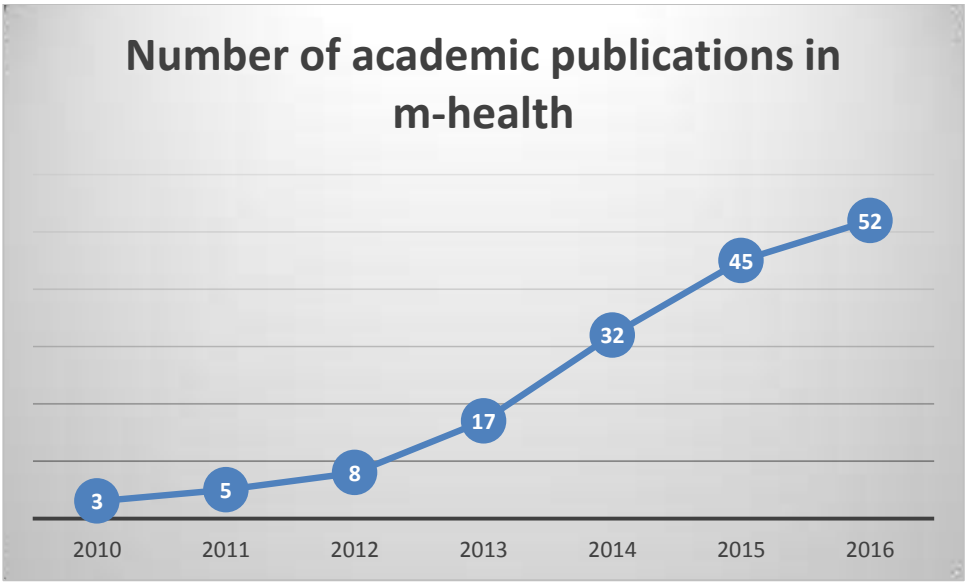

Figure 7: Recent growth of articles in M-health design field

Our review of the IS developments in M-health echoes views expressed in the more medically focused literature, which is primarily concerned with relevance to healthcare practice. They find a disconnect between the numerous apps that have been developed and the realities of medical practitioners, a familiar outcome when apps are developed without ongoing understanding of user requirements. Usability is not a proxy for relevance and applications developed outwith a research framework do not generally specify a knowledge contribution: in particular, those not using DSR as their approach may not cover the guidelines of Hevner et al [25] and Gregor and Hevner [24].

Secondly, there are very few M-health studies which explicitly use design science as their approach. Most use traditional systems development, but the evaluation phase is often lacking, and informed participation throughout development is infrequent. This reinforces earlier findings that there was a lack of testing, and that often developers lacked the medical knowledge to be relevant to their target audience. Most papers described instantiations, with very few more theoretically focused artefacts being developed. Although numerous M-health applications had been developed, without a design science framework being used, the theoretical contribution or

specification of the design is not always clear, limiting their use as design artefacts for later adaptation, or a generalizable knowledge. On the other hand, most M-health articles followed the general practices of reporting developments to an academic audience, with most of the components being approximately mappable to Design Science Research constructs, and broadly replicable. Those adopting user-centred approaches conform to the design principles of ensuring relevance to practical context, although evaluation of many systems by usability alone is inadequate if the application is not evaluated for relevance too.

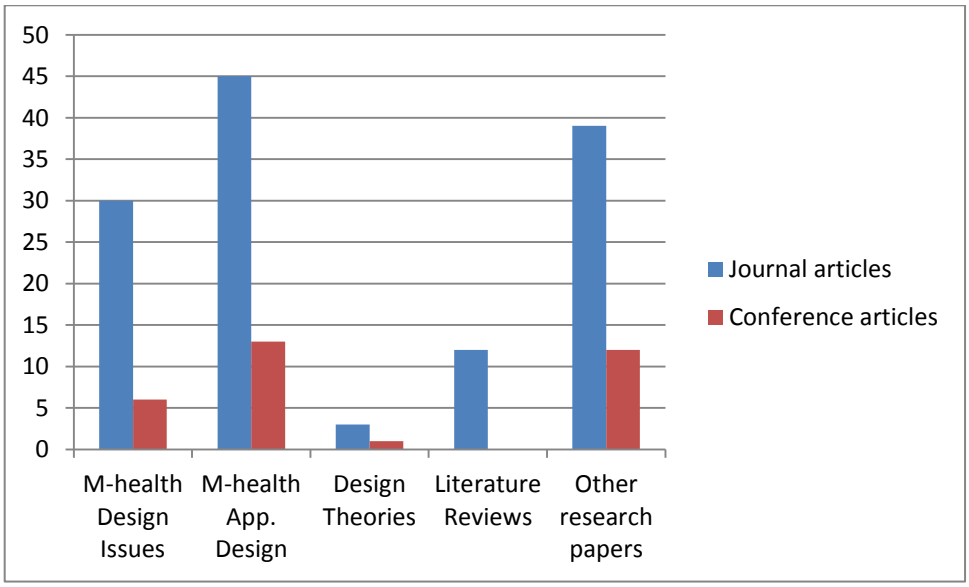

Figure 8: Recent M-health research areas profile (from 2010 to 2016)

Our analysis was also the first to focus on an IS development view of the research in M-health, which had been a limitation of previous studies, and to analyse the design and developments displayed in recent work. Our content analysis explored the emerging themes, potential design issues, key stakeholders and technologies and aimed to assess the applicability of DSR for M-health solution design. Although many studies have involved systems development, this has generally been done outwith a design science framework, and some gaps, particularly with respect to evaluation, kernel theories, and, as noted earlier, testing and user involvement in design are evident.

The limitations of the study are, firstly, that the sample of papers, despite our search efforts, was relatively small, and the categorisations must, as with Varshney's [76] proposal, remain less than comprehensive. The four areas identified by Varshney [76] were, however, validated by our up-to-date sample, and as other categories are likely to emerge as the field evolves we do not stress this formulation as definitive or final.

A second limitation is common to other systematic reviews of literature, and concerns the databases chosen and the search terms used, as well as the general limit of any data collection that is restricted by the research purposes. As inductive categorisation is appropriate in nascent fields, we avoided the top down searches available from established medical categories used in previous studies with a more medically-focused audience

in mind. By including both the top IS journals and relevant multidisciplinary outlets across major library databases we believe the sample chosen is, if not comprehensive, at least largely representative of the field.

A third limitation was that only one of us did the coding of the articles into IS categories based on DSR constructs. Some interpretation to fit these categories was required, and perhaps some cells might be described differently. Although these are not considered to be radically at variance with the constructs in question, cross checking by independent coders might add greater confidence in the interpretation of the source articles.

Our overall conclusion is that M-health is emerging as an important demand area to which IS is ideally positioned to contribute, but to date work has been inchoate and scattered. Although some examples of systems developments are beginning to emerge, these are largely one-off instantiations or developer-led apps, and not always informed by best practice. Without an explicitly research led approach to development, their general value as contributions to knowledge is reduced. In this regard, Design Science Research has unrealised potential, but is demonstrably well suited to M-health developments that make research as well as practical contributions.

References

[1] M.M. Al-Debei, D. Avison, Developing a unified framework of the business model concept, Eur. J. Inf. Syst. 19 (2010) 359–376.

[2] D. Arnott, G. Pervan, Design science in decision support systems research: An assessment using the Hevner, March, Park, and Ram Guidelines, J. Assoc. Inf. Syst. 13 (2012) 923.

[3] E. Anthes, Mobile Mental-Health Apps Have Exploded Onto The Market, But Few Have Been Thoroughly Tested, NATURE, 532 (2016), 20-23

[4] M.M. Baig, H. GholamHosseini, M.J. Connolly, Mobile healthcare applications: system design review, critical issues and challenges, Australas. Phys. Eng. Sci. Med. 38 (2015) 23–38.

[5] O. Banos, C. Villalonga, R. Garcia, A. Saez, M. Damas, J.A. Holgado-Terriza, S. Lee, H. Pomares, I. Rojas, Design, Implementation and Validation of a novel open framework for agile development of mobile health applications, Biomed. Eng. Online. 14 (2015) S6.

[6] D.N.F. Barbosa, P.B.S. Bassani, J.B. Mossmann, G.T. Schneider, E. Reategui, M. Branco, L. Meyrer, M. Nunes, Mobile learning and games: experiences with mobile games development for children and teenagers undergoing oncological treatment, in: Int. Conf. Serious Games, Springer, 2014: pp. 153–164.

[7] T.J. Betjeman, S.E. Soghoian, M.P. Foran, mHealth in Sub-Saharan Africa, International Journal of Telemedicine and Applications, 2013, (2013), 482324, 7.

[8] C. Catalani, W. Philbrick, H. Fraser, P. Mechael, D. M. Israelski, mHealth for HIV Treatment & Prevention: A Systematic Review of the Literature, The Open AIDS Journal, 7, (2013),17-41

[9] I.A. Chatzipavlou, S.A. Christoforidou, M. Vlachopoulou, A recommended guideline for the development of mHealth Apps, mHealth, (2016), 2.

[10] H.-S. Chen, M.-J. Su, F.-M. Shyu, J.-J. Luh, S.-L. Hwang, S. Su, S.-J. Chen, J.-S. Lai, Mobile hospital: healthcare for anybody in anytime and anywhere, in: Enterp. Netw. Comput. Healthc. Ind. 2005. Heal. 2005. Proc. 7th Int. Work., IEEE, 2005: pp. 144–149.

[11] W.Choi, M. A. Park, E. Hong, S. Kim, R. Ahn, J. Hong,. . . S.Yeo, Development of mobile electronic health records application in a secondary general hospital in Korea. Healthcare informatics research, 19(4), (2013), 307-313.

[12] J. W. Creswell, Educational Research: Planning, Conducting, And Evaluating Quantitative, 2012, Pearson.

[13] D.F. Conserve, L. Jennings, C. Aguiar, G. Shin, L. Handler, S. Maman, Systematic review of mobile health behavioural interventions to improve uptake of HIV testing for vulnerable and key populations, J. Telemed. Telecare. 23(2) (2016),347-359.

[14] O. Dieste, A. Griman, N. Juristo, Developing search strategies for detecting relevant experiments, Empirical Software Engineering, 14(5), (2009), 513-539

[15] J.M.G. Duarte, R.S. Yokoyama, L.A. Villas, A Low Cost Mhealth Non-Intrusive Method for Monitoring Patient Indoor Localization, IEEE Latin America Transactions, 13(8), (2015), 2668-2673.

[16] D.T. Dunsmuir, B.A. Payne, G. Cloete, C.L. Petersen, M. Gorges, J. Lim, et al., Development of mHealth applications for pre-eclampsia triage. IEEE Journal of Biomedical and Health Informatics, 18(6), (2014), 1857-1864.

[17] S. Elo, H. Kyngäs, The qualitative content analysis process, J. Adv. Nurs. 62 (2008) 107–115.

[18] F. Federici, R. Alesii, A. Colarieti, M. Faccio, F. Graziosi, V. Gattulli, F. Potenza, Design of wireless sensor nodes for structural health monitoring applications. Procedia Engineering, 87, (2014),1298-1301.

[19] C. Free, G. Phillips, L. Galli, L.Watson, L. Felix, P. Edwards, P., . . A.Haines, The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. PLoS med, 10(1), (2013), e1001362.

[20] M. Fiordelli, N. Diviani, P.J. Schulz, Mapping mHealth research: a decade of evolution, J. Med. Internet Res. 15 (2013) e95.

[21] J.Forman, L.Damschroder, Qualitative Content Analysis. Empirical Research For Bioethics: A Primer, Elsevier Publishing, Oxford, UK, 2008,39-62

[22] J.A. Garcia, K.F. Navarro, The Mobile RehApp???: an AR-based mobile game for ankle sprain rehabilitation. Paper presented at the Serious Games and Applications for Health (SeGAH), 2014 IEEE 3rd International Conference, IEEE, (2014), 1-6.

[23] S. Goyal, P. Morita, G.F. Lewis, C. Yu, E. Seto, J.A. Cafazzo, The systematic design of a behavioural mobile health application for the self-management of type 2 diabetes, Can. J. Diabetes. 40 (2016) 95–104.

[24] S. Gregor, A.R. Hevner, Positioning and presenting design science research for maximum impact., MIS Q. 37 (2013) 337–355.

[25] A. Hevner, S.T. March, J. Park, S. Ram, Design science in information systems research, MISQ. 28 (2004) 75–105.

[26] A. Huang, C. Chen, K. Bian, X. Duan, M. Chen, H. Gao, C. Meng, Q. Zheng, Y. Zhang, B. Jiao, WE-CARE: an intelligent mobile telecardiology system to enable mHealth applications, IEEE J. Biomed. Heal. Informatics. 18 (2014) 693–702.

[27] M. Hussain, A. Al-Haiqi, A.A. Zaidan, B.B. Zaidan, M.L.M. Kiah, N.B. Anuar, M. Abdulnabi, The landscape of research on smartphone medical apps: Coherent taxonomy, motivations, open challenges and recommendations, Comput. Methods Programs Biomed. 122 (2015) 393–408.

[28] K. Hwang, Dangers of Defective Mobile Health Apps and Devices, 2016, URL: https://www.verywell.com/dangers-of-defective-mobile-health-apps-and-devices-1739151

29] R. S.H. Istepanian, S. Laxminarayan, C.S. Pattichis, M-Health Emerging Mobile Health Systems, Topics in Biomedical Engineering. International Book Series, 2006, Springer

[30] M. Indulska, J. Recker, 13. Design science in IS research: a literature analysis, Inf. Syst. Found. Role Des. Sci. (2010) 285–302.

[31] IMS, Patient Adoption of mHealth. Report by the IMS Institute for Healthcare Informatics, 2015, URL: http://www.imshealth.com/files/web/IMSH%20Institute/Reports/Patient%20Adoption%20of%20mHealth/IIHI_Patient_Adoption_of_mHealth.pdf, Accessed on 23 Feb, 2017

[32] L. Jennings, L. Gagliardi, Influence of mHealth interventions on gender relations in developing countries: a systematic literature review, Int. J. Equity Health. 12 (2013) 85.

[33] S. Jeong et al., A Novel Model for Metabolic Syndrome Risk Quantification Based on Areal Similarity Degree, IEEE Trans. Biomed. Eng., 61(3), (2014), 665–679

[34] L.A. Jibb, B.J. Stevens, P.C. Nathan, E. Seto, J.A. Cafazzo, J.N. Stinson, A smartphone-based pain management app for adolescents with cancer: establishing system requirements and a pain care algorithm based on literature review, interviews, and consensus. JMIR research protocols, 3(1), (2014). e15. doi: 10.2196/resprot.3041

[35] M. Johnston, M. Mobasheri, D. King, A. Darzi, The Imperial Clarify, Design and Evaluate (CDE) approach to mHealth app development, BMJ Innov. 1 (2015) 39–42.

[36] K. Kallander, J.K. Tibenderana, O.J. Akpogheneta, D.L. Strachan, Z. Hill, A.H.A. Ten Asbroek, L. Conteh, B.R. Kirkwood, S.R. Meek, Mobile health (mHealth) approaches and lessons for increased performance and retention of community health workers in low-and middle-income countries: a review, J. Med. Internet Res. (2013), 15.

[37] B. Koo, K. Han, J.J.J.H. Park, T. Shon, Design and implementation of a wireless sensor network architecture using smart mobile devices, Telecommun. Syst. 52 (2013) 2311–2320.

[38] S. Kulkarni, S. Hoffman, T. Gadisa, Z. Melaku, M. Fantehun, M. Yigzaw, W. El-Sadr, R. Remien, O. Tymejczyk, D. Nash, Identifying Perceived Barriers along the HIV Care Continuum Findings from Providers, Peer Educators, and Observations of Provider–Patient Interactions in Ethiopia, J. Int. Assoc. Provid. AIDS Care. 15 (2016) 291–300.

[39] J.-A. Lee, A. L. Nguyen, J. Berg, A. Amin, M. Bachman, Y. Guo, L. Evangelista, Attitudes and preferences on the use of mobile health technology and health games for self-management: interviews with older adults on anticoagulation therapy. JMIR mHealth and uHealth, 2(3), (2014), e32

[40] C. J. Licskai, T.W. Sands, M. Ferrone, Development and pilot testing of a mobile health solution for asthma self-management: asthma action plan smartphone application pilot study. Canadian Respiratory Journal, 20(4), (2013), 301-306.

[41] W.-T. Liu, C.-D. Huang, C.-H. Wang, K.-Y. Lee, S.-M. Lin, H.-P. Kuo, A mobile telephone-based interactive self-care system improves asthma control, Eur. Respir. J. 37 (2011) 310–317.

[42] S.T. March, G.F. Smith, Design and natural science research on information technology, Decis. Support Syst. 15 (1995) 251–266.

[43] G. Markarian, L. Mihaylova, D.V. Tsitserov, A. Zvikhachevskaya, Video distribution techniques over WiMAX networks for m-health applications. IEEE Transactions on Information Technology in Biomedicine, 16(1), (2012), 24-30.

[44] B. Martinez-Perez, L. D.I. Torre-Diez, M.Lopez-Coronado, B. Sainz-De-Abajo, Comparison of Mobile Apps for the Leading Causes of Death Among Different Income Zones: A Review of the Literature and App Stores, JMIR, 2(1), (2014), e1, doi:10.2196/mhealth.2779

[45] K. Masters, Health professionals as mobile content creators: Teaching medical students to develop mHealth applications. Medical teacher, 36(10), (2014), 883-889.

[46] S.J. Miah, N. Hasan, R. Hasan, J.G. Gammack, Healthcare support for underserved communities using a mobile social media platform, Information Systems, 66, (2017), 1–12

[47] M. Milošević, M.T. Shrove, E. Jovanov, Applications of smartphones for ubiquitous health monitoring and wellbeing management, JITA-JOURNAL Inf. Technol. (2011), 1.

[48] M. H. Mobasheri, M. Johnston, D.King, D. Leff, P. Thiruchelvam, A. Darzi, Smartphone breast applications e What's the evidence?, The Breast, 23 (2014), 683-689.

[49] J. Morak, H. Kumpusch, D. Hayn, R. Modre-Osprian, G. Schreier, Design and evaluation of a telemonitoring concept based on NFC-enabled mobile phones and sensor devices. IEEE Transactions on Information Technology in Biomedicine, 16(1), (2012), 17-23.

[50] A.D. Nguyen, M.T. Baysari, D.R.W. Kannangara, A. Tariq, A.Y.S. Lau, J.I. Westbrook, R.O. Day, Mobile applications to enhance self-management of gout, Int. J. Med. Inform. 94 (2016) 67–74.

[51] J.A. Nhavoto, Å. Grönlund, Mobile technologies and geographic information systems to improve health care systems: a literature review, JMIR mHealth uHealth. 2, (2014), e21.

[52] J.F. Nunamaker Jr, M. Chen, T.D. Purdin, Systems development in information systems research. Journal of management information systems, 7(3), (1991), 89-106.

[53] A. M. Oluwafemi, M. Kasali Olanrewaju, Mobile - Health Application Software Design and Development, Int. Journalof Comput. Sci. Inf. Secur. 12, (2014), 59–67.

[54] M. Panou, K.Touliou, E. Bekiaris, T. Tsaprounis, Mobile phone application to support the elderly. International Journal of Cyber Society and Education, 6(1), (2013), 51.

[55] C.M. Payne, B.C. Knott, H.B. Mayes, H. Hansson, M.E. Himmel, M. Sandgren, J. Ståhlberg, G.T. Beckham, Fungal cellulases, Chem. Rev. 115, (2015), 1308–1448.

[56] H.E. Payne, C. Lister, J.H. West, J.M. Bernhardt, Behavioral functionality of mobile apps in health interventions: a systematic review of the literature, JMIR mHealth uHealth. 3 (2015) e20.

[57] C. L. Petersen, M. Gorges, D. Dunsmuir, M. Ansermino, G.A.Dumont, Experience report: functional programming of mHealth applications. Paper presented at the ACM SIGPLAN Notices, (2013), 1-8.

[58] A. L. Porter, J. Youtie, P. Shapira, D.J. Schoeneck, Refining search terms for nanotechnology, Journal of Nanoparticle Resaerch, 10(5), (2008), 715-728

[59] Y. Pulijala, M. Ma, A. Ayoub, Design and Development of Sur-Face: An interactive mobile app for educating patients regarding corrective surgery of facial deformities, in: Jt. Int. Conf. Serious Games, Springer, 2015,26–35.

[60] A. Rana, A. Gruessner, V.G. Agopian, Z. Khalpey, I.B. Riaz, B. Kaplan, R.W. Gruessner, Survival benefit of solid-organ transplant in the United States. JAMA surgery, 150(3), (2015), 252-259.

[61] M. Radzuweit, U. Lechner, Introducing tablet computers into medical practice: design of mobile apps for consultation services, Health Technol. (Berl). 4, (2014) , 31–41.

[62] A.J. Rothman, Toward a theory-based analysis of behavioral maintenance., Heal. Psychol. 19, (2000), 64.

[63] M. Sahinoglu, K. Incki, M. Aktas, Mobile Application Verification: A Systematic Mapping Study. ICCSA, (2015), 147–163.

[64] R. Schnall, S.J. Iribarren, Review and analysis of existing mobile phone applications for health care–associated infection prevention, Am. J. Infect. Control. 43, (2015), 572–576.

[65] R. Schnall, M. Rojas, J. Travers, W. Brown III, S. Bakken, Use of design science for informing the development of a mobile app for persons living with HIV, in: AMIA Annu. Symp. Proc., American Medical Informatics Association, (2014), 1037.

[66] R. Schwarzer, Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors, Appl. Psychol. 57, (2008), 1–29.

[67] R.J. Shaw, H.B. Bosworth, J.C. Hess, S.G. Silva, I.M. Lipkus, L.L. Davis, C.M. Johnson, Development of a theoretically driven mHealth text messaging application for sustaining recent weight loss, JMIR mHealth uHealth. 1, (2013), e5.

[68] S.R. Shinde, R. Shinde, S. Shanbhag, M. Solanki, P. Sable, S. Kimbahune, mHEALTH-PHC-Application design for rural health care. Paper presented at the IEEE Canada International Humanitarian Technology Conference-(IHTC), (2014), 1-10

[69] B.M.C. Silva, J.J.P.C. Rodrigues, I. de la Torre Díez, M. López-Coronado, K. Saleem, Mobile-health: A review of current state in 2015, J. Biomed. Inform. 56, (2015) 265–272.

[70] B.M. Silva, I.M. Lopes, J.J.P.C. Rodrigues, P. Ray, SapoFitness: A mobile health application for dietary evaluation, in: E-Health Netw. Appl. Serv. (Healthcom), 2011 13th IEEE Int. Conf., IEEE, (2011), 375–380.

[71] H.A. Simon, The sciences of the artificial, MIT press, 1996.

[72] E.G. Spanakis, S. Santana, M. Tsiknakis, K. Marias, V. Sakkalis, A. Teixeira, J.H. Janssen, H. Jong, Technology-Based Innovations to Foster Personalized Healthy Lifestyles and Well-Being: A Targeted Review, JMIR, 18(6), (2016), e128

[73] F. Thibaut, Digital applications: the future in psychiatry?, Dialogues Clin. Neurosci. 18, (2016), 123. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4969698/.

[74] J. P.Tregarthen, J. Lock, A.M. Darcy, Development of a smartphone application for eating disorder self-monitoring. International Journal of Eating Disorders, 48(7), (2015), 972-982.

[75] M. S.Tremblay, A. G LeBlanc, M. E. Kho, T. J. Saunders, R. Larouche, R. C.Colley, et al., Systematic review of sedentary behaviour and health indicators in school-aged children and youth. International Journal of Behavioral Nutrition and Physical Activity, 8(1), (2011) 1-8

[76] U. Varshney, A model for improving quality of decisions in mobile health, Decis. Support Syst. 62 (2014) 66–77.

[77] D. Varma, V. Shete, S. Somani, Development of home health care self monitoring system. Development, 4(6), (2015), 252-255

[78] R. Walton, B. DeRenzi, Value-sensitive design and health care in Africa, IEEE Trans. Prof. Commun. 52 (2009) 346–358.

[79] D.C. Wang, Are Apps the Future of Psychiatry? Psychology Today, May 2016

[80] A. Wolf, A. Fors, K. Ulin, J. Thorn, K. Swedberg, I. Ekman, An ehealth diary and symptom-tracking tool combined with person-centered care for improving self-efficacy after a diagnosis of acute coronary syndrome: A substudy of a randomized controlled trial, J. Med. Internet Res. 18 (2016).

[81] M. Xian, Z. Boya, W. Dongyan, C. Zheng, T. Yuan, D. Bowei, Research on the computer game in intelligent mobile phone neurological rehabilitation treatment system, in: Control Decis. Conf. (CCDC), 2015 27th Chinese, IEEE, 2015, 5836–5839.

[82] S. Zein, N. Salleh, J. Grundy, A systematic mapping study of mobile application testing techniques, J. Syst. Softw. 117, (2016) 334–356.

Appendix A:

Sample matrix for Type 1 articles:

Journals/Conferences	Year							
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Nurse education today							1	1
Journal of diabetes science and technology	1							1
Australasian Physical & Engineering Sciences in Medicine						1		1
Journal of medical Internet research			2				1	3
AIDS and Behavior		1						1
Mount Sinai Journal of Medicine		1						1
PLoS med				1				1
JMIR Human Factors					1			1
Procedia-Social and Behavioral Sciences						1		1
Procedia Technology					1			1
BMC geriatrics				1				1
JMIR mHealth and uHealth					2			2
Diabetes technology & therapeutics		1						1
Telemedicine and e-Health			1					1
European Respiratory Journal		1						1
Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring						1		1
Decision Support Systems				1	1			2
Studies in health technology and informatics						1		1
IEEE Journal on Selected Areas in Communications				1				1
Usability and Accessibility Focused Requirements Engineering (UsARE)					1			1
Proceedings of the 20th Americas Conference on Information Systems					1			1
System Sciences (HICSS), 2015 48th Hawaii International Conference						1		1
23rd Bled eConference. from www. bledconference. org	1							1
Proceedings of the 10th international conference on Mobile systems, applications, and services			1					1
Bioinformatics and Bioengineering (BIBE), 2015 IEEE 15th International Conference						1		1
Behaviour & Information Technology							1	1
Journal of The Association for Information Science and Technology					1			1
International journal of medical informatics	1			2				3
Journal of the American Medical Informatics Association							2	2
Total	3	4	4	6	8	6	5	36

Sample matrix for Type 2 articles:

Journals/Conferences for sample articles	2010	2011	2012	2013	2014	2015	2016	Total
ASE BigData/SocialInformatics/PASSAT/BioMedCom 2014 Conference, Harvard University.					1			1
Biomedical engineering online						1		1
0th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing						1		1
Mobile Health						1		1
Healthcare informatics research				1				1
Paper presented at the Proceedings of the 12th ACM international conference on Ubiquitous computing.	1							1
Biomedical and Health Informatics					2			2
International Journal of Medical Informatics						1		1
Procedia Engineering					1		1	2
Paper presented at the Serious Games and Applications for Health (SeGAH), IEEE 3rd International Conference					1			1
Canadian journal of diabetes						1	1	2
Paper presented at the Computer and Information Technology (ICCIT), 15th International Conference, IEEE,			1					1
Paper presented at the Informatics, Electronics & Vision (ICIEV), International Conference, IEEE				1				1
IEEE Journal on Selected Areas in Communications				1				1
International Journal of Medical Informatics						2	3	5
JMIR research protocols					1		1	2
Journal of the American Medical Informatics Association							4	4
Telecommunication Systems				1				1
International Journal of Emerging Research in Management &Technology						1		1
Canadian Respiratory Journal				1				1
IEEE/ACM Int'l Conf. on Green Computing and Comm. & Conf.on Cyber, Phy.& Social Computing	1							1
IEEE Transactions on Information Technology in Biomedicine			2					2
Medical teacher					1			1
Journal of Information Technology and Application		1						1
Expert Systems with applications					1			1
International Journal of Computer Science and Information Security					1			1
Information Technology & People					1	1		2
International Journal of Cyber Society and Education				1				1
Proceedings of the conference on Wireless Health						1		1
Paper presented at the ACM SIGPLAN Notices				1				1
Health and Technology					1			1
JMIR mHealth and uHealth				1				1
Humanitarian Technology Conference-(IHTC), IEEE Canada International					1			1
-Health Networking Applications and Services (Healthcom), 13th IEEE International Conference		1						1
Electronic Commerce Research					1			1
Decision Support Systems				1	1			2
Studies in health technology and informatics						1	1	2
2010 Annual International Conference of the IEEE Engineering in Medicine and Biology.	1							1
International Journal of Eating Disorders						1		1
Development						1		1
Journal of medical systems						1		1
Paper presented at the Intelligent Environments (IE), 12th International Conference							1	1
American Heart Journal							1	1
Journal of Biomedical Informatics							1	1

Heart, Lung and Circulation							1	1
Patient Education and Counseling							1	1
Endocrinology and Metabolism Clinics of North America							1	1
	3	2	3	9	14	14	17	62

Appendix B:

Table B1: m-health studies that describe IS issues

Issues	Numbers of studies
Security	12
Privacy	8
Literacy	5
Reliability	7
Accessibility	9
Acceptability	6
Usability	5
Confidentiality	5
Integrity	9
Knowledge Sharing	5
Systems Flexibility	2

Sample type 1 (Findings details - Issues of design)

Table B2:

Sample No.	Objective	Key Issue	Research Design	Study Area/Level	Key Findings
1	To evaluate the Reliability, efficiency and acceptability of m-Health application	Reliability, accuracy , efficiency and acceptability were considered	Systematic Literature Review	Healthcare industry	✓ Remote monitoring reduces medical error ✓ early assessment of the problems can enhance quality of healthcare service ✓ security and privacy of the transmitted data should be considered on wireless operation
2	To test the usability and acceptability of m-Health tools among older adults	usability and acceptability	A cross-sectional observational methods to compared two groups	Use m-Health tools Among Older people	✓ Improved m-heath tool after usability testing ✓ More than 56% of participants indicated they would continue using the m-Health tool
3	To investigate understanding graduate nursing students' perceptions of working in the aged care	Perception study of aged care placement	Systematic Literature Review	Aged care	✓ Provided an immersive clinical learning experience ✓ Perceptions of aged care placement, attitudes to working in aged care, and experiences in aged care are the main themes from the review
4	To ascertain barriers and facilitators of using m-Health of older people.	Evaluation study of m-Health tools for pain management	Qualitative study used focus group discussion with semi-structured questions.	Use of m-Health application for older adults'	✓ Using m-Health helps to manage pain and pain medications. ✓ Majority of the patients highly willing to try this process ✓ Older adults with self-reported are willing to use m-Health technologies
5	To explore how the mobile apps can be used in follow-up of type 1 diabetics adolescents and to find the further development of the apps	Implementation study for further development of the apps	Face to face interview, field note were recorded than transcript. 3 months of intervention periods.	Adolescents with type 1 diabetes	✓ Patients prefer picture based dairy more than the SMS service. ✓ Participants reported an increased understanding of applied knowledge, which seem to positively affect diabetes self-care
6	To investigate the short- and long-term effects of text messaging on exercise frequency in older adults.	Impact assessment	A cross-sectional Interviewing methods by quantitative approach	SMS service for older adults from an Upper-middle-income country	✓ SMS texting participant's exercised significantly more than non-SMS texting participant's ✓ Text SMS positively influences to the participant in terms of Exercise ✓ SMS text messaging is effective in promoting exercise in older adults from an upper-middle-income country
7	To investigate the picture of m-Health technology	Knowledge Sharing issue	Systematic Literature Review	m-Health technologies for	✓ Self-healthcare management, Assisted healthcare Service, Supervised healthcare and Continuous

	and suggest implementation strategy			chronic diseases and elders	monitoring are the main theme for ageing people using m-Health technology ✓ m-Health solutions and technologies for the elderly are steadily proliferating for elderly people.
8	To explore the attitudes and preferences of older adults on the use of m-Health technology and health games	Accustomed issue on elder self-management	Individual and Focus group discussion were conducted among the older people	Mobile Health Technology and Health Games for Self-Management in Older Adults	✓ The use of m-Health technology may be helpful for medication management ✓ m-Health technology may be useful for Elder-friendly designs, technology support, and physical safety
9	To suggest conceptual framework on 'm-Health for older users'	usability issues of an m-Health app for older patients	case-study analyzing on m-Health app designed for older patients	m-Health app for older patients	✓ In usability issue the mobile apps for older considered to hamper older adult users in using the App. ✓ Study also indicate App could be difficult for older adults on using perspective ✓ m-Health guidelines are not sufficient for developing a highly usable app for older adults
10	To enhance context-awareness and processing by wireless monitoring of the patients and improved presentation of information to healthcare professionals	Knowledge Sharing by designing and evaluating analytical model	The design of an alert generation and processing system were applied and model was developed	Design m-Health application for aged by mobile devices and networks	✓ Improve quality of overall health care by mobile computing systems. ✓ Improve quality of getting information on aged health care ✓ Enhance the presentation of professional at any time at anywhere
11	Investigates an approach based on leveraging mobile ad hoc network of remote patients monitoring.	Ensure quality of patient monitoring	Complex decision logic framework developed in leveraging mobile ad hoc network by in-depth review prior to design the research	Remote patients monitoring, introducing mobile network.	✓ Communication between patients and healthcare professional is reliable. ✓ Developed a framework of complex decision making for diverse patients monitoring. ✓ patients can be pervasively monitored for timely detection of anomalies and prompt medical intervention without any dependency on location and time
12	To understand the risk factors, inform users about the meaning of the risk, provide proper guideline and finally recommends on appropriate lifestyle.	Strictly maintain Data security	Mobile apps named CAIDE (Cardiovascular Risk Factors, Aging, and Incidence of Dementia) risk score developed based of dementia risk score	Reduce dementia risk factor for the aged people	✓ The apps detect the risk of dementia patients, ✓ Provide appropriate suggestion to modify the risk ✓ People with dementia motivated and pay attention to appropriate lifestyle changes.
13	To understand the current utilization of mobile technology in healthcare service	Literacy issued were discussed	Qualitative study, using purposive sampling and quantitative approach of understanding feedback of	Healthcare Industry for Disease Management and	✓ Mobile technology helps the patients to track their symptoms and improve self-efficiency which may recover their problems. ✓ Provides clues to the researchers for further

			the m-technology.	Wellness	research
14	To identify some important health systems functions and find the potential and challenges of ICT based systems.	Developed Implementation process by reviewing literature	Identifying some mobile system's function, developed m-Health tools and presents a comprehensive review for community workers	Survey of Information and Communication Technology for Community Health Workers (ICT4CHW)	✓ The systems are best seen as tools that can strengthen a program ✓ Mobile application addressed the challenges of providing opportunity of community health workers by strengthens and making them more efficient.
15	To develop a supporting lifestyle changes tools among the people with type -2 diabetics	Motivational effect on end-user	Both design and qualitative research methods were used where 12 people with diabetics type 2 patients aged 40-70 were participated	Self-Management Tools for Type 2 Diabetes patients	✓ A mobile phone based application names Few Touch Application was developed ✓ User able to perform self-management using the apps ✓ The system also is collaborating between the patients and professional
16	To provide insight about acceptance theories of health IS and their implementation on mobile platform.	Knowledge gathering	Systematic literature review	Review the Attitudes of Health Professionals	✓ Technology acceptance model gives powerful approach to explain the intention to use in health technology ✓ m-Health studies were in premature level and it was hard to deduct comprehensive and explanatory results about new trends
17	To investigate self-care systems through the mobile phone based interactive program of the asthma patients	Implementation and judgment procedure	Prospective controlled study within 120 outpatients in selected clinics for six months	Self-care system of achieving better asthma control through mobile - based interactive program	✓ Mobile telephone user group patients had better quality life after 3 months ✓ Mobile telephone-based interactive self-care system offers better self-management of asthma than a written action plan ✓ Better control of asthma is based on the adherence to treatment guidelines for daily management.
18	To qualitatively evaluate the expanded disease management program among individuals with type-2 diabetes	Implementation study on type 2 diabetic patients	Qualitative thematic analysis of semi structured interviews among eight diabetes patients	Take care for patients with type-2 diabetes	✓ Participants prefer wireless system than the mobile phone system and game systems. ✓ Most of the participants agreed their health awareness improved than before ✓ Most of the participants used to upload their blood glucose report timely for timely results
19	To design, develop, and pilot a m-Health intervention for the management of type 1 diabetes in adolescents.	Implementation study on Adolescent type 1 diabetic patients	Mobile apps developed based on thematic analysis, then using the apps the patients are evaluated.	m-Health Apps for the Self-management of Adolescent Type 1 Diabetes	✓ Able to design and development the apps of self-management system ✓ m-Health diabetics apps helps to improve frequency of blood glucose monitoring with type 1 diabetics patients ✓ Able to take decision on glycemic control and Self-care Inventory

20	to identify how mobile technologies and GIS applications have been used for improving health care	Knowledge gathering by reviewing literature	Systematic literature review	Health care and health information systems	✓ Study indicates the Applications of mobile technologies can be categorized by six themes and GIS can be categorized four themes ✓ Majority of the paper gives positive reports including patient's personal and economic improvement. ✓ Finding also indicates that there is little collaboration between GIS and mobile technologies
21	Conducted intervention program to observe patients, clinic stuff and health worker	Motivational effect on AIDS care in rural area	Mixed method evaluation of the study to understand the trial findings.	AIDS care in rural Uganda	✓ Support of mHealth improved health communication and patients care. ✓ Access and maintain to Phone as well as privacy concern were the main challenge of the intervention program. ✓ Participant seems text massaging improves the quality of work of the health worker and encouraged participation of patients
22	To observed existing states and encourages health care consumer in a effective way	Examine health care behavior and disease management of health care consumer	Systematic literature review	Intervention on HIV positive patients and other on smoker	✓ Intervention on HIV positives patients reduces the viral load but mortality rate was not significant ✓ Other findings on diabetics patients show text massaging improves the habit of physical exercise but insignificant in weight loss ✓ Text massaging also helps to close more smoking behavior
23	To establish long-term Indo-Swedish R&D collaboration around leading-edge applied health technology with mobile service	usability, accessibility	user centered design approach, Case study	Patients with type 2 diabetes	✓ The design high-lights power relations and ethical issues in m-health design ✓ Usability and user experience considered as strategic assets
24	To explore what contribution of m-Health can make to postponing main age-related diseases	System Quality, Information Quality	Design analysis	For aging population	✓ A group of patients has been identified as interested in actively contributing to their health and fighting their disease as a result of intervention ✓ This interventions help increase the motivation and success rates of specialists' patients
25	to construct a set of design guidelines to develop and design mobile app	Research Design	Literature review, Design Science Research	Emerging Adults	✓ A set of design guidelines to be used in developing further applications for character strength development ✓ Potential of the use of mobile apps in medical health has described
26	To develop taxonomy of m-Health Apps – Security and Privacy perspective	Security, Privacy	quantitative content analysis	For program developers perspective	✓ The taxonomy provides support for its usefulness and utility of m-health apps

27	To provide information on security and privacy issues of m-Health system	cyber security, privacy	Narrative discussion on security and privacy issues of m-Health system	m-Health system developers perspective	✓ Identified m-Health security requirements ✓ Mark off security threats, attacks and countermeasures in mHealth systems
28	to provide an overview of the issue and to encourage discussion on m-Health data security	Security, Privacy, integrity	Reviewing literature for Identified security option and their pros and cons of m-Health	For program developers perspective considering legal issues	✓ Provided an overview of potential data security solutions ✓ Suggested some steps of data security methods for flexible m-Health apps development
29	Propose a risk model in the context of healthcare decision support	Risk assessments of using mobile based support	Developed and evaluated theoretical model	Smoking resignation	✓ consumer views on mobile phone use in smoking cessation programmes are not influenced by the consumer level of previous exposure to mobile services;
30	Evaluate key challenges facing m-Health with a focus on privacy and security issues	Privacy and Security Issues	Literature review,	m-Health system developers	✓ provided recommendations for securing employee-owned mobile devices ✓ identified Common mobile threats and countermeasures ✓ provided recommendations Privacy and security for m-Health
31	investigates the potential value of iPad tablets for enhancing health services delivery by primary care physicians in rural Area	Usability, Impact assessment	Intervention study	Enhance rural healthcare service	✓ mobile devices such as iPad tablets improving healthcare access and quality in rural and frontier areas ✓ iPads increased efficiencies and improvement of care by enabling direct and immediate access to online medical resources
32	To evaluate stand-alone mobile personal health record (m-PHR) applications	Evaluating features and functionality	Reviewing and analyzing m-PHR applications	m-Health system developers perspective	✓ m-PHR capabilities and limitations currently available for smart phones ✓ Regardless of mobile platforms, m-PHRs have a similar average converge rate for data elements and application features
33	To provide a set of empirically based recommendations for usability testing of mobile ICT for clinical work	Methodological and practical challenges	Experimental study	Clinical service context	✓ Usability of mobile EPR systems is largely determined by factors that go beyond that of the graphical user interface. ✓ Due to concerns of privacy, ethics, and the possible fatal consequences of error, usability tests of EPR systems can rarely be done
34	To evaluate the impact of text message reminders on hepatitis B virus vaccination completion	Evaluation assessment	Intervention study	Australian sexual health setting	✓ there were no significant differences in these proportions between the pre-SMS and SMS group

35	To provide strong security and privacy guarantees for mHealth sensing applications	Security, Confidentiality and integrity	Both design and implementation of the system were used to ensure the trust of systems	Healthcare industry	✓ New approach of trusting m-Health system was successfully designed ✓ Plug-n-Trust (PnT) is feasible for healthcare industries ✓ Plug-n-Trust (PnT) achieved security goal to record medical information
36	To examine engagement with a mobile application	Impact assessment	Base line survey for intervention	behavioural health problems like Traumatic Brain Injury	✓ Exposure to m-Care did not differ by health status ✓ Mobile health has the potential to increase the quantity and quality of patient-provider communications in a community-based and rehabilitation care setting

Appendix C

Table C 1 (Sample type 2: M-health Application designs)

Sample No.	Studies	Artifact	Problem domain	Purposes	Design components	Methods	Kernel theories	Design steps	Evaluations
1	Expanding healthcare coverage	Instantiation	Public healthcare	To improve interaction between doctor and patients	Login, My Patients, Drugs module, Tests module, and help module	Prototyping	Theories of Healthcare practices	Problem identification, Design, deployment evaluation	Feedback of target user
2	Improving training support	Method	Medical students	To develop competency development	Software Developers' Kits (SDKs), Eclipse and Xcode	User centred approach	Capability development theories	Design, Development	Analytical approach
3	Managing chronic conditions	Model	Pain management	To develop cancer pain care algorithm	pain decision algorithm, catalogue of pain management system	User centred approach	Pain management strategies	Outline requirements, design and evaluation	potential effectiveness
4	Motivation support services	Instantiation	Type 2 Diabetics management	To improve self-management using m-health apps	Synchronize blood glucose meter, Log meal or snack, activity monitoring, and weight scale.	user-centred design	Health behavioral theory/ diabetic patients care	Development, feasibility , piloting, and evaluation	Feedback of providers
5	Expanding healthcare coverage	Method	Public Healthcare	To design health monitoring solution	processing capabilities, memory availability, and interfacing options	Experimental method	wireless sensor networks theories	Design, Analysis	Analysis of recorded response
6	Improving decision making	Instantiation	Public Healthcare	To develop m-health apps considering individuals' need	Ontologies, diet, suggestion, education disease alert generation	Traditional design approach	Monitoring of patient diseases	Design, development, implementation, evaluation	Survey on patient's experiences
7	Improving hospital or clinical management	Instantiation	Cardiovascular patient care	To develop m-health tool for cardiovascular disease	Mobile 7-lead ECG device, wireless network, Bluetooth, and smartphone	Prototyping	Standard clinical function knowledge for Cardiovascular detection	Problem identification, Design, development, analysis, evaluation	Error rates analysis
8	Training support	Instantiation	Human behavior modelling	To design effective health solution	System manager, communication manager, visualization	Agile method	Healthcare design strategies	Design, implementation, validation	Performance analysis

					manager, storage, data process, service				
9	Expanding healthcare coverage	Instantiation	Pregnant care	To design m-health for community based health care providers	User Interface, data Security, tracking and Synchronize	Prototyping	healthcare support strategies	Development, solution	Usability
10	Supervision support service	Instantiation	Health monitoring care	To develop mobile apps for health monitoring	Body sensor, wireless sensor, motion sensor, server, wireless network, weight monitoring sensor	Unspecified design approach	ubiquitous health monitoring strategies	Design, development, monitoring	Performance analysis
11	Expanding healthcare coverage	Model	Design of m-health	Provide solution of data encryption for m-health systems design	Web interface, web server, network, health records, wearable sensors, specialised mobile devices	Prototyping	healthcare support strategies	Development, evaluation	system validation
12	Providing suitable healthcare in emergencies	Instantiation	Asthma care	To design Asthma care self-management solution	Web browser, user interface, information, Forecast, Current Zone	Design method for mobile app	Asthma care theories	Design, development, pilot testing	Usability
13	Patient monitoring	Methods	Aged care	Providing batter monitoring system of aged people	Heart rate, breathing rate, activity level, measuring blood pressure, skin temperature, posture	user-centred design	Opportunity for aged people	Design, development, evaluation	Pre-lunching test by expert and then user usability
14	M-health security theory	Theory	Design of m-health	Provide an information security framework for managing m-Health data	Data encryption service, authorisation capacities, transport security, digital filter	Theoretical investigation	Standard security framework	Problem identification, background theories, proposed solution concept	Not evaluated
15	M-health coverage of service	Models	Healthcare service	To increase capability of sensor network application	Wireless sensor network, general and smart mobile devices, network camera	Experimental approaches	Opportunity in healthcare service	Design, Implementation	Experimental
16	Hospital management	Theory	Design of m-health	Propose an interconnection framework for m-health in remote monitoring	Hospital Information System (HIS), Service providers, and other systems for context	Use case analysis	Advancing wireless communications from the perspective of the Internet of Things (IoT)	Requirement, design and evaluation	Performance testing
17	Interaction support	Instantiation	Healthcare provider	Interaction between nurse and patients	Web app prototype, logged in, basic layout,	Prototype	Facilitate to healthcare professional	Design, Implementation,	Usability by observation

					information gather and view layer			Evaluation	and survey, focus group analysis by management
18	Self-monitoring of patient	Instantiation	Assist eating disorder/ Disabilities care	develop m-health apps for self-monitoring of eating disorder	Login, reinforcement, social support, summary feedback	Prototypes	Opportunity of disable people	Development, feasibility, utilization	Utilization rating by consumer
19	Design technique	Theory	Design of m-health	Propose a multi-view variability model for designing adaptive m-health	Features availability, features degradation, running example of problems,	Proof of concept	Software Product Lines (SPL) techniques	Problem identification, specification of context requirement development, model design, and proof of concept dev.	Not evaluated
20	Patient monitoring	Model	Public healthcare	To increase remote monitoring of aged patients	Login, register, about us, contract us, patients & doctors oriented interface	Design method	Opportunity in public healthcare	Design, implementation	Usability
21	Patient monitoring	Theory	Public healthcare	Propose a framework in terms of decision making for patient monitoring	Categories of available power, transmission and density	Analytical modelling	Opportunity for designing patient monitoring healthcare	Design and analysis of framework	Not evaluated
22	M-health evaluation	Theory	Healthcare for ageing community	Propose a framework for evaluating m-health for ageing group	Categories of issues, ageing related concept, ageing dependent ability	Methodology of application design	Ease of use theories for adopting m-health	Design and evaluation	Simplicity, navigation, effective use of language
23	Public health care	Construct	Public healthcare	To design m-health apps for weight loss	Login, configure verification	Quantitative pilot study	Healthcare service	Design, development, feasibility, usability	Acceptability, usability
24	Healthcare management	Instantiation	Healthcare providers	To develop a mobile application for healthcare provider	Login, patients list, LIS and PACS, EMR, My page, privilege management interface	prototype	Support healthcare	Design, development, implementation	Usability
25	Patient monitoring	Instantiation	Cardiovascular Patients	To build smart remote monitoring system of Cardiovascular Patients	Functions for storing ECG data in mobile device, display it, and retransmit it to a server using Internet	Experimental design study	Monitoring patient with Cardiovascular diseases	Design, development, implementation, Evaluation	Validation
26	Patient	Instantiation	Healthcare service to	To design and	The near-field	prototype	Support healthcare	Design,	Usability,

	monitoring		ageing	evaluate an app for solving problem of integrating a medical sensor device for providing a useful data to an existing monitoring system	communication based system			development, implementation feasibility, usability	feasibility
27	Public health care	Instantiation	App for public health and life style improvement	To design an app (SapoFitness), for a dietary evaluation and gives challenges, lerts, and constantly to motivate user	Patient health records, global communications network and	prototype	Opportunity in healthcare support	Design, Development, Implementation, Evaluation	Testing general application functionality, user experience
28	Patient monitoring	Instantiation	mHealth app for personalized healthcare of wheelchair users at home	to develop an intelligent system with real-time monitor and interaction, for personalized healthcare	The nodes of WBSNs include wireless heart rate and ECG sensors, wireless pressure detecting cushion, home environment sensing nodes and control actuators	prototype	For personalized healthcare of wheelchair users	Problems identification, design, implementation	User experimental
29	Treatment support	Methods	m-health for Mobile Augmented Reality to deliver range of motion training exercises	Mobile RehApp™ for mobile devices designed for therapeutic support that aims to assist physiotherapists and patients	Design components a) power Consumption, calculation, storing and matching; b) light sensibility and depth perception c) inability to measure force and pressure	System development approaches	Personalized rehabilitation component for ankle sprain patients	Problems identification, design, development, implementation	User interaction, feasibility
30	Remote healthcare service	Instantiation	Infant and maternal healthcare	Develop m-health for mobile based remote healthcare delivery	captures the experience of designing a health care application for rural India, the tools and methodologies used,	Pilot project	Opportunity for infant and mother healthcare service	Design, implementation, Analysis	Statistical analysis of collected data
31	Patient monitoring support	Model	To model for health monitoring systems for data analysis	The model is a layered architecture for data analysis, based on two decision tree -predictor	Sensor, cloud infrastructure	Model development approach	Theory of decision tree based prediction for implementing the system	Design and evaluation	Feasibility

				hardware implementations: a high performance architecture, and a lightweight architecture					
32	Patient monitoring support	Model	Android Mobile Apps for monitoring of a patient's blood pressure (BP)	To remote monitoring of a patient's blood pressure	wireless sensor network, Bluetooth, Android cell phones	Conceptual framework design	Decision Tree for the Machine Learning Approach Decision tree are either classification trees or regression trees. When it is trying to predict the values on some numerical approach	Design Evaluation	Experimental
33	Home-monitoring	Instantiation	Self-home care system for monitoring heart rate, oxygen saturation and body temp.	m-health for home-care and monitoring	Microcontroller, tem. Sensor, accelerometer, Bluetooth, heart rate sensor	System development	Simple monitoring technique through to Bluetooth communication	System design details	Not evaluated
34	Patient monitoring support	Model	Propose a for mobile diagnostics, tele-monitoring and automated drug infusions	m-health for medical application	Wifi point,vital node server, patient monitors, switch board.	Use case based study for designing the pilot model called iControl	an Integrated Development Environment based application design	Application design and implementation	Not evaluated
35	Patient monitoring	Theory	Propose design guidelines for mobile patient monitoring systems	m-health for medical application	Requirements in terms of the number of variables to monitor and user need for data mobility.	Theoretical analysis	Various wireless sensor network	Conceptual approach for m-health	Not evaluated
36	Treatment support	Instantiation	M-health *(iWander)* application which is used to assist dementia patients and their caregivers	m-health for providing treatment support	Hardware, patient interaction, implementation	System development	Bayesian network based theories	Design and implementation	Not evaluated
37	Patient monitoring support	Instantiation	Propose a m-health (iCare) for mobile health monitoring	medical care at home for elderly and assist for self-management	User interface, real time health monitoring, regular	Prototyping	Tele-monitoring theories	Problem identification, concept	Not evaluated

			for the elderly		reminder and medical guidance			development and solution implementation	
38	Patient monitoring support	Instantiation	develop a blood donation service to assist in the management of blood donor records and ease/or control the distribution of blood	Medical care practice	SMS based functionality for blood donation service	System development methodology	Record keeping	detailed software and hardware requirements and realizations of the system	Performance and usability
39	Treatment support	Instantiation	Developing and evaluating m-health called "MoviPill" that persuades patients to be more adherent to their medication	To support for medication Compliance for Elders	Pill box, database, move pill	Prototyping	Patient's non-compliant behavior	Research questions setup, conceptualise solution, implementation	Performance and usability
40	Early intervention of childhood anxiety	Instantiation	Developing m-health for prevention and early intervention of childhood anxiety	To support early intervention of childhood anxiety	Story boarding and Click through, translating protocol.	User-Centered Design approach	A game based strategies	Requirement analysis, design and development of application	Validation through usability study
41	In-house monitoring	Model	Perspective of caregivers to support with monitoring capabilities while hiding the complexity to end users	Propose a framework to address problem of in-home monitoring.	Acquisition of bio-signals, wireless transmission of bio-signals, patient information systems, intelligent agent	Prototyping	Theories of bio-sensing and intelligent systems	Exploring relevant literature, outline requirement, design model	Not evaluated
42	Decision making	Model	To support self-care decision making by patients	For the benefits of self-care for patients	Problem detection, sense making, operation generation, planning	focus groups to elicit information from elderly cardiovascular disease patients	applies Cognitive Work Analysis to analyze patient's decision making	Collection information about requirement, analysis, model development, Competencies Analysis	Competencies Analysis
43	Nurse management in field for assisting clinician	Instantiation	M-health for assisting rural clinicians taking care of hypertension patients in western Kenya.	m-health for nurse's management	Data entry and validation, branching logic and decision suooprt and integration with AMRS	Iterative design	Kenyan Ministry of Public Health and Sanitation.	Problem identification, design and evaluation	Usability and feasibility
44	Clinical support	Method	Develop app ("The FLOW") for allowing	For clinician's use	Data collection, data analysis and result	Quantitative method	usage patterns and user experiences of a	System description, and	Usage patterns and

			mobile devices to be used for rounding and handoffs		analysis		novel application	evaluation	user experiences of a novel application
45	Clinical support	Instantiation	propose an innovative m-Health solution for quantification of Congo Red Dot test	For healthcare professional	Image acquisition, sheet detection, sheet extraction, cell extraction, dot detection, dot extraction, test result calculation	Experimental study	standardized procedure of diagnosis for preeclampsia	Design requirement, solution introduction and testing	Performance and Tolerance Analysis
46	Self-management	Instantiation	Mobile health applications designed to facilitate management of chronic conditions, present novel opportunities for supporting patient self-management	For patients to manage their arthritic condition (Gout).	ArthritisID, Gout by AZoMedical, Gout Channel, Gout Manager, iGout app for Managing Gout.	Experimental study	supporting patient self-management	Design, implementation and evaluation	adoption and effectiveness
47	Self-care management	Instantiation	design of personal health record systems (PHRs) and self-monitoring technology supporting self-care	For changing the self-care practices	User profile, tag editor, graph log,	Qualitative analysis for solution design	Theories of clinical care in formal and controlled settings	Problem identification, design and implementation	Effectiveness and usability
48	M-health design theory	Theory	identify motivational factors for using wearable healthcare devices and examine the process by which these factors are integrated with the technology acceptance model (TAM)	For improving design knowledge of m-health	Research design, analysis and findings	Quantitative analysis and assessment through to TAM model	Developing new understanding of mobile devices for health	Contribute to current theory of m-heath adaption	Validation
49	Public care service	Method	GeoHealth that will address geo-reference and security issues in collecting primary care data in Brazil	m-health for healthcare professional	three main components: (a) an Application Server, with database containing family health conditions; and two clients, (b) a Web Browser running visualization tools for	Prototyping	Theories of GIS for geo-health	Scenario and requirements, solution outline, defining features, system development , evaluation	efficiency and data quality

					management tasks, and (c) a data-gathering device (smartphone) to register and to geo-reference the family health data				
50	Home monitoring	Instantiation	Personalised mobile-based home monitoring system for heart failure	For patients and healthcare professionals	Self-monitoring, self-management education through videos, review of personal readings for self-tracking and communication with health professionals	Prototyping	Theories of physiological measurements	Understanding patients' monitoring needs, system overview, system development, implementation and evaluation	system usage
51	Clinical support	Method	Developed a method of video distribution for m-health in terms of a structural framework (called WiMAX)	proposed segmentation of real-time data flows provides both quantitative and qualitative system resources utilization	networks service categories, extended-real-time priority service that are used for video-application data delivery	Experimental study	Extended functionality of the conventional classifier/analyzer module	Method design and Scenario testing	Standard compatibility
52	Self-monitoring	Theory	examine the degree to which LTR (Lung transplant recipients experience) followed decision support messages	Assessing health self-monitoring across 96 patients	Unified theory of acceptance and use of technology model is used	Experimental study	Confirmed the effective use of m-health for patients	Understanding patient self-management	With secondary data
53	Patient care and support	Instantiation	Developed a m-health app for reminding patients to take medicine	For improving patients' adherence support	A trial study for developing and evaluating an m-health application's effect on blood pressure and medication adherence	Trail design: recruitment, screening, treatment aims, follow-up assessments, statistical analysis, outcomes	For improving self-reporting adherence support	Self-management and support	Effectiveness
54	Patient care and support	Model	Developed a m-health model for health behavioral interventions	For improving health behavioral interventions	Developed a model by identifying barriers and facilitators to the use of m-health	Iterative design research: three cycles:	For identifying barriers and facilitators of using m-health	Consumers' support need	Usability

					for HIV prevention	relevance, rigor and design			
55	Disease management	Theory	Identify current issues and success factors of Cardiovascular m-Health	Improving support and care service of Cardiovascular disease management	Identified various interventions of m-health for Cardiovascular disease management	Literature analysis	For exploring m-health intervention for Cardiovascular disease management	Disease management	N/A
56	Treatment support	Instantiation	Developed and evaluated m-health for medication adherence	For improving tobacco cessation medication adherence	Discussed findings of the development	Three phases of design: capturing inputs, testing feasibility and develop and evaluate m-health app.	Generalized the result for other similar design of m-health	medication adherence	Trail evaluation
57	Patient care and support	Instantiation	Developed m-health for proving guidance for insulin management	For improving evidence based support to diabetic patients	m-health app design for diabetic care	Literature review, app design and app evaluation	For design and evaluation of m-health solution	For the support of diabetes self-care measures	Effectiveness
58	Self-management and patient care	Method	Proposed a design method for a diabetes self-management mobile app	Improving diabetes self-management	m-health for self-monitoring of blood glucose, physical activity, diet and weight for the positive behaviour change	a scoping review ; development of theoretical approach and validation of the app using through user-centred design methods	For the patients' self-monitoring and taking positive behavioral change	Assisting self-monitoring	Effectiveness, validation
59	Design understanding	Theory	Developed four themes of m-health design	Improving understanding on previous m-health design	Literature analysis	Review existing literature	To identify future directions of m-health	Understanding current state of research	N/A
60	Patient care and support	Construct	Developed themes and understanding on m-health for promoting patient engagement	Improving patient engagement	Thematic analysis	Review existing literature	Confirmed the use of m-health	Understanding patient engagement issues	Effectiveness of the themes
61	Disease management	Method	Developed a framework of m-health for chronic disease	For improving chronic disease management	Developing m-health intervention (solution framework)	Using seven different design states	Identification and development of m-health application	The method is for guiding the design of m-	Effectiveness

						(problem specific)		Health solutions	
62	Patient care and support	Instantiation	Developed a personalised m-health for runners	m-health is developed to replace personal trainer	Personal healthcare support (for recreational runners)	Design approach	Developed m-health app for the basic need of users	Profiling, designing and validating	Usability