Aligning Healthcare Innovation and Software Requirements through Design Thinking

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ABSTRACT
In recent years, there has been significant growth in software companies across the healthcare sector developing new technologies to improve healthcare delivery and services. This has given rise to the emergence of Connected Health – a new model for healthcare management. This also places considerable emphasis on the process of software development in supporting Connected Health. In addition, it highlights the growing reliance and trust we place on software to support healthcare decisions. However, unlike many other sectors, such as business and education, failure to align healthcare needs with software requirements can have devastating consequences on people’s health and potentially cause death. Our research and experience with healthcare companies confirms the need to establish a Connected Health Innovation Framework using Design Thinking principles to a) support software developers in clearly identifying healthcare requirements and b) extend and enrich traditional software requirements gathering techniques. This paper presents an e-pharmacy case study and describes the impact this approach has within a Connected Health context.

CCS Concepts
• Software creation and management • Designing software • Requirements analysis • Software design techniques • Health care information systems • Health informatics

Keywords
Connected Health; Software Requirements; Design Thinking; Healthcare Innovation; E-pharmacy

1. INTRODUCTION
The healthcare industry is in the midst of a turbulent global transformation. Coupled with resource constraints, healthcare reform provides a natural environment in which to explore technological innovations to improve healthcare effectiveness and efficiency. Healthcare services continue to face both increased demand from an expanding population of consumer-patients and growth in costly chronic disease management. Thus, technology and software services play an increasingly dominant role in supporting the delivery of healthcare services. As a result, Connected Health has emerged as a field to support the evolution of modern healthcare services and solutions. However, there is an increasing blur between software capabilities and healthcare needs whereby technologists are now providing the solutions to support consumer wellness and provide the connectivity between patient data, information and decisions.

There is an apparent lack of insight on how healthcare requirements are mapped onto software requirements, which, if ill informed, can have a devastating effect on people’s health. For example, within ARCH (the Applied Research Centre for Connected Health), a technology centre in Ireland, we often support technology companies in improving their evidence-based research and identify healthcare needs using technological solutions. However, there is a lack of an established framework to guide software developers in identifying healthcare needs. Our research and experience with healthcare companies indicates the need to establish a Connected Health Innovation Framework to both a) support software developers in identifying healthcare requirements and b) extend and enrich traditional software requirements gathering techniques. We propose that this should be done using Design Thinking principles.

Section 2 provides an overview of Connected Health and the challenges faced in software development. For the purposes of this paper, we focus on an e-pharmacy case study to explain the challenges in understanding healthcare processes and software innovation. Section 3 outlines the Research Aims and Objectives.

Section 4 discusses Software Requirements and the shortfalls within a Connected Health context. In Section 5, a discussion on the suitability of Design Thinking to extend software requirements practices in healthcare is provided. It also describes how we employed Design Thinking to support our e-pharmacy case study and how we successfully aligned healthcare and software requirements that have led to the development of the Connected Health Innovation Framework. Section 6 discusses how this work extends traditional software requirements engineering practice. Section 7 offers a discussion on the implications of this research, future works and a conclusion.

2. CONNECTED HEALTH
Connected Health has been defined by Richardson [1] as “patient-centred care resulting from process-driven health care delivery undertaken by healthcare professionals, patients and/or carers who are supported by the use of technology (software and/or hardware)”. Therefore Connected Health can be considered to be a socio-technical healthcare model that extends healthcare services beyond healthcare institutions [2]. Through the exploitation of technological innovations, healthcare providers can generate accurate and timely information for patients and clinicians to make better decisions. Improved decision-making tools can improve the likelihood of saving lives, saving money and ensuring a better quality of life during and post treatment [3]. However, as we face growing needs in healthcare solutions, e.g. elderly population [4] this inevitably leads to a growing demand
on treatments in hospitals, e.g. pharmacy services. Therefore, we must clearly identify patient’s needs and understand how healthcare technology aligns with their needs to avail of improved care pathways.

2.1 E-Pharmacy
Pharmacy is the science and technique of preparing and dispensing drugs to ensure the safe and effective use of medicines. As increased demands for healthcare services and new progressive technology healthcare models evolve, new methods such as telemedicine and e-pharmacy present significant promise to enable improved connectedness between healthcare professionals and patients and offers greater accessibility to pharmacy services. E-pharmacy may be described as online pharmacy services that enable healthcare professionals to prescribe medications for patients through digital technologies. Thus, e-pharmacy is becoming an attractive model in the modern healthcare sector.

Working with healthcare professionals, in this case, pharmacists, we can develop rich and deep insights on the barriers and requirements to validate the problem-solution fit to develop e-pharmacy within a Connected Health context. Thus, we set out to develop a framework that provides a practical yet innovative solution to address pharmacists’ needs, identifying opportunities while mitigating the risks often associated with technologies [5]. This research approach is novel because, guided by Design Thinking [6], it successfully extends healthcare innovation by bridging healthcare needs and software requirements. Design Thinking presents a human-centered, prototype-driven process that can be applied to any product, service, and business design [7]. The importance of undertaking this research can be gauged by recent developments in Connected Health and the need to carefully align healthcare innovation processes and healthcare needs to improve health quality and safety.

2.2 Motivation
There is a growing demand for technological healthcare solutions such as e-pharmacy [8]. We go beyond state-of-the-art in healthcare developments to fundamentally examine how we can re-design new healthcare pathways through Connected Health innovation. Learning about the needs of healthcare professionals ensures that the ‘correct’ technological solution is developed to support healthcare services. Ultimately, this will better empower staff who frequently face the day-to-day challenges associated with delivering safe healthcare services with dwindling supportive resources. Our ultimate ambition is to promote greater accessibility of health care services; improve the connections between people; enhance collaboration between key stakeholders (patients, carers, healthcare providers) and establish better communication through improved healthcare software design principles. We argue that e-pharmacy is critical to the success to Connected Health within a wider healthcare system and demonstrate our research approach in this context.

3. RESEARCH AIMS & OBJECTIVES
Our aim in this research is twofold. Firstly, to understand current practice we must identify and model current pharmacy practices within a hospital and community context. Secondly, having a thorough understanding of current practice, we develop the Connected Health Innovation Framework to guide software developers in providing healthcare solutions that are specifically tailored to meet pharmacists’ needs (Figure 1).

3.1 Requirements-led Pharmacy Innovation
We adopt a healthcare requirements-led approach that accounts for pharmacy software innovation. To address our research aims, we set achieve the following objectives:
1. To explore the pharmacists experiences with current services;
2. To identify factors which enable/inhibit pharmacy services;
3. To assess the effectiveness of current healthcare services from the pharmacist perspective;
4. To assess whether Connected Health innovation can offer an effective care pathway for the patient;
5. To establish a Connected Health Innovation Framework to inform software developers regarding the development of e-pharmacy solutions.

Figure 1. Research Overview

4. SOFTWARE REQUIREMENTS
Identifying software requirements is a process within software engineering that establishes the needs of stakeholders and the behavior of “the machine” in a specific domain [9]. Therefore a requirement may be considered to be a specific condition or capability needed by a user to solve a problem or need to enable them achieve an objective. Understanding the stakeholders’ need requires a software engineer to undertake a number of process stages, i.e. requirements elicitation, analysis, specification, and management. These process stages describe specific software features and functionalities of a system. The requirements can be obvious or hidden, known or unknown, expected or unexpected from a client’s point of view. Considering the complexity often associated with healthcare, uncovering healthcare requirements can be a difficult task for healthcare professionals to clearly describe and for technical people to address. This has often led to the mismatch in technical solutions and healthcare needs. In some cases, software developers provide ‘novel’ software solutions but fail to address patients ‘real’ needs. The high failure rate in healthcare software start-up companies and the slow uptake of e-health solutions globally is often attributed to this situation [10]. We identify this as an opportunity to establish a novel approach to improve how software requirements are informed. This can enable us to develop and maintain sophisticated healthcare innovation requirements specification (including the feasibility study, requirement gathering, software requirement specification, software requirement validation and verification).

One of the core questions that emerges from systems and software engineers is: How does Design Thinking differ from requirements engineering? It may be argued that Design Thinking methods are similar to systems and software engineer’s methods and that there is no real value in adopting such approaches. We argue that Design Thinking complements traditional systems and software requirements engineering techniques in prototype-driven
requirements analysis by encouraging the generation of innovative outputs through the imaginative forethought and explorative interplay of people, processes, technology and business needs. It is worth noting that Design Thinking is a suitable approach to solving problems at the point where systems and software engineering techniques move towards the prototype development stage. Design thinking is centered on truly understanding client needs and exploring the preferred solution within the agile/waterfall spectrum. Thus rather than focusing on technology solutions in the early stages of the process, we become more immersed in the problem space and identify various needs to improve healthcare service processes and practices.

5. CASE STUDY: USING DESIGN THINKING FOR E-PHARMACY

5.1 Background
In the study presented in this paper, we examine how the field of Design Thinking can support the collection of software requirements for Connected Health, using e-pharmacy as an exemplar. Nowadays, pharmacy service providers view their healthcare service systems in a process-orientated manner. Borrowing many of the techniques from which business has benefited, we witnessed how pharmacists have begun to adopt new approaches to increase efficiencies and optimise service operations. However, pharmacy is a complex system and a core part of many healthcare pathways. Thus, the improvement, redesign and management of complex healthcare systems are necessary to rebuild an improved e-pharmacy model, yet a challenging area in which to implement change. How this improved e-pharmacy model can be successfully achieved still remains unclear. We turned to the literature in search for what may be described as ‘best practice’ in pharmacy. We examined various process models to identify the most prominent process modelling approaches, which approaches may work best and which element of the modelling techniques could be extended to generate new insights on optimising pharmacy. However, we found that there was little consistency as to what approach is best to optimize pharmacy processes within a hospital context. We then undertook three case studies in Ireland, in two public hospitals and one private hospital to examine real world pharmacy services.

5.2 Design Thinking
Design Thinking provides a formal process to capture people’s various needs or pain-points. Therefore, this is particularly apt to guide our research in identifying healthcare innovation requirements, in this case, pharmacy. Such guidance is vital since innovation enabled through healthcare software development has much at stake, most notably patient safety. Our research suggests that Design Thinking moves beyond requirements gathering and prevents us from being constrained by preconceptions of software solutions in isolation [10]. It supports our ability to gain rich insights on the e-pharmacy case study. In fact, Design Thinking adopts five key phases (Figure 2) guiding innovation through: 1) empathising to fully understand the experience of the pharmacists, 2) defining a wide variety of possible e-pharmacy solutions, 3) ideating creative e-pharmacy solutions, 4) prototyping ideas into tangible form, and 5) testing to refine and examine the value/impact of e-pharmacy solutions. This fosters a learning lifecycle through various actions (outlined in the following subsections) about both the solution and informing how we can bridge our understanding of healthcare needs and the software design process.

As a delivery model for health services, co-production is considered to be a key process for sharing information and decision-making between the service users (i.e. patient) and healthcare providers [11]. This led us to examine the promise of Design Thinking and how we can better inform technology innovation in a Connected Health context. This differs from software requirements engineering which guides the process of eliciting individual stakeholder requirements [12] meaning that once a solution is launched on the marketplace, the level of engagement and uptake of the technology is high. We adopt a new stage in pre-requirements gathering to inform software developers of specific healthcare needs and how software requirements can be best aligned with those needs.

To guide our efforts, we adopted Stanford University’s D-School’s Design Thinking method to initiate the research. This Design Thinking process offers a formal approach for practical, creative resolution of barriers, which can guide improved healthcare software solutions. This approach also supports Connected Health solutions development and can reduce the risks of failure through our framework for healthcare innovation. Through the five Design Thinking phases, we examine the benefit of using the following key activities in software requirements. The development of the Connected Health Innovation Framework was influenced by the need to structure how we gather healthcare needs from Connected Health research developments [1, 2] and bio-design literature [13] in order to support software requirements in healthcare technology innovation.

![Figure 2. Overview of Design Thinking Phases](dschool.stanford.edu)
manual and labour intensive. This proved to be one of the key barriers to optimization of service processes.

5.2.1 Empathise:
As part of the case study, we interacted with the pharmacists though the following steps and identified the key problems and needs (summarized in Table 1):

- **Observation**: we shadowed the pharmacists and observed their behaviour in the context of their working environment. Observations of pharmacists in relevant contexts in addition to interviews enabled us to clearly identify any disconnect between what they described and how they behaved.

- **Engage**: through a series of semi-structured interviews, we engaged in a conversation with the pharmacists. It was important to allow the pharmacists to direct the conversation and deviate from the original questions to facilitate the exploratory nature of Design Thinking and explore “why?” to uncover deeper meaning on their working environment and workflow norms.

- **Watch and Listen**: we combined observation and engagement, for example, by asking pharmacists to demonstrate how they complete a task. When pharmacists agreed to demonstrate how they undertake specific steps and explained why they are doing what they do, it enabled us to develop rich insights of their experiences. Through various storytelling activities, we began to uncover the core issues associated with healthcare needs and process flows and prompts deeper questions on how Connected Health innovation may support them.

5.2.2 Define:
Having gathered information on the core problem or ‘pain points’ experienced by pharmacists, we began to define the core issues using the following key steps and identified the key problems and needs (summarized in Table 1):

- **Contextualise**: we identified emerging themes from the ‘empathise’ phase. The patterns that emerged and which appeared to offer interesting insights on ways to support pharmacists were further examined. For example, exploring why pharmacists or other healthcare professionals demonstrated certain behaviour or feeling allowed us to examine connections from that person to the larger context and solution development.

- **Synthesise**: at this point, we defined the ‘user’ of a possible healthcare solution. This is achieved by synthesising and prioritising a limited set of needs. The end-user prospective (i.e. it may shift workflow from the pharmacist to a pharmacy technician) was influenced by combining three core elements: user, need, and insight into an actionable problem statement [13]. This ultimately influenced the Connected Health design process. We began to define the core problems as follows:
  - Skills gap to manage pharmacy change in areas of process improvement, technology implementation and service analytics (for example, pharmacy informatics);
  - Lack of a clear national medicine management strategy to achieve consistency across national hospitals and strengthen national pharmacy services;
  - Patient safety and the harm misprescription can bring about to patients, healthcare professionals, healthcare reputation and/or trust and impact on the wider community through poor medicine management;
  - Workflow inefficiencies through repeat ordering and supply of medicines that is slow to arrive between pharmacy, nurses and patients;
  - Stress on staff due to peak overloads in medicine demands, work-in-progress and long lead times;
  - Waste of medicine and impact on pharmacy performance analysis through the adoption of ‘just-in-case’ medications rather than a ‘just-in-time’ (JIT) approach to high-risk drugs;
  - Knock-on impact of pharmacy performance on other vital healthcare services and patient satisfaction;
  - Financial loss due to poor inventory management;
  - The lack of clarity in purpose and feedback loops: staff do not know if and when they are doing a good job (individually and collectively);
  - Lack of focus on equity in queue management;
  - Demand exceeding flow-capacity at different times of the day;
  - Loss of flow-capacity due to resource scheduling and highly variable productivity quotas amongst staff;
  - Highly variable productivity quotas as a result of lack of standardisation in work due to a fear of ‘letting go’, and managing the supply problem as a collective (high performing team).

From the list, we got a real insight of the day-to-day issues experienced by pharmacists. We summarised the outcome from each phase into an e-Pharmacy Connected Health Innovation Framework (Table 1).

<table>
<thead>
<tr>
<th>Phase</th>
<th>Key Problem(s)</th>
<th>Key Need(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Empathy</td>
<td>• Lack of insight and competence/skills to improve processes, implement technology, develop service analytics. This frustrates the pharmacy staff and leads stress, waste of resources (time, stock and financial) and inefficiencies.</td>
<td>A quality management system that guides process improvement and medicine management.</td>
</tr>
<tr>
<td>2. Define</td>
<td>• Lack of visibility to manage and monitor drug orders within the hospital makes it difficult to manage service operations.</td>
<td>A system that monitors and tracks drug-flow within a hospital system.</td>
</tr>
<tr>
<td>3. Ideate</td>
<td>• Need a system which provides access at anytime from anywhere; • Believe that robotics or machines to complete ‘mundane tasks’; • Suggests that they need a system to monitor and track drugs being ordered, dispatched, consumed (including dosages); • Suggests that they need a system which facilitates just-in-time stock controls; • Suggests that they need a system that provides pharmacy intelligence capabilities for data analysis, e.g. a learning healthcare system.</td>
<td>An online system that monitors and tracks drug-flow within a hospital system using mobile devices and tracking services that offers analytical capabilities to optimise service performance.</td>
</tr>
<tr>
<td>4. Prototype</td>
<td>• Would like to track and monitor drug supply and usages from various perspectives: efficiency of delivery, cost, availability, ordering, etc.</td>
<td>Drugs resource-flow software system using RFID technologies and patient quality feedback on service operations.</td>
</tr>
<tr>
<td>5. Test</td>
<td>• Validating the use, usefulness and usability of the new system to support pharmacists needs</td>
<td>Examining the use of various technologies (see Figure 3) combined within a software tool.</td>
</tr>
</tbody>
</table>
5.2.3 Ideate:

The ‘define’ phase allowed us to concentrate our efforts on generating new solutions ideas in the ‘ideate’ phase and identified the key problems and needs (summarized in Table 1). We summarise these steps as follows:

- **Create**: Combining various stakeholder expertise through a number of tasks was achieved as part of a brainstorming process. This enabled us to leverage the synergy of the stakeholders to reach a refined solution. Adding constraints, being surrounded with inspiring resources and embracing misunderstanding allowed us to develop new ideas on Connected Health for pharmacy services rather than simply thinking about a problem through a technology lens at this stage.

- **Prototype**: We began to build prototypes to support the ideation technique. Through various development stages, we came to points where decisions were made and encouraged new ideas to come forward. This phase comprised of a number of ideation techniques such as brainstorming, mind mapping and sketching.

- **Separate**: we encouraged stakeholders to separate the generation of ideas from the evaluation of ideas to improve our creativity throughout the process.

5.2.4 Prototype (Patient-Centric Innovation):

Base on a number of key ideas which were generated in the previous phase, we had to commence developing various forms of prototypes based on the key problems and needs (summarized in Table 1). We summarise these steps as follows:

- **Build**: if we were unclear as to what the outcome was at any given time, we began to model key processes, build something or coding simple solutions as a good start towards a prototype. The main process was undertaking short exercises to developing prototypes.

- **Variables**: we clearly identified what was being tested with each prototype. Each prototype answered a particular question when tested as to how it improves existing pharmacy practice.

- **Build from insights gained**: we clearly identify what we wanted to test with the user. We also monitored the type of behaviour the pharmacists expected from the prototype and received some meaningful feedback in the testing phase.

Focusing on one of the outcomes, we identified the value of integrating Design Thinking through the five phases. We take this finding from the Connected Health Innovation Framework and examine how software solutions may be implemented to address this healthcare needs (Table 1) using the following outcome example:

“*Workflow inefficiencies through repeat ordering and supply of medicines that is slow to arrive between pharmacy, nurses and patients.*”

Software requirements express the needs and constraints placed on a software product that contributes to the solution of some real-world problems which we identified [14]. In this case, we aim to automate part of the pharmacy service processes of hospitals, to correct shortcomings of the existing system which software solutions are possible [14]. The activities related to working with software requirements can broadly be broken up into Elicitation, Analysis, Specification, and Management, which forms part of our future research and development towards e-pharmacy.

Having identified the core problems experienced by pharmacists, we can begin to explore possible software solutions. One proposed solution (Figure 3) appears to address the pharmacist needs and allows us to commence software requirements analysis.

This process becomes less problematic since we had gathered rich insights on the ‘pharmacist world’ and identified their key needs. We then translate these needs into software requirements. In Section 4 we explain how requirements may be considered to be a specific condition or capability needed by a user to solve a problem or need to enable them achieve an objective. We begin to visualize the solution in Figure 3 which identifies the pharmacist needs for a medicine management system and interaction with various user groups, including GPs, pharmaceutical supply chains, quality management, health insurers and incentives for medicine adherence. These must align software requirements to address the pharmacists healthcare needs (Figure 4).

5.2.5 Testing (Validation with Collaborators):

The final phase of the Design Thinking process involved testing the solution to address the key problems and needs (summarized in Table 1). We summarise the key steps as follows:

- **Observe and Refine**: we placed the prototype in the user’s hands (i.e. a pharmacist and technologist) to observe their experience. We did not explain everything about the prototype to allow the pharmacist interpret its functionality (i.e. testing its usability and usefulness). Observing how they use (and misuse) the prototypes and how they handle and interact with it provided valuable learning outcomes. We listened to feedback about the solution and address the questions they had.

- **Create Experiences**: we identified the key features of a Connected Health solution to test them in a way that feels like an experience that the user is reacting to, rather than an explanation that the user is evaluating.

- **Comparing**: bringing multiple prototypes to the field to test gives users a basis for comparison that often reveal latent needs.

![Figure 3 Towards an E-Pharmacy Innovation Solution](image)

This solution-based thinking approach highlights the important role that Design Thinking can also play in gathering Connected Health software requirements. Other methods for Design Thinking include creating user profiles, examining existing solutions (possibly in different domains), creating prototypes, mind mapping, and identifying opportunities through various situational analysis [15]. Through the ‘stories of individuals’ we can develop an insight on the ‘story of the organization’ to guide software innovation. The five design phases successfully guided our research to achieve the aims and objectives by aligning healthcare and software requirements through the Connected Health Innovation Framework (Table 1). As a way forward, through additional research and collaboration, our Design Thinking approach informs us of e-pharmacy software requirements and highlights that there is an apparent need to examine methods to:
1. Redesign the pharmacy ordering transmission system and delivery service to minimise workflow potentially using Connected Health, RFID and service analytics solutions;
2. Introduce e-prescribing initiatives for doctors to communicate directly to pharmacy in both a hospital and community context;
3. Improve inventory management and storage systems;
4. Reduce the use of batching of job requests and therefore removing the spike in demands at certain intervals throughout the day;
5. Introduce pharmacy informatics which will support in measuring pharmacy diagnostic flows;
6. Introduce an innovative ordering and queue system using Connected Health mobile devises;
7. Introduce more rigid standards on employee workflow;
8. Introduce initiatives to improve staff productivity and job satisfaction.

These areas will form part of our future research. As Table 1 indicates, having identified the required healthcare system, we must now align these healthcare needs with software requirements. It is it is only at this point that we start thinking about software as a solution. This guides the innovation process towards an improved solution-fit approach in Connected Health.

6. ALIGNING HEALTHCARE & SOFTWARE REQUIREMENTS

In identifying software requirements for Connected Health innovation, Figure 4 illustrates our initial developments based on the Connected Health Innovation Framework. We identify four core stages to gather healthcare software requirements:
1. **Identify healthcare problem / need**: focuses on defining healthcare requirements through a Design Thinking structure;
2. **Identify software capabilities**: examines the feasibility, requirements, regulations, and solution specification requirements which will influence the solution design;
3. **Aligning requirements**: specifies the innovation development process. We verify and validate the requirements through an innovation management process;
4. **Management of healthcare and software solution**: ensures that healthcare requirements are clearly met through the development of a software solution.

These key phases guide our ability to clearly align healthcare needs and software requirements and will be further tested and validate in different Connected Health solutions (for example, wellness devices and medical devices). We will continue to build on this research with a view to drilling down on each process and sub-process to inform software developers on healthcare needs and innovation (Figure 5). We view the opportunity of healthcare innovation as the ability to identify a core problem, need and solution. Within the problem space, we focus on the healthcare needs that are described by the key stakeholders, in this case, pharmacists, who experience a particular problem. While focusing on the specific needs, we begin to define the solution in technical terms and bridge findings from both social and technical requirements. Within the solution space, we focus on integration and verification of the proposed software solution. We allow the end-users to exploit the software solution but we must also evaluate the impact the solution has on healthcare from various different perspectives. This evaluation process will also form a key part of our future research and feedback on how we can further refine the Connected Health Innovation Framework.

**Figure 4 Identifying Connected Health Software Requirements**

7. DISCUSSION & CONCLUSION

Design Thinking, in this sense, involves first a domain analysis in which one studies the actual system to be improved. In this paper we explore pharmacy functionalities within a larger healthcare system. This research describes the need to facilitate an in-depth understanding of healthcare stakeholders ‘realities’ in context of their day-to-day experiences, identifying the need to introduce a pre-software requirements phase. Thus we used Design Thinking techniques to inform healthcare innovation. Incorporating Design Thinking in the software requirements process presents an exciting opportunity to support software developers in gaining new insights on Connected Health innovation. In particular, it can support the addressing of patients’ and healthcare professionals’ needs using healthcare devices. Limitations of this work include the use of one case study that would suggest that there is a need for additional cases to test this proposed method and compare with other requirements engineering methods. Through the development of the Connected Health Innovation Framework, this research sets out to provide an evidence-based approach towards action research in healthcare innovation. We have demonstrated how guidelines for healthcare innovation supported by Design Thinking can complement software requirements engineering.

**Figure 5 Extending Software Requirements Engineering**

### 7.1 Designing ‘Safer’ Software Solutions

This research is also timely given the emergence and promise of Connected Health as a model for technology-enabled healthcare delivery. In order to ensure that Connected Health maximises healthcare resources and provide increased, flexible opportunities...
for healthcare professionals to engage with pharmaceutical suppliers, patients and other stakeholders suggest that software requirements must accommodate for the complexities associated with patient-centric solutions. The mismatch between healthcare needs and software solutions presents significant risks in healthcare due to the “improper or unsafe use of technology” [16]. Our research to date has demonstrated how Design Thinking offers a step towards addressing this need and supports software development in Connected Health. We will continue to build on this research in identifying methods to further evaluate Connected Health solutions [17, 18]. We will align healthcare innovation with software requirements through Design Thinking developments. We expect that this approach will allow us to expand on this research in different healthcare-related areas.

7.2 Connected Health: Interdisciplinary Education

Our research also indicates that there is a significant gap between the software engineering community and the healthcare community in identifying and developing healthcare solutions. For example, we have learned from previous research [19] that there is a mismatch across the software and healthcare communities in their ability to develop effective and safe solutions. Employing approaches such as Design Thinking provides a significant step towards narrowing this gap and adopting a common approach to capture both healthcare and software requirements. We identified how healthcare professionals are now beginning to develop in-house solutions to support clinical decision-making but lack the expertise to ensure healthcare innovation meets healthcare and medical device standards [20]. We also identified the difficulties experienced by software engineers to clearly define healthcare needs, thus presenting both challenges and threats to people’s health and wellbeing if software solutions are inadequate. We have described the need to introduce an improved process and we argue that Design Thinking complements traditional requirements gathering techniques which invites different stakeholders to influence technological innovation design, planning and implementation.

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