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Connected Health Avenues for Child and Adolescent Mental Health Service: A Case Study on the Digitization of Attention Deficit Hyperactivity Disorder Diagnosis and Treatment

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for the degree of

Doctor of Philosophy

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Statement of Originality

"This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism and intellectual property."

Digital signature of the candidate: Richard Harris

Abstract

Child and Adolescent Mental Health Services (CAMHS) in Ireland are struggling to meet the demands of their service. Public CAMHS services in Ireland deal with individuals under the age of 18 struggling with mental health conditions, both acute and chronic, and serve the needs of those who require diagnosis and treatment for attention deficit hyperactivity disorder (ADHD). Over the last number of years, reports have emerged highlighting deficiencies within the service and subsequently have made recommendations on how to improve the services operations. These include the recommendation to implement health information systems (HIS) within the service.

This thesis explores avenues for connected health systems integration into the service through the lens of ADHD diagnosis and treatment, in line with these recommendations. Connected health systems have been proven to support clinical decision making, reduce inequalities in the provision of healthcare, and provide greater clinical oversight and governance. These systems present an opportunity to streamline the provision of ADHD care within the CAMHS and ultimately assist in the management of demands for the service.

This thesis has primarily leveraged the design science research methodology (DSRM) to produce tangible artifacts that can be used to both identify the requirements for a connected health application to support ADHD diagnosis and treatment in CAMHS, and to produce a proof-of-concept mobile application design to service CAMHS clinicians and service users.

Findings of this thesis include the presentation of an integrated patient journey map artifact that presents several representative personas that progress through the Dundee ADHD Clinical Care Pathway, identified in reports as the preferred care pathway for ADHD diagnosis and treatment. The goal of which is to visually represent the pathway to a multidisciplinary team of connected health researchers, to facilitate a shared understanding of the clinical setting and engage team members in conversation around key requirements of a potential connected health intervention.

This thesis also identifies several key risks and benefits associated with the use of connected health systems within a CAMHS context. Benefits identified include increased access to relevant clinical information, reduced risk of misplaced records, and increased compliance with format requirements. Risks identified include a lack of personal connection to patients when leveraging telemedicine, the risk of cyber security breaches resulting in the inappropriate access of information, and the inability to access patients to make a physical intervention when using remote monitoring.

This thesis also produces a proof-of-concept mobile application, connected child and adolescent mental health services (C-CAMHS), leveraging a dual platform low code development approach that attempts to both design an appropriate artifact which can be leveraged in clinical testing, while also demonstrating the viability of a dual platform low code development approach in the creation of healthcare research applications.

The totality of this thesis produces a roadmap for the implementation of a connected health application in the contacts of a CAHMS, leveraging novel development techniques grounded in proven information systems research methodologies. Future research is targeted towards the clinical testing of the C-CAMHS artifact to identify its applicability in a clinical setting and identifying areas for further improvement and implementations.

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Firstly, I would like to thank my lead supervisor, Professor Fredric (Fred) Adam. I am immensely thankful to you for the opportunity to complete my PhD, along with your guidance, support and kindness shown to me during this incredible journey. This is a debt that will never be repaid.

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Finally, I would like to express my deepest love and thanks to my family for their support during this incredible journey. To my mother Trish, father Roger, sisters Amy and Eimear, thank you for your love and support.

Dedication

In loving memory of my beloved grandparents, Patrick and Maighréad Kearns, whose wisdom, kindness, and unwavering belief in me have been a constant source of strength. The values you instilled - integrity, perseverance, and compassion - continue to guide every step I take. Your love shaped my character, and your memory remains deeply woven into all that I do.

Chapter 1

1.0: Introduction

The Information Systems (IS) research domain may be viewed as an applied discipline, the scope of which can be defined broadly as "*the development, use and application of information systems by individuals, organizations and society as a whole*" (Baskerville & Myers, 2002, p. 11). While the application of IS appears across a large number of organizational sectors and domains, such as manufacturing, legal services, and education, a sub-domain of information systems research that has emerged is that of health information systems. *"A health information system (HIS) is the socio-technical subsystem of a health-related setting which comprises all data, information, and knowledge processing as well as the associated human or technical actors in their respective data, information, and knowledge processing roles"* (Winter et al., 2023, p. 18). This definition provides appropriate context for the role of HIS within modern healthcare organizations, describing their function of assimilating, processing, retaining, and disseminating health related data to relevant stakeholders.

Healthcare organizations, public or private, are a fundamental component of society and are generally regarded as a critical service in times of need. This was seen most recently during the Covid-19 pandemic, when those working in the healthcare sector were considered critical workers, and thus where able to continue work during "stay at home" public health guidelines imposed during the height of the pandemic (Health Service Executive, 2020a). It is therefore of utmost importance to ensure these organisations continue to provide service in the most efficient and effective manner. There are a number of ways in which HIS can assist in this endeavour, one approach is that of connected health.

Connected health is defined as *“a conceptual model for health management where devices, services or interventions are designed around the patient’s needs, and health related data is shared, in such a way that the patient can receive care in the most proactive and efficient manner possible.” (Caulfield & Donnelly, 2013, p. 407).* This aligns with the definition of HIS in the context of the technologies and individuals involved but also presents a wider definition which also encompasses the policies and service designs in place to facilitate the effective transfer of information. A successful connected health system, therefore, relies on robust HIS to underpin its implementation and the lack of such systems substantially hinder any potential connected health aspirations of a healthcare organization. Section 2.1 establishes the relationships between connected health and its underlying HIS technologies based on a review of existing literature on the topic.

At a national level, Ireland was highlighted by the Organization for Economic Co-operation and Development (OECD) in a 2017 report as the lowest ranked in its technical and operational readiness to provide national health information from Electronic Health Records (EHRs), a form of HIS (Oderkirk, 2017). Since this report, Ireland has invested in its eHealth strategy, with investment rising from 55 million euro in 2017 to 120 million in 2021, according to the Economic and Social Research Institute (ESRI) (Walsh et al., 2021).

This investment, however, may not be sufficient to tackle the needs of the Irish Health Service, which is in need of a larger scale investment to tackle its Information and Communication Technology (ICT) requirements, particularly in the context of community health. Community health in Ireland refers to healthcare services outside of traditional acute settings, such as hospital wards, and include services such as Social Care, Mental Health, and Health & Wellbeing Services. One area of particular need is that of Child and Adolescent Mental Health Services (CAMHS), which falls under the community health setting in Ireland. The acute nature of the need for digital transformation in the healthcare sector and, specifically in CAMHS in Ireland is explored in detail in the next sections.

CAMHS within the Irish Health Service is a service targeting the provision of *“assessment and treatment of mental health difficulties for young people and their families.”* (Health Service Executive, 2024a). The services provides care to those up to the age of eighteen who are suffering from conditions including depression, anxiety, eating disorders, psychosis, and Attention Deficit Hyperactivity Disorder (ADHD) (Health Service Executive, 2024a). As noted above, CAMHS in Ireland has operated within “Community Health Organisations” or CHO’s where services are *“provided outside of the acute hospital system and includes Primary Care, Social Care, Mental Health and Health & Wellbeing Services.”* (Health Service Executive, 2014). While the support of child and adolescent mental health is of the upmost importance, CAMHS has a history of struggling to meet recommended staffing levels (Health Service Executive, 2013a) which presents a risk of decreased service efficiency and increased waiting lists due to the lack of appropriate clinical resources to meet service demand.

1.1 Maskey Report

January 2022 proved to be a critical time for Irish CAMHS, with the release of the “Report on The Look-Back Review into Child & Adolescent Mental Health Services County MHS Area A” (Maskey, 2022), hereby referred to as the “Maskey Report”. This report was commissioned as a result of concerns raised as to the practice of a Non-Consultant Hospital Doctor (referred to as NCHD1 in the report), operating in CHO Area 4 (Cork/Kerry), which were viewed as potentially dangerous under the Health Service Executive (HSE) Incident Management Framework.

The report is a detailed reflective account of an incident that occurred within the CAMHS services where “*events exposed many children unnecessarily to the risk of significant harm*” (Maskey, 2022, p. 12). The incident resulted in coverage by *“local and national* *press and there will have been an inevitable loss of trust in the Child and Adolescent Mental Health Service" (Maskey, 2022, p. 54)*.

The report highlights a number of concerning outcomes from 1,332 cases reviewed by the report team. While no cases of "*extreme or catastrophic harm had occurred*" during the time period of the review (July 2016 – April 2021), there were a number of outcomes of serious concern (Maskey, 2022, p. 49). Table 1.1 below presents the reported negative outcomes from patients under the care of NCHD1. These negative outcomes are generally a result of side effects from medications prescribed that may not have been appropriately prescribed or monitored. Cases of actual harm refer to *"clear evidence of significant harm caused"* (Maskey, 2022, p. 49), while risk of significant harm refers to *"diagnosis and/or treatment exposed them to the risk of significant harm"* (Maskey, 2022, p. 49)

Table 1.1: List of negative outcomes and the numbers of cases involved

Case Number and Classification	Negative Outcomes (Including Side Effects) in One or More Cases Identified
46 cases of actual harm:	Galactorrhoea (the production of breast milk) Considerable Weight Gain Sedation During the Day Elevated Blood Pressure
227 cases of the risk of significant harm:	Sedation Emotional and Cognitive Blunting Growth Disturbance and Serious Weight Changes Metabolic And Endocrine Disturbance Psychological Distress

Under the care of other doctors within the service, 13 other children were found to have been unnecessarily exposed to a risk of harm (Maskey, 2022).

1.1.1 Causal Factors

While there are a large number of contributing and causal factors noted in the report, a number of which are not within the scope of this thesis, there are a key number of factors where the lack thereof HIS could have played a key role in the cause of the aforementioned findings. The causal factors, conditions or events that directly lead to an incident, that are noted in the report relevant to this thesis are presented below (Maskey, 2022, p. 49).

1) The diagnoses of attention deficit hyperactivity disorder (ADHD), particularly for secondary-school children, were frequently made without adequate evaluation and/or without the required level of information in relation to their presentation in school from their teachers. Feedback from teachers was not requested as part of the management of treatment response for ADHD. There was evidence that this was the practice of the doctors who were prescribing for ADHD in general rather than being confined to NCHD1 (Maskey, 2022).

2) There was evidence of inconsistent and inadequate monitoring of adverse effects of medications, this included: Children started on stimulants did not routinely have a baseline pulse, blood pressure, height or weight measured and charted, to establish pre-treatment values. Children who started antipsychotics did not routinely have a baseline blood test to establish pretreatment values. There was no expectation of checking pulse and blood pressure seven days after starting stimulant or increasing the dose. Repeated height, weight, pulse and blood pressure measurements were erratic and not plotted on developmental charts. The patient’s General Practitioner (GP) was asked to do the blood tests in some but not all instances when children were started on antipsychotics. There were no results of this on file in the majority of cases. The tests were not routinely repeated at regular intervals (Maskey, 2022).

The aforementioned causal factors were noted as relevant as they relate to the lack of key information gathering steps during the course of treatment of many children within the service, resulting in gaps in the patients' clinical files. Remaining causal factors noted in the report were deemed to be out of scope as they are noted to relate to HSE employment contract structure, which is deemed to be a Human Resource (HR) or Occupational Health concern and thus out of scope for this thesis, given its research objectives.

1.1.2 Contributing Factors

A substantial number of contributing factors, conditions that influence the chance of an incident, were identified (Maskey, 2022, pp. 50–51) during the course of the report. While a number of these factors were categorised as out of scope, identified as being relevant to HR or occupational health, the relevant factors relating to IS were identified.

Ten percent (10%) of the referrals which were not initially accepted were not dealt with promptly and were left awaiting a decision on acceptance, and where subsequently labelled as *"lost to follow-up"*, indicating a breakdown in the treatment pathway (Maskey, 2022, p. 30). Despite several efforts documented over the past five years by the line managers, one particular team (referred to as Team A in the report) did not keep a shared diary. Reception staff did not know who was coming in for appointments, those in coordinator roles could not quickly identify who was working on a case, and cases were lost from the clinical pathway. Line managers were not able to enforce the policy on case-record management. The administrative office/record store was open to all clinicians who could and did remove files without signing them out. Neither staff nor managers knew how to authorize the file room door being locked as a possible solution; clinicians saw record management as an administrative problem and administrators did not think clinicians would agree to such changes and there was no sense that safe practice adherence to the HSE policy would occur. Records management processes were not robust within the service. Clinical information was not always recorded in the appropriate patient record, and there is evidence of 2 missing referrals and 10 full case records missing. Missing records have been reported in line with the HSE Data Protection Policy 2019. One hundred and thirty-six files had gaps in the clinical record and for ninety two of these, the absent information contributed to the need for recall as it was not possible to be sure the child had not been exposed to harm (Maskey, 2022, p. 38).

Risk management for Team A, from the front line to the Area Management level, was generally considered in terms of "making the problem go away", fixing something broken or recruiting to a vacant post, instead the emphasis should have been placed on identifying the breadth of potential consequences of the identified risk, taking steps to avert them occurring and on monitoring to ensure the system worked safely. However, the service managers have limited quality measures to enable them to gauge team performance, quality and risk. The report notes there are nationally approved Key Performance Indicators (KPI's), but these are of limited value as they are activity level focused and not service level focused (Maskey, 2022).

1.1.3 Recommendations

The report identifies a number of key recommendations to tackle the aforementioned challenges. While many are out of scope of this thesis, the report does highlight the following, "*The CAMHS Governance group should explore the options available in ICT to improve the governance, effectiveness, efficiency and accessibility of CAMHS in the CHO. At the very least this should include a shared team online diary and a clinic database built around episodes of care.*" (Maskey, 2022, p. 61).

Further, the report notes that the Dundee ADHD Clinical Care Pathway (Coghill & Seth, 2015) is the preferred framework for the diagnosis and treatment of ADHD within an adolescent population. This pathway focuses on facilitating *"the dynamic integration of new knowledge in order to provide effective, evidence- based therapy; speed up the* *transfer of research findings into clinical practice; use staff skills and time effectively; and provide a consistent approach to the management of waiting lists and treatment."* (Coghill & Seth, 2015, p. 2) In the context of ICT integration, it is therefore critical to ensure that an ICT system is ready for the application, or site/service specific variation, of the Dundee pathway.

A key number of technologies that would be relevant to the CAMHS are highlighted in the report, including EHR. The report discourages the creation of a bespoke EHR system and encourages the acquisition of a white label product which can be adapted to the needs of the services. As the results of the report are likely to impact how the CAMHS operates over the coming months and years, the creation of a bespoke EHR system runs the risk of immediate obsolescence upon delivery.

The use of computerised screening questionnaires, such as the "*Connors Questionnaire for ADHD*" are noted as being another area of opportunity for ICT inclusion within the CAMHS services, as ADHD accounts for a large percentage of those attending the CAMHS services, while also constituting the single largest referral cohort to CAMHS (Finnerty, 2023). The use of these evaluation questionnaires, electronically delivered and scored, has a number of possible benefits including the elimination of human error in calculation, the reduction in clinician time needed to score these questionnaires, the reduction in the risk of lost records, and the possibility of a quicker return of the results to the clinician, thus reducing the diagnosis time in straightforward cases.

Telemedicine, a term used to describe a situation where healthcare is provided where the individual patient is not physically present with the clinician (Harte et al., 2017), is another area identified in the report as an ICT implementation opportunity. The COVID-19 pandemic, requiring services to adopt these tools to continue operation (Gomes & Brito, 2022), has proven their viability in some use cases for the remote monitoring of patients. This thesis has identified some key risks associated with this approach;

however, existing literature appears to agree that its selective use may be of benefit to those in remote areas or with mobility issues.

1.2 Finnerty Report

In light of the Maskey report findings, a total independent review of CAMHS (Finnerty, 2023) was conducted, with a number of findings relevant to the implementation, or lack thereof, of IS within the wider CAMHS service nationally. The report, titled *"Independent Review of the provision of Child and Adolescent Mental Health Services (CAMHS) in the State by the Inspector of Mental Health Services"* (Finnerty, 2023) highlights that *"The lack of IT systems in HSE CAMHS is a major concern as it leads to inefficiency, the risk of not identifying cases that may become lost to follow-up, and the inability to comprehensively audit practice" (Finnerty, 2023, p. 45)*. This aligns with the outcomes noted above from the Maskey report, illustrating these issues are not confined to a single CAMHS region, and are national concerns. The Finnerty report highlights that digital infrastructure was almost completely absent from many of the services, with the use of excel spreadsheets being the exception. Computerized systems across the services were noted as being out of date, with one team noted as running Microsoft's "Windows 7" operating system, which has been marked as end of life by Microsoft since 2020 (Microsoft, nd). This use of outdated operating systems presents clear security concerns, with vulnerability in these older operating systems often left unpatched due to their lack of ongoing support from Microsoft.

While most CAMHS teams are leveraging Microsoft Excel to keep data, there is no database which stores details of open cases, resulting in teams needing to conduct manual searches for case files, which in extreme cases can take days. One team was noted as having *"no idea which cases were open or closed in their filing room"* (Finnerty, 2023, p. 45). When files were located, it was noted that due to poor handwriting and inappropriate storage of files, many cases were not stored in chronological order, and some were incomplete.

The majority of teams did not have a robust patient management system to monitor appointments, rotas and schedules. This lack of a system, while undoubtably creating an inefficient work environment for clinicals, also resulted in a large number of patients not attending scheduled appointments due to a lack of follow-up functionality such as SMS reminders. One team was noted for using a clinical information system (MAISY), to manage appointments and generate reports, however this system lacked information in other areas. Other services were also leveraging information management systems, but each service had their own software, resulting in disparate information storage processes and procedures. Only one services was noted as having access to an EHR system, however this was provided by an external party (Lucena, St John of God Community Services) and was not internally implemented within that CAMHS services.

HealthLink (a system used for the real-time transfer of information such as laboratory and radiology reports, discharge information and waiting list updates) was not common in CAMHS services, with only two of seventy-three teams leveraging the service. It was noted that the setup of HealthLink is a straightforward process, yet the system was not set up for all CAMHS teams. Ireland was noted as being *"the country least ready for electronic record introduction"* (Finnerty, 2023, p. 46) and this is clearly reinforced by the disjointed implementation of ICT within Irish CAMHS.

The report makes some key remarks on the use of telemedicine within CAMHS, with the technique noted as being *"both safe and effective, in some cases with better outcomes than conventional face-to-face care"* (Finnerty, 2023, p. 49). The report does however note that there is a lack of literature in this area and further study is needed before a clear outcome on the topic presents itself. This thesis examines the implications of telemedicine within CAMHS. While there are clear benefits, many issues are noted in the Finnerty report, such as "*less able to examine vital forms of non-verbal communication during telepsychiatry sessions"* (Finnerty, 2023, p. 49) and difficulty maintaining engagement and forming connections and trust while using telemedicine within CMAHS.

1.3 A Digital Transformation Required

It is clear from both the Maskey and Finnerty reports that a complete digital transformation of the CAMHS service is required to ensure the effective and efficient delivery of the services to a growing population of young people in Ireland. It is critical that Irish CAMHS improve its services to ensure Ireland remains in line with United Nations (UN) conventions of human rights of the child, particularly article 24 which notes "*States Parties recognize the right of the child to the enjoyment of the highest attainable standard of health and to facilities for the treatment of illness and rehabilitation of health. States Parties shall strive to ensure that no child is deprived of his or her right of access to such health care services" (United Nations, 1989)*. The World Health Organization (WHO) has illustrated the importance of a strong CAMHS services by issuing the warning that *"The lack of attention to the mental health of children and adolescents may lead to mental disorders with lifelong consequences, undermines compliance with health regimens, and reduces the capacity of societies to be safe and productive."* (World Health Organization, 2003).

Based on a review of existing reports published on Irish CAMHS, as noted above, it appears that the Irish health service may not be leveraging all possible assets readily available to assist in the delivery of adolescent mental health services. From a review of the reports mentioned above, many young people engaging in the service have not received *"the highest attainable standards of health"* (see Table 1). In order to achieve the highest attainable standard of care, many recommendations are made, including the implementation of ICT services, thus presenting the need for digital transformation within the service.

There are a number of emerging technologies within the IS research domain that have shown potential to assist with the digital transformation of a healthcare organization. One of which is that of low-code/no-code platforms. These platforms facilitate the creation of process/service specific applications that can streamline the delivery of said process or service. These platforms offer the ability for developers to engage with the software development cycle by obfuscating the majority, or all, coding and instead present the user with a user-friendly interface where logic can be added or removed via interfaces such as drag and drop. This gives rise to the "*citizen developer*", described as an individual who has extensive process knowledge but lacks development expertise to develop applications (Viljoen et al., 2024).

1.4 Research objectives

This thesis aims to contribute to the delivery of the digital transformation required within Irish Child and Adolescent Mental Health Services, through the implementation of connected health solutions where appropriate within the CAMHS domain, based on findings from the Maskey and Finerty reports. The objective of this research is to contribute to the design and development of connected health solutions, leveraging Irish CAMHS as a lens for which design science principles can be applied to the digital transformation within the services. This issue of under resourcing public health services is a well-documented one, thus a focus on CAMHS in an Irish context lends itself to being described as an instrumental case (Stake, 1995). In this context, the case is how connected health can assist with under resourcing and high demand for public mental health services, and the bounds are set as the Irish health service.

The research objective for this thesis is to provide clarity on the requirements for this digital transformation by contributing to the body of knowledge of digital transformation and connected health within the context of the Irish Child and Adolescent Mental Health Services, and beyond this, within the context of global adolescent mental health services and connected health solutions in general. This is achieved through the implementation of novel techniques and technologies such as Integrated Patient Journy Mapping and No-Code development platforms in context, as explained in detail in chapters five and six.

1.5 Irish CAMHS Context

Irish CAMHS has been identified as an area of particular interest for the implementing of connected health. As noted in both the Maskey and Finerty reports, there is a lack of direction within the Irish CAMHS when it comes to operational connected health readiness. This aligns with the ESRI report noted that *“basic information, such as having a systematic minimum dataset for public healthcare services provided in the community, is lacking” (Walsh et al., 2021).* This seems to indicate that Ireland is “*behind the curve*” when compared to the rest of the European Union (EU) (Oderkirk, 2017), it presents an opportunity for study in the context of an “*Extreme or Deviant case*”, as per Pattons qualitative sampling strategies (Patton, 2002). These are cases which are unusual in their result (success or failure) or in the case of Irish CAMHS, being divergent in its readiness of digital infrastructure when compared to EU contemporaries.

Following the results of the various reports it is apparent that connected health solutions can play a role in reshaping the diagnosis and treatment of ADHD in CAMHS. To that end, this thesis has focused its efforts on creating a solution for CAMHS to digitize various elements of the diagnosis and treatment of ADHD withing CAMHS. While specific in its scope, the researcher believes that clearly illustrating the learnings from this research can be used in future research in the area of connected health within CAMHS. It may serve as:

A) a jumping off point for future work on connected health within CAMHS, focusing on more acute mental health issues within the service, such as depression, anxiety, eating disorders, and psychosis and

B) a justification for clinical trials within this service, focusing on connected health’s ability to support an under-resourced CAMHS in the management of waiting lists through increased clinical efficiencies while facilitating greater oversight and governance of clinical practice.

1.6 Research questions

This thesis proposes three research questions, derived from the findings of the Maskey and Finerty reports, along with a literature review on relevant topics(presented in chapter 2) for the implementation of ICT within Irish CAMHS.

1) How can the complexities of the Dundee ADHD Treatment Pathway be effectively communicated to a multi-disciplinary team?
2) What are the risks and benefits associated with digital transformation within the Irish CAMHS service?
3) How can Low-code/No-code development platforms assist in a connected health led digital transformation of Irish CAMHS?

1.7 Limitations

CAMHS in Ireland is suffering from an acute case of understaffing and staff turnover. This is an issue that has been documented both in reports (Health Service Executive, 2013a) and experience from the researcher, with a number of senior clinicians leaving the CAMHS environment over the course of this research project. Subsequently, the pool of experienced clinicians is limited when compared to other healthcare contexts within the Irish Health Service. This presents a difficulty when attempting to establish ongoing relationships for the purpose of clinical trials of potential connected health solutions. Although, this thesis is primarily theoretical in nature, practical insights are also illustrated from opportunistic case studies as they arise (Patton, 2002).

1.8 Thesis Outline

The overall aim of this thesis is to provide a formative piece of research in the area of connected health implementation within the CAMHS domain, specifically focusing on ADHD treatment withing the Irish public CAMHS. This is achieved by way of a review of existing literature surrounding connected health solutions and digital transformation tools and, subsequently, identify areas within CAMHS where novel technologies can be implemented.

The objectives for each chapter of this thesis are as follows. Chapter 2 presents a literature review, focusing on connected health systems and their application within a mental health setting. This includes terms such as e-health, mobile health, and the benefits of connected health. Chapter 2 also covers the potential for connected health to support teams under pressure, particularly within the context of CAMHS, and the requirements of digital transformation in CAMHS, along with technologies that can facilitate this transformation, such as low code and no code platforms. Additionally, it discusses tools fundamental to the success of digital transformation within connected health and the multidisciplinary nature of digital transformation within a healthcare setting. Patient journey mapping is also covered, along with an overview of ADHD and its implications for adolescents and adults, including an overview of the diagnosis and treatment pathways available for young people and adults with ADHD.

Chapter 3 covers the methodology employed for chapter four and six, notably design science within the context of connected health. It discusses the conceptualization of design science, operationalizing design science, and the preferred design science research methodology employed within this thesis, the design science research methodology (Peffers et al., 2007). It covers relevant design science entry points within the methodology and discusses the interplay between design theory and artefactual output within design science, including how design science research can be effectively presented within literature.

Following on, Chapter 4 focuses on connected health requirements gathering for ADHD through clinical journey mapping, specifically addressing research question one. This design science research study has been published in the *Journal of Medical Internet Research: Formative Research*. The chapter contains an introduction to the relevant literature, followed by the application of the design science research methodology to create a patient journey map that effectively illustrates the requirements for a connected health application within CAMHS, specifically applying the Dundee ADHD clinical care pathway as the standard for ADHD diagnosis and treatment. It covers several iterations of this diagram. Each iteration received feedback from relevant clinical professionals to advise on the evolution of this artifact. Each evolution is noted within this chapter, with subsequent learnings from each evaluation and demonstration highlighted.

Following on from creating a journey map that effectively represents the Dundee pathway along with modifications proposed to the integrated patient journey mapping tool as described by McCarthy et al. (2016), a practical case study is then presented. This case study leveraged a modified integrated patient journey mapping within an SME organization looking to implement a software-as-a-service electronic health record management system. The case study findings along with detailed quotes from participants are highlighted in this chapter.

Chapter 5 focuses on a risk-benefit analysis of a connected health-led digital transformation within the context of CAMHS, specifically targeting research question two. This chapter is an applied research chapter covering the background pertinent to digital transformation within CAMHS. It includes a description of several interviews with CAMHS clinicians to assess the risks and benefits of a connected health-led digital transformation within the service. Both a risk matrix and benefit matrix have been created to illustrate the risks and benefits identified. This work has been published as a conference proceeding in the *Journal of Decision Systems, Supplementary Issue*.

Chapter 6 covers the design and proposal for a connected health mobile application to support adolescent ADHD care, focused on research question three. The chapter utilizes a two platform no code software development approach. This chapter again uses the design science research methodology highlighted by Peffers et al. (2007) to guide the research through various iterations of this artifact. The artifact takes the form of a mobile application, referred to as Connected Child and Adolescent Mental Health Services (C-CAMHS).

Finally, Chapter 7 constitutes a discussion of the overall findings and contributions to knowledge that this thesis ultimately provides, including presenting an avenue for connected health-led digital transformation within CAMHS, and discusses the contributions of each primary research chapter in the context of the research question in which they are targeted.

Figure 1.1 below visualizes the structure of this thesis. Published chapters and the relevant research question (RQ) are noted and are colour coded to blue for chapters synthesizing previous research (secondary research), or green for original research (primary research).

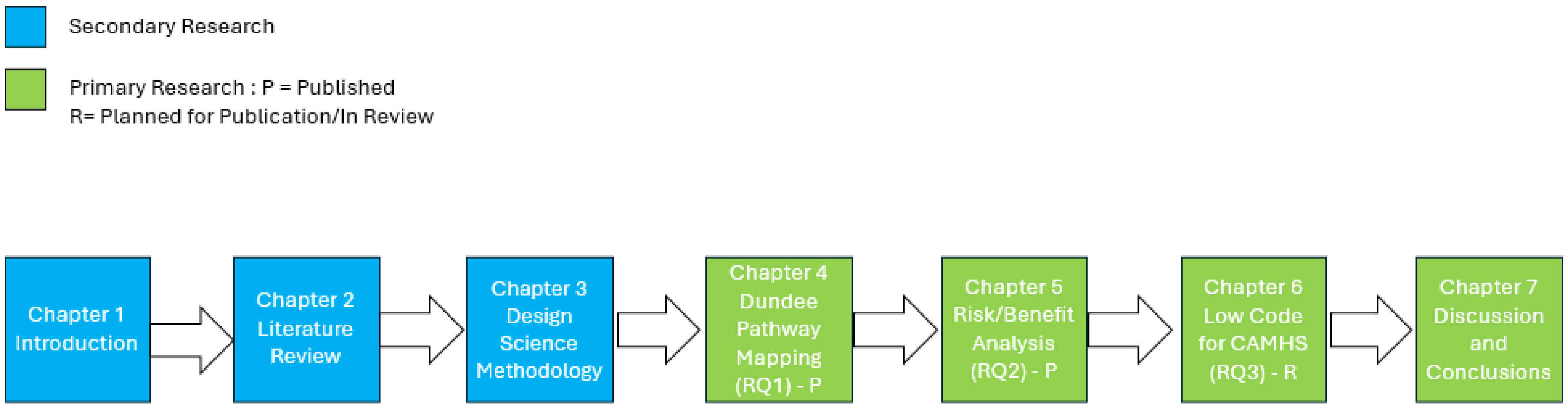


Figure 1.1 Thesis Structure

Chapter 2: Literature Review

Chapter 2 presents a comprehensive literature review conducted based on literature pertinent to connected health, ADHD, and patient journey mapping. The chapter begins with an examination on connected health literature, exploring its relationship with e-health and m-health, while also discussing the benefits of connected health and its role in supporting teams under pressure to meet service demands.

Next, I review digital transformation literature within Child and Adolescent Mental Health Services, focusing on technologies such as low-code and no-code platforms that facilitate this transformation, while also reviewing the context of no-code within the low-code environment. I continue by highlighting the importance of a central resource within a multidisciplinary team, a crucial aspect of connected health application design. Additionally, I review journey mapping literature and how journey mapping has been used in a clinical context to derive actionable insights into a patients journey through a service.

Finally, I examine ADHD as a condition, detailing its diagnosis and treatment. Special reference is made to the Dundee ADHD treatment pathway, recognized as a gold standard in the Maskey report.

In this section, information is drawn from academic and professional sources published within the last 25 years, the exception to this timeline is seminal literature in the areas of methodology and medicine, where its exclusion, solely due to its publication date falling outside this timeframe, would be a determent to the overall narrative. This includes peer reviewed journal articles and conference papers, as well as grey literature relevant to connected health, system design and development, digital transformation, and diagnosis and treatment of ADHD. Publications must be in the English language.

Exclusion Criteria are any literature outside of the area of connected health, system design and development, digital transformation, and diagnosis and treatment of ADHD, papers not in the English language, and non-seminal works over the age of 25 years.

These criteria are set out as the focus of this work is an exploration of connected health systems in ADHD diagnosis and treatment and, as such, requires a review of relevant literature to establish the current state of literature in the above areas. This ensures that appropriate research questions are identified and that this work has not already been completed and subsequently ensures the work expands on current literature.

2.1 Connected Health

Connected Health, as defined by Caulfield and Donnelly *"encompasses terms such as wireless, digital, electronic, mobile, and tele-health and refers to a conceptual model for health management where devices, services or interventions are designed around the patient's needs, and health related data is shared, in such a way that the patient can receive care in the most proactive and efficient manner possible." (Caulfield & Donnelly, 2013, p. 704)*. The aim of connected health is to connect all stakeholders within the patient journey to ensure the most efficient and effective care is provided to the patient at the right time (Caulfield & Donnelly, 2013).

The term "connected health" has been used as an umbrella term which incorporates areas such as "Telehealth" and "Telemedicine". While there is no single universal definition for these terms, both are used to describe a situation where healthcare is provided where the individual patient is not physically present with the clinician, and instead information technology, such as voice and video chat, are used to provide healthcare services. The term mHealth, the use of mobile devices to facilitate communication and healthcare service provision, is also found under the connected health umbrella (Harte et al., 2017; Kvedar et al., 2014; World Health Organization, 2011).

2.1.1 Benefits of Connected Health

Connected Health systems have been shown to provide health service providers with the ability to closely monitor patients' status and provide proactive care to patients before more significant issues arise. This is of most benefit to chronically ill patients, who require regular care and attention from healthcare providers. Studies suggest that a connected health approach utilizing telehealth can reduce the readmission rate of chronically ill heart patients by 21% (Clark et al., 2007). According to reports, this decreased time in hospital for patients and the increased use of electronic records suggests that paperwork time can be cut by as much as 60%, ultimately leading to an increase in patient interaction time by 29% (Nambiar et al., 2017).

While the ramifications of the Covid-19 pandemic are still being discovered and quantified, it has presented a unique opportunity to highlight the benefits of connected health applications, with stakeholders and decision makers within the public healthcare space identifying their healthcare and cost-saving benefits (Stefano, 2021). During periods of restricted movement, connected health has facilitated the continued provision of healthcare for both the screening of acute illness and continued care for the chronically ill, through an increased adoption of telemedicine (Omboni et al., 2022). Some of the key areas of healthcare services provided using telemedicine include Consultation, Follow-up, and Caregiver support (Bitar & Alismail, 2021).

Connected Health systems have particularly been shown to produce positive outcomes for mental health services. Computerised cognitive behavioural therapy (CBT) used in the treatment of depression and anxiety has been shown to produce positive results without drug treatment, while also yielding greater patient satisfaction (Proudfoot et al., 2004).

2.1.2 Risks of Connected Health

While connected health systems have proven to provide positive outcomes, as seen above in section 2.1.1, it is critical to note that they carry both general and CAMHS specific risks. Chapter 5 highlights CAMHS specific risks in detail, while general risks include the increased attack surface for nefarious individuals to exploit during a cyber-attack, damaging a health services ability to provide care when these services have critical processes that rely on functioning HIS. A recent example is that of the Cyber-attack on the Irish public health services which resulted in significant down time and delays for those under the service's care (Health Service Executive, 2023b). It is therefore of the upmost importance that when connected health systems are introduced, appropriate training is implemented to ensure their safe and effective use.

2.1.3 eHealth

A similarly broad term for the application of technology within the healthcare sector is that of electronic health (eHealth). eHealth has been defined as *"the application of information and communications technologies across the whole range of functions that affect the health sector"* (European Commission, 2004, p. 4). This definition of eHealth has evolved over time, with the European Commission stating in 2012 that eHealth *"covers the interaction between patients and health-service providers, institution-to-institution transmission of data, or peer-to-peer communication between patients and/or health professionals". (European Commission, 2012, p. 4)*. Examples cited in this document include *"information networks, electronic health records, telemedicine services, wearable and portable systems which communicate, health portals, and other ICT-based tools designed to assist disease prevention, diagnosis, treatment and follow up"* (European Commission, 2012).

The World Health Organization defines eHealth as *"the cost-effective and secure use of information and communications technologies in support of health and health-related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research" (World Health Organization, 2005, p. 109).* This definition, while two decades old at the time of writing, still remains the WHO's official definition, with WHO web pages still referencing this definition (World Health Organization, 2024).

When compared to connected health, the term eHealth appears to be a more specific reference to the technologies, similar to Health Information Systems (HIS), that are used to deliver healthcare in the twenty first century, while connected health refers to a digitally supported model of healthcare, which also includes the services and interventions associated with a digitally supported health service. In essence, eHeath appears to be a key part of connected health service provision, as it underpins the technological aspect of connected health systems.

2.1.4 Electronic Health Record Systems

Arguably the most important part of an eHeath, and by extension, a connected health system is a robust Electronic Health Record (EHR) System. EHRs are systems that contain the results and details of both clinical and administrative contacts between the service provider and the service user, including information such as medication, progress notes, and lab results (Ambinder, 2005; Menachemi & Collum, 2011). EHRs provide the clinical decision-making team with a central source of truth to access, review and share clinically relevant information in a timely manner, a critical component of connected health(Caulfield & Donnelly, 2013; Upadhyay & Hu, 2022). Benefits of EHRs include real-time access to patient data, reduced time spent on paper documentation, effective report generation, facilitating effective audit, effective exchange of clinical information between staff, and reduced costs (Thakkar & Davis, 2006; Upadhyay & Hu, 2022). Some risks identified, which need to be mitigated, Include technical issues preventing access to patient data, security, an overreliance on EHR systems to provide care, inaccurate data entry, overwhelming complexity of the system, and decreasing face-to-face time with patients (Thakkar & Davis, 2006; Upadhyay & Hu, 2022).

EHRs often act as the central source of information for connected health solutions. It is critical to note, however, that not all EHR's are initially suitable for implementation within a connected health environment. EHR's may not be appropriately set up to collect, store, or disseminate the information that a connected health solution requires to deliver tangible value to both service providers and users. Many EHR's have been set up for reasons other then facilitating connected health solutions, such as billing or accounting systems (Reza et al., 2020). This is particularly true in the United States, where "*The majority of EHRs … were designed to support billing" (Kim et al., 2019, p. 355)*. This naturally presents the possibility that the relevant data points needed to drive connected health solutions may not be collected, or if they are, are in a format that proves it difficult to access, analyse and utilise due to factors such as redundancy or non-standardisation. (Kim et al., 2019; Wrenn et al., 2010). Technological advancements, such as recent advancements in Large Language Models (LLM's), may provide an avenue for identifying redundancy and standardising textual data. This process of standardization and redundancy removal/management is critical to establish a single source of truth, which underpins other connected health technologies such as mHealth.

2.1.5 mHealth

Devices play a critical part in the connected health echo-system. m-Health is a term used to describe the suite of mobile devices, such as sensors, mobile phones, and related software applications; used to remotely monitor patient health and wellbeing. They enable the patient to *"actively engage in their chronic disease care and can potentially reduce demands on clinicians"* (Payton et al., 2011, p. 1743). While

Connected Health refers to the entire ecosystem, mHealth refers to technology that enables the transfer of information between patients and healthcare providers, acting as an intermediary between both (Payton et al., 2011). This mHealth, or device, intermediary act to ensure patients and relevant clinicians receive the most up to date and relevant information.

The benefits of mHealth solutions are well documented when the general population is confined to their homes or to a certain radius of said home, as seen by isolation instructions during the height of the Covid-19 pandemic (O'Byrne et al., 2025). It is important to highlight the benefits that mHealth provides to those in disadvantaged areas where gaining access to a healthcare professional can be difficult, for reasons such as mobility, access to transportation, or financial limitations. mHealth adoption and acceptance has come about due to the incredible speed that mobile technology has disseminated throughout the world's population. As of 2022, the International Telecommunication Union estimated that 5.3 billion individuals have access to the internet (International Telecommunication Union, 2023b). mHealth, like eHealth and HIS, play a role in effective delivery of a connected health service.

2.2 Connected Health Supporting Teams Under Pressure

As mentioned above in section 2.1.1, connected health systems can greatly increase the effectiveness of medical services with limited resources. One area particularly under pressure in the UK and Ireland is the Child and Adolescent Mental Health Services (CAMHS). Ensuring that children and adolescents have access to high quality and evidence based mental health services is of critical importance. Article 24 of the Convention on the Rights of the Child outlines that *"Parties recognize the right of the child to the enjoyment of the highest attainable standard of health and to facilities for the treatment of illness and rehabilitation of health." (United Nations, 1989)*. Supporting these services benefits not only the individual, but society as a whole. The World Health

Organization highlights that *"The lack of attention to the mental health of children and adolescents may lead to mental disorders with lifelong consequences, undermines compliance with health regimens, and reduces the capacity of societies to be safe and productive." (World Health Organization, 2003)*. As discussed in chapter 1, there are clear ramifications for children who do not receive appropriate mental health supports, of note for this thesis being the inappropriate diagnosis and treatment of ADHD. This can be due to a lack of treatment, which while discussed in detail in section 2.5.1, results in issues such as reduced executive functioning and lower overall academic achievement (Loe & Feldman, 2007; Willcutt et al., 2005). In the case of mismanaged care, both actual and risk of harm presents itself, as seen in table 1.1. It is therefore of the utmost importance that state run, and private health service providers ensure that these services have access to the most up to date technologies and research to provide the best service possible.

While it is clear that the mental health of adolescents is of critical importance, CAMHS services are struggling to meet demand. Reports indicate an increasing number of adolescents presenting to CAMHS services for treatment. Figures from the UK's NHS show an increase in the number of children (5-19 years old) with a diagnosed "mental disorder" grew from one in eight (12.8%) in 2017 (NHS Digital, 2018) to one in six (16.0%) in 2020 (NHS Digital, 2020) and again to 17.4% in 2021 (NHS Digital, 2018) . The Covid-19 pandemic may have played a part in this, however as the world began to return to normality in 2022, figures were still on the rise, with rates standing at 18.0% during 2022 (Newlove-Delgado T et al., 2022). While demands for these services are increasing, the number of staff available to tackle this demand is limited, with Irish CAMHS services falling 44% short of recommended staffing levels in recent years (Finnerty, 2023; Health Service Executive, 2013a).

Waiting lists, an indicator of a services ability to meet demand, have presented concerns internationally. Australia's National Youth Mental Health Foundation, "Headspace", reports that wait times are a concern for almost 90% of their centres (headspace., 2019).

The Australian private sector is also showing difficulty in managing demand, with one third of private practices closed to new referrals, and an average waiting time of 34-44 days depending on service needed (Mulraney et al., 2021) . While Covid-19 has certainly had an effect on mental health service demand, Australia has seen long waiting lists for some time now, with reports of five to nine months waiting time for CAMHS services in Western Australia in 2012 (Stokes, 2012). This extended waiting period presents the possibility of unaddressed Mental Health Disorders, a relevant example of which is Adverse Childhood Experiences (ACEs). ACE's are negative circumstances which occur in a child's life before the age of eighteen. ACE's in the context of ADHD are noted in section 2.5.1, which may be mitigated by early intervention of services (Asmussen et al., 2019). The details noted in this section above, combined with section 1.3 highlighting the possible consequences of non-intervention in adolescent mental health, highlight the importance of timely and appropriate interventions for adolescents.

Canada is also facing strong demand for youth mental health services, with Children's Mental Health Ontario reporting *"average wait times for counselling and therapy is 67 days and for intensive treatment the average is 92 days"(Children's Mental Health Ontario, 2020)*. This again seems to be an ongoing concern, with a pre Covid study showing only 31.4% of 116 polled Canadian CAMHS service providers able to meet the benchmark waiting list time set by the Canadian Psychiatric Association (Kowalewski et al., 2011). These benchmarks are set based on the urgency of the condition and range between seen within 24 hours to seen within 4 weeks (Canadian Psychological Association, 2006).

With a rising demand for services, Irish CAMHS have struggled to meet recruitment targets to keep on top of the rise, with the service falling short of recommended staffing levels (Health Service Executive, 2013a). Reports note that as of March/April 2023, CAMHS in Ireland are at 66% of recommended staffing levels (Finnerty, 2023). This is a critical issue as reports from The Expert Group on Mental Health Policy of Ireland states that "*at any point in time approximately 2% of children will require specialist mental* *health expertise"* (Expert Group on Mental Health Policy Ireland, 2006, p. 84). The same report also highlighted that those under the age of 18 make up 25% of the Irish population; this means that, taking an estimated child population of 1.25 million, approximately 25000 children in Ireland will require intervention from CAMHS.

To tackle the shortfalls of the CAMHS, the *Maskey* report (2022) highlights the clear need to modernise the CMAHS service by adopting ICT within the service; thus, a digital transformation of the service is needed to action this recommendation. The implementation of Telemedicine, adoption of EHR's, and utilisation of electronic questionnaires are all recommended in the report.

2.3 Digital Transformation of CAMHS

As part of an action plan to modernize and update CAMHS services to ensure continued provision of CAMHS services within Ireland. The Maskey report (Maskey, 2022, p. 9) notes that the CAMHS governance group should review ways in which ICT systems can be leveraged in CAMHS to improve service delivery and provide greater clinical oversight and governance. This highlights an opportunity to embed connected health within the CAMHS services as a critically needed digital transformation is in its early stages within the Irish CAMHS service.

Digital Transformation, as defined by Vial (2019, p. 188), is *"a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies"*. In the context of CAMHS, this means that the service will need to review its service provision and aim to leverage ICT systems to improve its overall efficiency, while ensuring appropriate clinical oversight and governance. When viewing digital transformation within the healthcare domain, several key technologies come into focus, including telemedicine, mHealth, eHealth, and EHR systems. (Kraus et al., 2021). These technologies also form the basis of connected health systems.

As mentioned above, and in section 2.1, there are a number of connected health solutions that drive digital transformation within a connected health context. However, the cost and time required to developed connected health applications often poses a challenge for organisations looking to implement such initiatives, thus organisations are looking for ways to streamline this process to reduce cost and time overheads. Low Code development platforms offer a potential solution.

2.3.1 Low-Code Development Platforms

Low-Code Development Platforms (LCDP), as the name suggests, are platforms that provide users with a suite of tools that allow for the creation of software applications, while keeping code writing to a minimum. These platforms are generally targeted at those who have little practical coding knowledge and experience, but have an in depth knowledge of a process or service. These platforms offer the possibility of enabling these experts to become what is known as 'citizen developers.' (Viljoen et al., 2024). This is achieved through the use of graphical user interfaces that utilize visual diagrams, drag and drop features, and declarative language to create a high level of abstraction from the source code (Alamin et al., 2021; Gomes & Brito, 2022; Khorram et al., 2020). Gartner Group highlights that LCDP's, at minimum, must include 'Low-code capabilities' (through model-driven or graphical programming approaches) to develop a complete application; with support for interfaces, business logic, workflow, and, data services, as well as simplified application development, testing and deployment (Vincent et al., 2022).

While the citizen developer is a key target for LCDP's, it is not the only group that can benefit from the platform, with experienced developers also benefiting from the speed and ease at which applications can be developed using these platforms, with Gartner highlighting that software engineering leaders must accept that progress continues to be made in the area of software development, and low-code solutions are able to accelerate application development through higher levels of abstraction away from traditional coding processes (Vincent et al., 2022).

The benefits of LCDP's for developers include quicker development time to meet market demands, a reduction in bug fixing measures and improved system quality, as well as lower deployment efforts (Alamin et al., 2021; Gomes & Brito, 2022).

2.3.2 Low Code Development Risks and limitations.

It is also important to note some of the disadvantages and fears that these platforms present. Vendor lock in, defined well as "*the situation where customers are dependent (i.e. locked-in) on a single cloud provider technology implementation and cannot easily move in the future to a different vendor without substantial costs, legal constraints, or technical incompatibilities*" (Opara-Martins et al., 2016, p. 2), is a key fear for organizations using low-code platforms. In practice, this means that an organization may be tied to another organization for the delivery of their ICT services when leveraging low-code platforms and may incur significant cost to remain with the vender, in the case of price increases, or to transfer to another vender, in the case of a breakdown in relationship. A high learning curve, pricing and lack of detailed customization of out of the box features are also key limitations (Gomes & Brito, 2022; Khorram et al., 2020).

LCDP's address a common cause of software development delays by reducing or eliminating the gap between domain requirements and developers' understanding. This gap is a key concern in the domain of connected health, where large multi-disciplinary teams were traditionally leveraged to bridge this knowledge gap. (Alamin et al., 2021; Harris et al., 2022).

2.3.3 No Code Platforms

No Code Development Platforms (NCDP) differ from LCDP’s in that no code solutions eliminates the need to create any code, where low code solutions require some level of hand-coding (Käss et al., 2022). NCDP’s provide drag- and-drop interfaces that provide visual representations of coding concepts, eliminating the need for traditional coding expertise (Carroll et al., 2024). No code development platforms are suitable for “straight forward” applications, such as digitization of paper-based materials. In contrast, low-code platforms provide an additional layer for custom development and thus may be suited for more complex applications (Carroll et al., 2024).

While low code and no code platforms may be referred to together, for example as “low code/no code platforms” (Rokis & Kirikova, 2022; Yan, 2021), some argue there is a distinction between the two. A disagreement exists within the literature as to whether NCDP’s are their own concept, or a subset of LCDP’s (Lethbridge, 2021; Prinz, 2021). This thesis will take the view that NCDP’s are a subset of LCDP’s and therefore NCDP’s fall under the LCDP category.

2.3.4 Low Code in Healthcare

Within a connected health context, the literature on the applicability of low code development platforms is limited, with research in the area mainly coming into the literature in recent years. Low code / No code development offers researchers the ability to create several application iterations, where each can be evaluated for effectiveness in a number of conditions. (Liu et al., 2022). A key benefit highlighted for the use of low code / no code development is the speed at which applications can be iterated, with connected health teams able to *“rapidly make changes to the app based on user feedback during the iterative design process.”* (Willms et al., 2023, p. 1). As connected health applications are created by the joint efforts of many individual experts, the ability to quickly iterate based on feedback is an attractive proposition.

2.4 The importance of a central reference for working within a multidisciplinary team.

Connected health projects find themselves crossing disciplinary lines as feedback from both medical clinicians and Information Systems (IS) professionals is critical for the success of a connected health system. Both design methodology and case studies that surround the development of connected health systems make specific reference to the multidisciplinary nature of the development process (Harte et al., 2017; McCarthy et al., 2020). This is due to the vast amount of knowledge that must be present within a connected health development team to ensure that all aspects of the proposed solution have been adequately identified and understood. This reflects the structure of healthcare delivery itself, where multidisciplinary teams, made-up of doctors, nurses, admin staff etc, are generally required to effectively provide patients with the appropriate care.

A critical step in ensuring the success of a connected health system is a clear understanding of the existing journey that patients go through as part of their treatment plan and ultimately establish areas of opportunity, or “pain points” within the patient journey where connected health systems can be effectively implemented (Carroll, 2016). To ensure that all team members are clear on both the patient journey as well as areas of opportunity within the patient journey, a visual representation of a patient’s journey used as a reference point can be extremely beneficial for multidisciplinary teams as visual aids are often effective in conveying complex concepts quickly and effectively.

Studies suggest that visual aids are very effective within the healthcare sector when conveying risk factors to vulnerable individuals (Garcia-Retamero & Cokely, 2013; Garcia-Retamero et al., 2012).

2.5 Patient Journey Mapping

While a robust suite of mHealth devices is critical to the success of an overall connect health application, one must also consider how these devices are integrated into the provision of services (McCarthy et al., 2020). In order to ensure that the services designed to support the connected health echo-system are robust and comprehensive, one may wish to consider the three central pillars highlighted by Doyle et al (2013), Clinical Effectiveness, Patient Safety, and Patient Experience.

To illustrate a patient's journey across these pillars, a journey mapping tool may be used. A clear patient journey map can assist the design team in ensuring that devices are integrated into the service at the correct time to maximize the benefit of technology for both the patients and the service providers.

Several tools exist to map the patient's journey (Curry et al., 2006; Simonse et al., 2019). Simonse et al. (2019) proposes a patient journey mapping method designed for integrated services design. This shows a patient journey across a timeline, with an hour-by-hour timeline and a clearly noted measure of a patient mood during a procedure. Curry (Curry et al., 2006) presents a "*multi-layered patient flow*", that resembles Unified Modelling Language (UML) techniques to map out a patients flow through a service. This presents the opportunity to map the patient journey in a condensed way, while maintaining accuracy.

A standout and well cited tool in this area is that of the integrated patient journey mapping (IPJM) tool *(McCarthy et al., 2016)*. This tool is designed to support *"multidisciplinary practitioners in designing healthcare solutions that meet the demands of existing constraints, performance improvement, and patient experience "(McCarthy et al., 2016, p. 354)*. Subsequent research has found that the *"IPJM can support multidisciplinary teams in exploring connected health solutions that consider the 3 pillars of health care quality: patient experience, clinical effectiveness, and patient safety"* (McCarthy et al., 2020, p. 10).

While the IPJM is a robust tool for mapping a patient's journey, its current iteration presents some limitations including difficulty in gaining access to both clinicians and IS professionals at the same time when using focus groups to populate the journey map, and a lack of key performance indicators on the journey map itself. Accessibility limitations are also highlighted, noting that the journey map requires a large screen or large physical page, such as an A2 sized page, in order to effectively illustrate the entire journey map (McCarthy et al., 2020).

Within the context of CAMHS, acute cases often require individualized responses to ensure patients receive appropriate care. This is due to the nature of the conditions involved, often times presenting with self-harm or suicidal ideations. These cases can be extremely high risk, and as such, should be delt with on a case by case basis. The presence of these risks have slowed the development and implementation of novel technologies, such as connected health and mHealth, in this context due to the concerns relating to the possibility of adverse outcomes for patients.

By contrast ADHD, although also falling under the CAMHS remit, does not entail the same level of unforeseen risk as its the diagnosis and treatment are very structured and documented endeavor (Coghill & Seth, 2015), therefore presenting as a suitable candidate for journey mapping and connected health implementation.

2.6 ADHD

As noted in section 1.1.3, a prevalent diagnosis within CAMHS is ADHD, defined as "*A persistent pattern (e.g., at least 6 months) of inattention symptoms and/or a combination of hyperactivity and impulsivity symptoms that is outside the limits of normal variation expected for age and level of intellectual development." (World Health Organization, 2025)*. ADHD is a quite common behavioural disorder, while figures differ, reports indicate a 5% prevalence in children (American Psychiatric Association, 2013; Polanczyk et al., 2007), with the US National Survey of Children's Health a rate of 7.9% with a current ADHD diagnosis (HRSA, 2014). ADHD is noted as harming an individual's social, academic, or occupational performance (de Graaf et al., 2008; Loe & Feldman, 2007; Nijmeijer et al., 2008). Individuals with ADHD have been shown to have a notable decrease in full-scale IQ, with significantly impaired reading and arithmetic ability, with executive function defects also present (Biederman et al., 1996; Willcutt et al., 2005)

The International Classification of Diseases (ICD) 11 (World Health Organization, 2019) highlights the diagnostic criteria for ADHD, noting two key areas of importance, inattention symptoms and hyperactivity-impulsivity symptoms. Inattention symptoms include, but are not limited to, carelessness or lack of attention to detail to work/activities, difficulties keeping attention on task, difficulties in organization, and being easily distracted by extraneous stimuli. Hyperactivity and impulsive symptoms include difficulties keeping still while sitting, resulting in fidgets or squirms, running, and climbing when not socially appropriate, and an inability to remain quiet during leisure.

2.6.1 Implications of ADHD

ADHD has a profound impact on the daily life of individuals with the disorder (Danckaerts et al., 2010). In childhood, it negatively affects children's school performance (Barry et al., 2002; Loe & Feldman, 2007; Rapport et al., 1999). The negative impact can be substantial, with Loe & Feldman stating that *"Children with ADHD show significant academic underachievement"* (Loe & Feldman, 2007, p. 644). Individuals with ADHD show a notable decrease in full-scale IQ, significantly impaired reading and arithmetic ability estimates when compared to a control group of children without the disorder (Biederman et al., 1996). Executive function deficits have also been demonstrated in visuospatial and verbal working memory (Willcutt et al., 2005).

Childhood interpersonal relations and peer relationships are impacted by ADHD. Young people and children with ADHD can display elevated levels of aggression, difficulties when handling interpersonal conflict, and difficulty in reacting to other individuals appropriately (Buhrmester et al., 1992; Grenell et al., 1987; Nijmeijer et al., 2008). These interpersonal issues extend to family relations, with children with ADHD showing more frequent instances of conflict or impaired cohesion with siblings and parents (Biederman et al., 1996). Those with ADHD may also have an increased risk of injury and negative lifestyle habits. Studies suggest that there is a strong link between ADHD and increased risk of injury (Pastor & Reuben, 2006; Schwebel et al., 2011). Those with ADHD have an increased risk to substance misuse (Charach et al., 2011). The literature supports an increased risk of dependence on substances such as nicotine and other addictive substances (Lee et al., 2011; Wilens et al., 2008).

Of most significance, Danckaerts et al. (2010) reported that children with a diagnosis of ADHD self-reported lower health related quality of life scores than their peers. This illustrates the importance of supporting and delivering consistent high-quality care and treatment to children and young people presenting to services with a diagnosis of ADHD. Early intervention is critical when supporting ADHD, with studies suggesting that early intervention yields positive results for ADHD sufferers, including managing symptoms and improving social functioning, while reducing risk of anxiety, addictive disorders and academic failure among others(Biederman et al., 2019; Feil et al., 2016; Halperin et al., 2012). As mentioned in this section, ADHD left untreated has profound impacts on a person's life, and it also presents the possibility of producing Adverse Childhood Experiences (ACEs). ACE's are negative circumstances which occur in a child's life before the age of eighteen, including but not limited to, emotional, physical or sexual abuse, household mental illness, or neglect (Boullier & Blair, 2018). Early intervention in cases of ACE has also been shown to have positive results, compounding the need to reduce waiting lists to improve patient outcomes by early implementation of best practice treatment plans (Asmussen et al., 2019).

2.6.2 Diagnosing ADHD

The process of diagnosing ADHD typically takes the form of a multistage assessment where data is gathered from parents and teachers in the first instance to provide clinicians with background information and initial indications of ADHD. Screening questionnaires, such as the Conners Parent Rating Scale (Conners et al., 1998) or the Snap-26 point parent teacher screener (Swanson et al., 2001), are used to provide an early indication of ADHD. These questionnaires attempt to provide an early indication of the presence of ADHD by providing the participant with a series of questions where responses are weighted to provide an overall score which is used to determine if a full assessment is required. These questions include areas such as the child's school and home life, interactions with others and emotional regulation.

2.6.3 Dundee ADHD Clinical Care Pathway – A Gold Standard for ADHD treatment

While there are several publications that advise on the treatment of ADHD including the NICE guidelines (National Institute For Health And Care Excellence (NICE), 2018), one that has been well received is that of the Dundee ADHD Clinical Care Pathway (DACCP) (Maskey, 2022). This pathway, originally used in Scotland, creates a "*clearly structured, evidence based clinical pathway for the assessment and management of children and adolescents with ADHD*" (Coghill & Seth, 2015, p. 1) and has been identified in a systems review by Maskey (2022) as the preferred guidance for the delivery of high-quality ADHD care in Ireland. This pathway identifies 4 stages in the diagnosis and treatment of ADHD as described in the publication by Coghill and Seth (2015).

Stage 1: Referral and pre-assessment screening – This is the initial stage of the pathway where a referral letter is received by a CAMHS service. This, in most cases, is sufficient to determine if a full assessment is required. In some cases, a more in depth, pre-assessment screening is conducted to ensure that a full assessment is warranted. This screening involves the interview and completion of questionnaires by parents, teachers and other relevant parties who are in a position to provide additional details to the service.

Stage 2: Assessment, diagnosis and treatment planning – The Dundee pathway sets out standard protocols where the majority of clinical information is received and reviewed by specialist nursing staff, with the role of the doctor confined to diagnosis and treatment planning.

- The information gathering stage involves interviews with the child, parents, and other relevant parties. Educational or school reports are used as initial information sources. Medical history is documented, and a full screening of physical and mental health is conducted. Following this, additional information may be requested where deemed necessary.

- Diagnosis and treatment planning – Once the required information has been gathered, a report is sent to clinicians to review and conduct a final assessment appointment to discuss diagnosis and treatment planning with parents and the patient. In the absence of an ADHD diagnosis at this point, follow-up care should be arranged to address any other mental health problems that were identified.

Stage 3: Initiating treatment – Treatment usually involves medications for individuals over 6 years of age, with non-pharmacological treatment employed for those below this age and for those whose parents do not consent to prescribing medication. If treatment is of benefit, any additional or remaining difficulties are addressed. If no benefit is clear from treatment, further options are discussed. Methylphenidate, a stimulant, is considered the first line treatment in the absence of co-morbidities or clinical contraindications to its use. Dose titration, where the dosage is optimized for each patient, is used to maximize benefits of medication while limiting possible side effects. Several “titration appointments” are recommended, where weight, pulse and blood pressure are monitored to ensure the health of the patient is maintained. Following a four-week period, an additional meeting with a physician and nurse is conducted to discuss progress and dosage.

Stage 4: Continuing care/monitoring treatment – Following titration, patients are continuously monitored to ensure pharmacological safety and to avoid adverse effects of treatment. This ensures that any other problems that may arise are identified and treated where required. For patients receiving medication as part of treatment, appointments are typically spaced 6 months apart and are held to ensure patients are responding to treatment. Those who are not being actively treated are followed up on annually to ensure that, if difficulties return, they receive appropriate treatment (Coghill & Seth, 2015).

2.7 Conclusions

My literature review has identified that CMAHS and in particular the effective diagnosis and management of ADHD is an area which is struggling with long waiting lists and understaffing. There is a clear and well accepted pathway for the management of ADHD along which connected health systems may be of benefit.

As noted in sections 1.3 and 2.5.1, there are clear ramifications to the lack of quality mental health services to children and adolescents, both for those with untreated ADHD and acute mental health issues. As I have highlighted in section 1.1, 1.2 and 1.5, Irish CAMHS services are in need of supports to effectively manage the ever-growing demands of the service and the long wait lists that result, as noted in 2.2.1. Existing literature, which I have noted in section 2.1, highlights a number of key connected health solutions that can support clinicians in their delivery of services, such as telemedicine, mobile applications, and EHR systems. These applications have been demonstrated to provide efficiency within the context of clinical governance and clinical decision-making, a number of which are recommended as per the Maskey and Finerty reports discussed in sections 1.1 and 1.2 respectively. These reports also note that, at time of their publication, Irish CAMHS services lack a coherent and organized approach to the implementation of ICT technologies. However Irish CAMHS appear to be “behind the curve” when it comes to digitization and the implementation of modern connected health applications. This presents an opportunity for research in this area, particularly in relation to a digital transformation of the CAMHS service within an Irish context.

The benefits of connected health, highlighted in section 2.1.1, presents CAMHS with an opportunity to increase efficiency of existing clinical resources, in an attempt to “stem the tide” of excessive waiting lists while the service awaits further investment in recruitment. The shortening of waiting lists has the potential of reducing the number of unaddressed instances of ACE, thus preventing these cases from turning into more complex acute cases within the service. As noted in section 2.5.1, untreated ADHD has the potential to spiral into more acute cases which require urgent action, and in contrast, ADHD treatment with suitable monitoring have shown to have generally very positive outcomes (Peterson et al., 2024). A reduction in these acute cases may subsequently allow clinicians to work through waiting lists more efficiently, further reducing the number of unaddressed ADHD and improving long term outcomes. Treatment has been shown to significantly reduce the risk of development of drug addiction, alcohol dependency, and co-existing mental health problems of young people with ADHD.

Within CAMHS, the diagnosis and treatment of ADHD presents a unique opportunity to integrate connected health solutions into the service. The structured nature of ADHD diagnosis and treatment, especially with the established Dundee ADHD Clinical Care Pathway, provides a clear framework for implementation. Consequently, the first logical step for research is to conduct an in-depth analysis of the Dundee ADHD Treatment Pathway within CAMHS. This analysis will focus on the context of Irish CAMHS to identify where connected health applications can be effectively embedded within the treatment pathway.

Chapter 3: Design Science for Connected Health

3.1 Design Science in Information Systems

The distinction between design research and design science research is a critical one. While Design Science Research (DSR) was initially referred to as "Design Research", it quickly became apparent that a name change was needed as design research has a longstanding link to the field of study which focuses on the concept of design itself. This is distinct from DSR in that DSR aims to provide learnings through the design and development of an artifact (Vaishnavi & Kuechler, 2021), with academics stating that design research "is research about design whereas DSR is primarily research using design as a research method or technique." (Vaishnavi & Kuechler, 2021).

Design Science Research, as per vom Brocke et al., is *"central to Information Systems (IS) studies"* (vom Brocke et al., 2020, p. v). The goal of Design Science Research is to create what is referred to as design knowledge (DK), which is knowledge about how an artifact should be constructed (vom Brocke et al., 2020). Artifacts generated from Design Science can be constructs, models, methods or instantiations (Gregor & Hevner, 2013b; Hevner et al., 2004). In practice, design science is a problem solving approach to research, and seeks to generate DK by solving real world problems (Hevner et al., 2004).

3.1.1 Conceptualising Design Science

Vom Brocke et al. (2020) provide a conceptual model, based on (Hevner et al., 2004), for design science research, shown in Figure 4.1. The model is broken into three key areas, environment, knowledge base and design. Environment comprises of people, organisation and technology, and ultimately defines the problem space. This is where the opportunities, goals, problems and tasks that define the needs of the system and guide the research problem and subsequently the scope of the research project is derived. Appropriate review of the people, organisation, and technologies available subsequently informs the relevance of the project and how interventions derived from the project can benefit both internal and external stakeholders.

The Knowledge Base consists of the current state of knowledge, made up of Foundations and Methodologies as defined in the current state of literature. Foundations include theories, foundations, models, constructs and methods. Methodologies consist of the tools used to identify new knowledge, including data analysis techniques, optimizations and experimentation. Appropriate review and implementation of the knowledge base ensure the rigor of the process.

The design section consists of both build and evaluate sections. These sections, as their names suggest, involving the process of building and evaluating an artifact in the context of both the knowledge base and environment contexts. This generally involves multiple iterations of the artifact to ensure that feedback is implemented, where feedback is derived from well-established social research methods such as interview, survey, and focus groups.

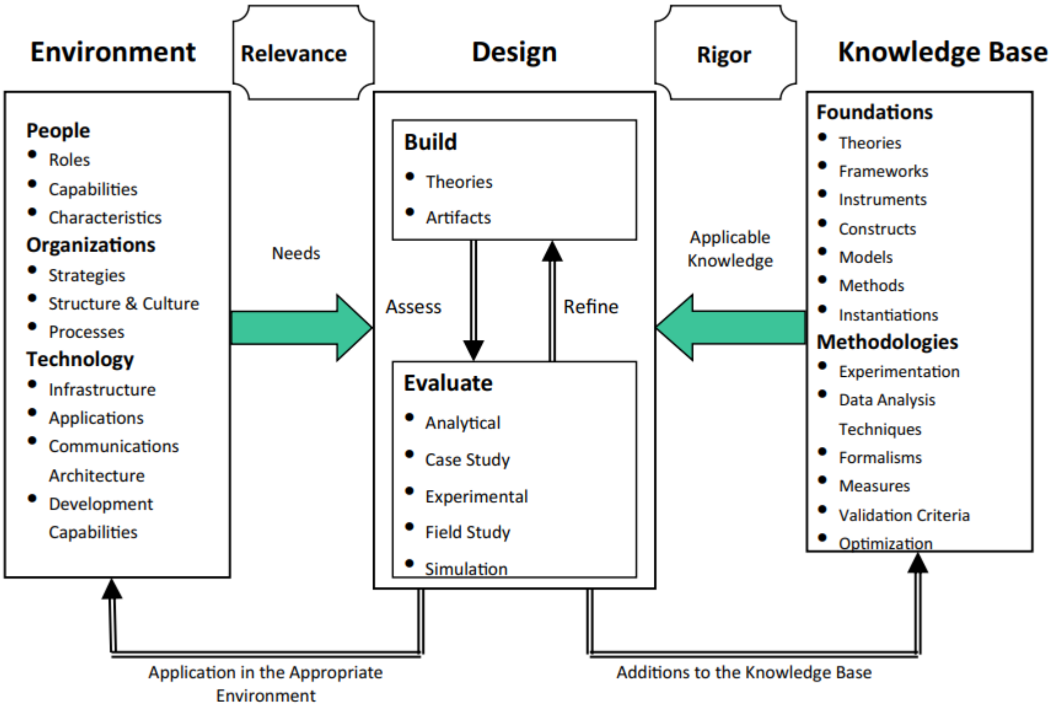


Figure 3. 1 Design science research framework (vom Brocke et al., 2020) (Initially adapted from (Hevner et al., 2004))

3.1.2 Operationalising Design Science

A number of process models exist for operationalising design science research within the IS domain, including those produced by Alan Hevner, titled *"A Three Cycle View of Design Science Research"* (2007) which closely aligns with the design science framework noted above by leveraging the three key areas of the framework while overlaying three research cycles, the relevance cycle, the rigor cycle and the design cycle. The Relevance cycle comprises of requirements gathering and field testing, with the rigor cycle focuses on grounding the work in the knowledge base and subsequently adding to the knowledge base. The design cycle follows the build and evaluate model highlighted in the framework noted above. While this model has not been used as the basis for the research conducted in the remainder of this thesis, a key learning was identified that guided the implementation of the chosen design science output for the thesis. Hevener notes that *"While theories can serve as sources of creative ideas, to insist that all design research must be grounded on descriptive theories is unrealistic and* *even harmful to the field"* (Hevner, 2007, p. 90). Hevenr continues by noting that additions to the knowledge base, noted as the key selling point for academic audiences, will include *"any extensions to the original theories and methods made during the research, the new meta-artifacts (design products and processes), and all experiences gained from performing the research and field testing the artifact in the application environment". (Hevner, 2007, p. 90).*

Based on this, the contribution of this thesis to the Knowledge Base, or Body of Knowledge, can take the form of learnings from individual implementations of rigorous design science research process applications in a CAMHS context. These findings, along with the artefactual outputs, may yield value to the academic community. The artefactual output itself may also constitute a contribution to knowledge as the presentation of its development and final iteration may provide avenues for discussion and evolution from the scholarly community. This aligns with Davis who states that a PhD thesis presents a contribution to the field if it *"develops and demonstrates new or improved design of a conceptual or physical artifact. This is often termed "design science." The contribution may be demonstrated by reasoning, proof of concept, proof of value added, or proof of acceptance and use"* (Davis, 2005)

3.1.3 Design Science Research Methodology

To that end, the design science process employed for the remainder of this thesis is that of Ken Peffers et al (2007), titled *"A Design Science Research Methodology for Information Systems Research"*. This methodology known as the DSRM, highlighted in figure 3.2, provides a clear pathway for the implementation of design science research within an IS context. The methodology highlights six key activities, which the project may progresses through, depending on its entry point in the process. vom Brocke et al. (2020) highlights each stage in the DSRM:

Problem identification and motivation – This activity is where the problem is identified and the justification for the solution is rationalized. The rational for the solution is critical as it underpins both the researcher's motivation to pursue a solution and it also conveys the researcher's understanding of the problem to the audience.

Define the objectives for a solution – These objectives can be inferred from the problem statement identified above, or via review of both the Environment and Knowledge Base to identify what is feasible.

Design and development – This activity is where the artifact is created or modified based on feedback from a previous demonstration and evaluation stage. Creation of the artifact or additions/changes to an artifact's functionality are performed in this step

Demonstration – This phase is where the proposed artifact is presented to stakeholders for review or implemented in an attempt to solve the problem identified. This can take the form of simulation, case study or proof.

Evaluation – This phase is where results of the demonstration are evaluated and learning from the outcomes are derived. The results are compared to the objectives for a solution to determine if another iteration is warranted. If another iteration is to be developed, the artifact moves back to the design and development phase.

Communication – This is where the results from the DSR project are presented to the relevant stakeholders, for an academic research project, this typically takes the form of an academic publication so results can be reviewed by the academic community.

3.1.4 DSRM Entry Points

As noted in the DSRM, there are a number of possible entry points within the methodology, corresponding to the first four phases of the process. Entry point one is a problem centred initiation, which as its name suggests, denotes that the project is initiated as a response to a problem, or perceived problem. Therefore, activity one must be conducted to establish if the problem does in fact exist, and the rationale for a solution can be justified.

An objective-centred solution occurs when the problem has already been clearly identified and a rationale for implementing a solution is established. Activity two is therefore the first activity actioned as objectives for solutions should be established at this stage.

A design and development-centred solution occurs when an objective for the solution has been established but an artifact has yet to be developed. Activity three is therefore the first activity performed at this entry point.

A client/context initiation occurs when there is an existing artifact in place, but its effectiveness must be evaluated with the view of possible refinements implemented. Activity four is therefore the first activity at this entry point. This entry point represents the most advanced stage in the methodology that a DSRM project should be initiated.

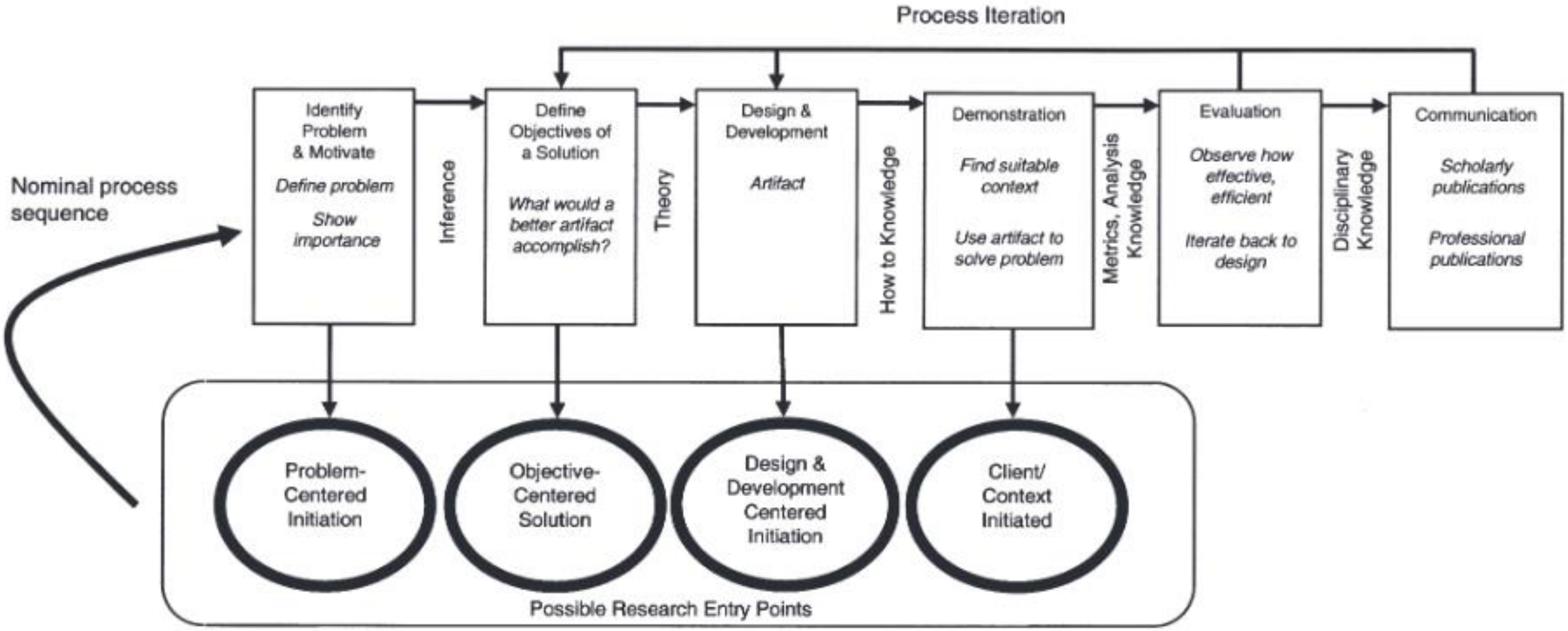


Figure 3. 2 – Design Science Research Methodology (Peffers et al., 2007)

3.2 Presenting Design Science Research

3.2.1 Design-Theory

While design science has been a generally accepted research paradigm within IS for a number of years, there has been some debate as to what constitutes a contribution to knowledge within the IS domain (Gregor & Hevner, 2013a). Two prevailing beliefs are present within literature, the first prevailing theory is that of design-theory (Gregor, 2006; Jones & Gregor, 2007). Design theory can be viewed as *“abstract entity, an inter-meshed set of statements about relationships among constructs that aims to describe, explain, enhance understanding of, and, in some cases, predict the future”* (Gregor & Hevner, 2013a, p. 339).

The key point here is that the nature of a design-theory is that it is “abstract” and can therefore be applicable to a wide range of domains or projects. This is supported by Gregor and Jones (2007) closing remarks in their paper which notes that theories derived from the design and development of complex systems should *“satisfy the requirements of being abstract and general” (Jones & Gregor, 2007, p. 331)*. The design-theory approach notes the importance of the tangible, artefactual output, but limits its scope within the contribution to a “test” of the design theory, and notes *“one would need to represent the important principles underlying its construction in such a way that they are applicable to other systems yet to be constructed.”* (Jones & Gregor, 2007, p. 331)

3.2.2 Artifact Output

This is in contrast to the second prevalent belief, which notes the importance of the artefactual output as a contribution to knowledge in its own right, pioneered by Hevner and others. Hevner notes that IS research is “*both an organizational and a technical discipline that is concerned with the analysis, construction, deployment, use,* *evaluation, evolution, and management of information system artifacts in organizational settings"* (Hevner et al., 2004, p. 98) and continues to note that DSR focuses on *"creating and evaluating innovative IT artifacts that enable organizations to address important information-related task"* (Hevner et al., 2004, p. 98). This illustrates the position that an artefactual output in of itself, may be a valid scholarly output within DSR.

3.2.3 DSR Balance

Hevner notes, however, *"the dangers of a design-science research paradigm are an overemphasis on the technological artifacts and a failure to maintain an adequate theory base, potentially resulting in well-designed artifacts that are useless in real organizational settings."* (Hevner et al., 2004, p. 98). Similarly, Hevner also notes the danger in the opposite extreme in the case of an *"overemphasis on contextual theories and failure to adequately identify and anticipate technological capabilities, potentially resulting in theories and principles addressing outdated or ineffective technologies"* (Hevner et al., 2004, p. 98). It may therefore be logically inferred that the effective implementation of design science may be found in the equilibrium between these two extremes. Interestingly balance between theory and artifact is illuded to in Gregor and Jones paper (2007) noting that, for an effective design theory to emerge, *"A number of instantiations in multiple case studies may need to be studied before the general principles enabling them to function can be extracted"* (Jones & Gregor, 2007, p. 331).

3.2.4 DSR Contribution Types

This balance between artifact and theory is subsequently formalized in the joint Gregor and Hevner paper titled "Positioning and Presenting Design Science Research for Maximum Impact", published in MIS Quarterly Vol. 37 No. 2, 2013. This paper was published to *"harmonize what we see as complementary rather than opposing perspectives, a repositioning that can enhance the conduct and reach of rigorous and impactful DSR" (Gregor & Hevner, 2013a, p. 338)* and has subsequently become a seminal piece of work when it comes to DSR publication within IS. The paper has combined the beliefs noted above into a unified approach to publications of DSR.

The work highlights the importance of both the artefactual output of DSR, functioning as the initial research output of a less mature research domain, and the design theory formed from the learnings of multiple artefactual DSR outputs. Three types of DSR contributions emerge from the paper, as noted in figure 4.3. Level 1 contributions are noted as “situated implementation of artifact” and are the instantiations of software or processes. They are the least mature form of knowledge and act as the case studies that are evaluated to produce Level 2 Contributions. These comprise of “Nascent design theory—knowledge as operational principles/architecture” and are the constructs, methods, and models that are derived from the results of Level 1 construction. Level 3 contributions are “Well-developed design theory about embedded phenomena” and are the result of refinement and generalizations of level 2 contributions and take the form of mid-range and grand design theories.

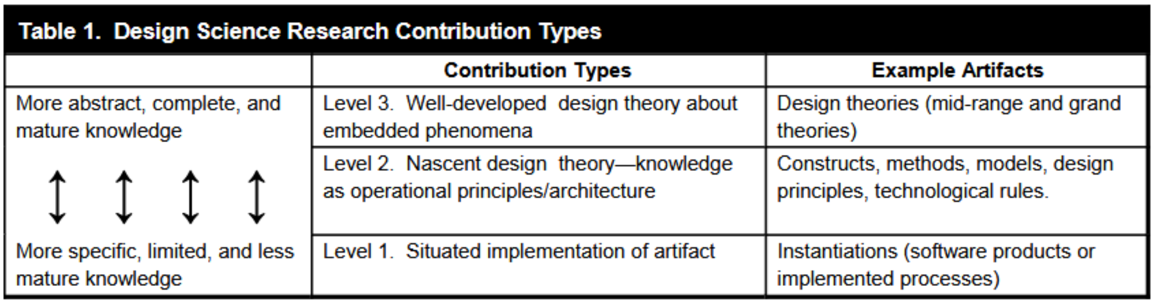


Table 1. Design Science Research Contribution Types

	Contribution Types	Example Artifacts
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
↕ ↕ ↕ ↕	Level 2. Nascent design theory—knowledge as operational principles/architecture	Constructs, methods, models, design principles, technological rules.
More specific, limited, and less mature knowledge	Level 1. Situated implementation of artifact	Instantiations (software products or implemented processes)

Figure 3. 3 – DSR contribution as per (Gregor & Hevner, 2013b)

3.2.4 Current Design Science Research

During the course of this thesis, the results of a DSR methodology study were presented in MIS quarterly by prominent DSR researchers, titled *“Dealing with Complexity in Design Science Research: A Methodology Using Design Echelons”* (Tuunanen et al., 2024), that has the potential to impact the use of DSR in IS research going forward. While the methodology proposed in this work was published after the final stages of this thesis had begun, the author reflects on the implications of this publication in the final chapter of this thesis, with the goal to effectively derive insights that may inform subsequent research in this area.

3.3 A Focus on Design Science in This Thesis

The DSRM highlighted above does not specifically require end users, only that a demonstration *“could involve its use in experimentation, simulation, case study, proof, or other appropriate activity.”* (Peffers et al., 2007). For the remainder of this thesis, qualitative interview and focus group using a “think aloud” protocol will be used to form the demonstration step of the DSRM. Research participants will be professional individuals, including clinicians, case managers, special needs teachers, special needs assistance, connected heath researchers and connected health consultants will all be engaged as part of the DSRM implementation for the creation of research artifacts within this thesis.

3.4 Summary of Research Approach

The objectives for this research project have been broken down into the three research questions noted in section 1.7. Questions one, two, and three provide context for which a conclusion can be derived. Figure 3.6 highlights the steps involved in providing answers to the research questions proposed.

Step one, as seen in chapter 4, is to establish the context in which a potential connected health application, to support ADHD diagnosis and treatment, can being implemented. Connected health applications are applied within healthcare settings and therefor require a development team to possess an appropriate understanding of the setting to ensure value delivery. The DSRM is applied to the Integrated Journey Mapping tool to provide a visualization of the Dundee ADHD clinical care pathway. Interviews using a think aloud protocol were used to gain insights into the participants view and feedback on the diagram presented at each phase. Those interviewed where relevant professionals in the connected health and CAMHS clinical domains. These include connected health researchers, connected health consultants, CAMHS clinical consultants and CAMHS nurses.

Step two, also discussed in chapter four, is to examine the finalized Dundee ADHD clinical care pathway, resulting from a three stage DSRM implementation, to provide recommendations for the placement of connected health solutions within the pathway.

Step three, illustrated in chapter 5, is to identify risks and benefits associated with the recommended connected health solutions, and their ancillary technologies, within CAMHS. Interviews were conducted with CAMHS Consultant Psychiatrist, Senior CAMHS Registrars, Senior CAMHS Registrar Trainees, and an Adolescent Psychiatrist with experience working in CAMHS.

Step four, shown in chapter 6, is to map the risks identified in step three, taking into account associated benefits, to the visualized Dundee ADHD treatment pathway visualization to establish areas of increased risk and identify appropriate patient interaction points to imbed connected health solutions.

Step five, also illustrated in chapter 6, is to apply the DSRM to create a suitable connected health mobile application artifact to provide support for clinicians in the delivery of the Dundee ADHD clinical care pathway in a CAMHS setting. Those interviewed for application evaluation and feedback included CAMHS Consultant Psychiatrist, Senior CAMHS Registrar trainee, Managing Director of a private ADHD diagnosis and treatment service, and a Child & Family Support Network Coordinator

Step six, highlighted in chapter 7, is to reflect on the creation process of the artifact, noted in the previous steps, to provide a possible framework for creating other connected applications within a CAMHS setting.

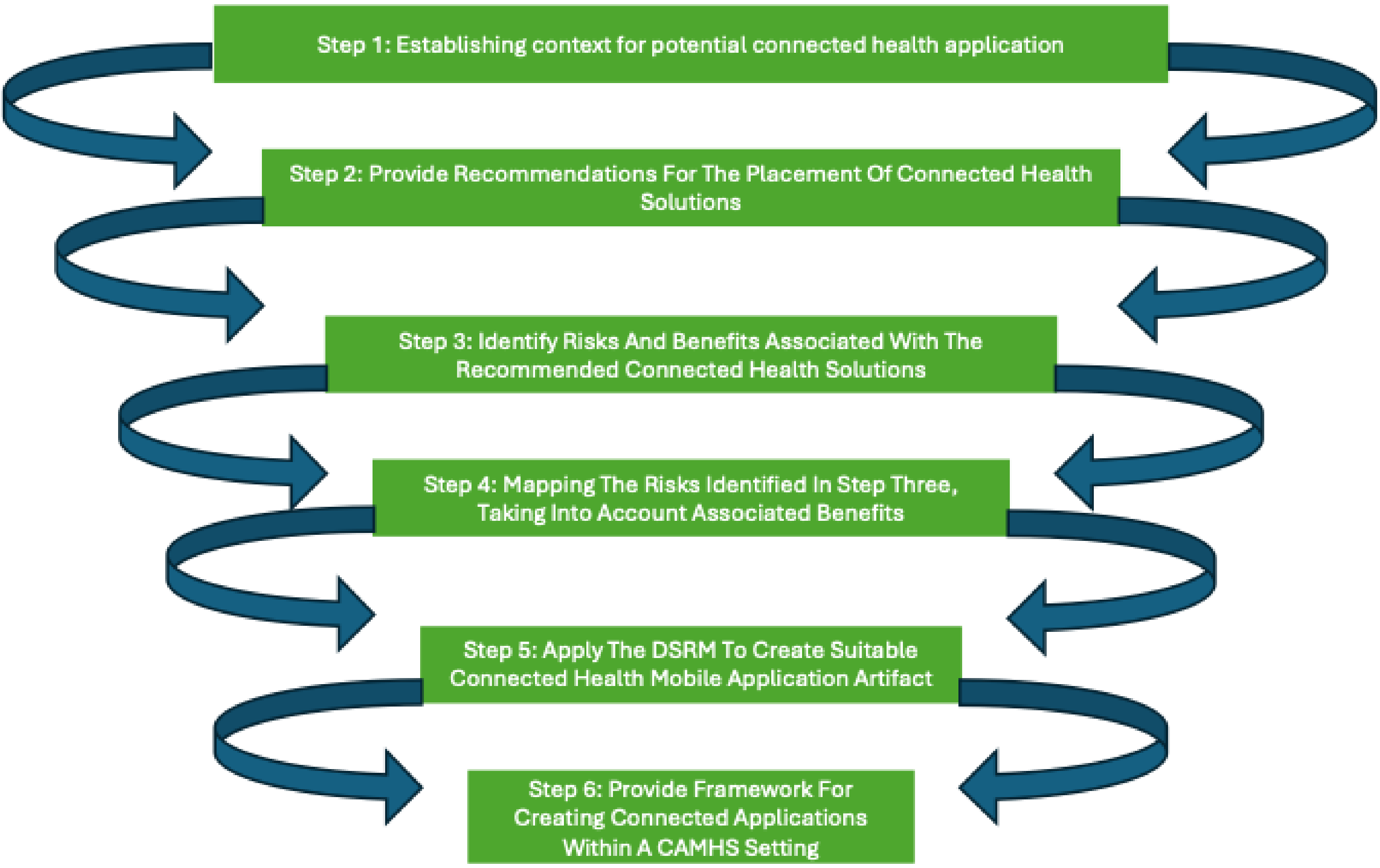


Figure 3. 4 – Summary of Research Approach

Chapter 4: Clinician-Focused Connected Health Requirements Gathering for ADHD Through Clinical Journey Mapping: A Design Science Study

A condensed version of this chapter has been published as *Harris, R., Murray, D., McSweeney, A., & Adam, F. (2025). Clinician-Focused Connected Health Requirements Gathering for Attention-Deficit/Hyperactivity Disorder Through Clinical Journey Mapping: Design Science Study. JMIR Form Res, 9, e53617.* https://doi.org/10.2196/53617

Richard Harris (RH) Statement of Contribution: RH conceptualized and designed the chapter, reviewed and revised the chapter as per feedback from supervisors (FA and DM), clinical advisor (A McS), and peer reviewers of the above publication. RH gathered and analyzed all primary research data.

4.1 Abstract

Background: The creation of a robust connected health application, by its very nature, requires a multidisciplinary development team. Integrated patient journey mapping presents an opportunity to streamline the requirements-gathering process by clearly illustrating the patient journey to individuals who are not familiar with the clinical practice. However, there are limitations to integrated patient journey mapping, particularly the size of the diagrams themselves which often require specialized equipment to adequately present (McCarthy et al., 2016). This research has focused on ADHD as a case study for implementing Clinical Journey Mapping, with the Dundee Clinical Care Pathway (Coghill & Seth) identified as the gold standard for ADHD treatment and thus used as the preferred patient journey template.

Objective: The objective of this chapter will be to answer three research questions. The first pertains to visualizing the Dundee ADHD clinical care pathway using Integrated Patient Journey Mapping and how this benefits multi-disciplinary teams within the connected health domain. The second question pertains to how the integrated patient journey map (IPJM) can be operationalized through the lens of the Dundee Treatment Pathway. The third question relates to how the existing IPJM implementation can be updated to improve its accessibility, with the final question examining the areas for connected health integration within the Dundee pathway. Following the creation of a modified IPJM, a pilot study will be conducted on a private ADHD diagnosis and treatment service that have applied the modified IPJM to their adoption of a cloud EHR system.

Methods: This study has utilized a design science approach proposed by Peffers et al. (2007) where a sample artifact is presented to a relevant audience for review and feedback, which is then leveraged to iterate the artifact. This artifact has received input from both information systems professionals and clinical professionals to achieve relevant feedback for each iteration. For the creation of the pilot study, reflexive thematic analysis is employed to identify trends and sentiment in user feedback.

Results: The implementation of the above methods has resulted in the creation of a clinical patient journey map which highlights multiple persona journeys through the Dundee clinical care pathway on one diagram. Utilizing unified modelling language (UML) concepts and colour coding, multiple patient personas can be mapped onto a streamlined diagram, allowing the diagram to be used in a wider variety of situations. The applied pilot study yielded positive results, with interview participants noting its ability to effectively convey requirements and foster group discussion.

Conclusions: Based on research conducted, the modified patient journey map is an effective tool to gather and convey requirements for multi-disciplinary teams. Based on

a review of feedback from participants who engaged with the journey mapping tool for visualizing the Dundee pathway, the following recommendations for where connected health can be embedded within the Dundee clinical care pathway are presented:

1. Leverage software-based screening questionnaire to reduce face to face clinician time.
2. Utilized software-based teaching materials, including digital content libraries using text, audio and/or video, to assist in the non-medical intervention stages of the pathway.
3. Adopt smart remote monitoring tools, for example Bluetooth blood pressure cuffs, to streamline the continued care process with the aim of reducing the number of required continued care appointments while maintaining a high level of oversight and care for patients.

4.2 Introduction

This chapter aims to build on the Integrated Patient Journey Mapping tool (IPJM) (McCarthy et al., 2016) by using a design science approach to create a visual representation of the Dundee ADHD Clinical Care Pathway (Coghill & Seth, 2015), used to manage Attention-Deficit/Hyperactivity Disorder (ADHD). A key goal of this paper will be, through patient journey mapping, to highlight areas where connected health systems can be embedded within the Dundee Pathway. Connected health systems offer the potential to streamline clinical practice and meet the demands of a changing, and increasingly demanding, healthcare space (Caulfield & Donnelly, 2013). Youth mental health supports, including ADHD treatments, are in high demand around the world, with many services, public and private, struggling to meet demand (Children's Mental Health Ontario, 2020; headspace., 2019; Health Service Executive, 2013a; NHS Digital, 2021). It is envisioned that mapping patient journey, using a modified IPJM highlighted in this paper, will both address some of the key limitations of the original IPJM, while also presenting opportunities, and thus recommendations, for connected health integration within the Dundee pathway.

This section has presented a review of the literature surrounding ADHD, connected health and patient journey mapping tools. Section 4.3 consists of the research methodology and the research questions, with section 4.4 covering the results of the research, broken down into stages reflective of the research methodology used. Section 4.5 discusses the findings, with section 4.6 comprising of recommendations for embedding connected health into the Dundee pathway, section 4.7 consist of an applied pilot study for a private ADHD treatment service that leveraged the modified integrated journey map to represent multiple patient personas to convey their patient pathway to the developers of their cloud EHR system. Section 4.8 covers for areas of future research and section 4.9 concludes this chapter.

4.2.1 Connected Health

Connected Health, as defined by Caulfield and Donnelly *"encompassess terms such as wireless, digital, electronic, mobile, and tele-health and refers to a conceptual model for health management where devices, services or interventions are designed around the patient's needs, and health related data is shared, in such a way that the patient can receive care in the most proactive and efficient manner possible." (Caulfield & Donnelly, 2013, p. 704)*. The aim of connected health is to connect all stakeholders within the patient journey to ensure the most efficient and effective care is provided to the patient at the right time (Caulfield & Donnelly, 2013).

The term "connected health" has been used as an umbrella term which incorporates areas such as "Telehealth" and "Telemedicine". While there is no single universal definition for these terms, both are used to describe a situation where healthcare is provided where the individual patient is not physically present with the clinician, and instead information technology such as voice and video chat are used to provide healthcare services. The term Mobile Health (mHealth), the use of mobile devices to facilitate communication and healthcare service provision, is also found under the connected health umbrella(Harte et al., 2017; Kvedar et al., 2014; World Health Organization, 2011).

Connected Health systems have been shown to produce positive outcomes for mental health services. Computerized cognitive behavioural therapy used in the treatment of depression and anxiety has been shown to produce positive results without drug treatment, while also yielding greater treatment satisfaction (Proudfoot et al., 2004).

4.2.2 Benefits of Connected Health

While the ramifications of the Covid-19 pandemic are still being discovered and quantified, it has presented a unique opportunity to highlight the benefits of connected health applications, with stakeholders and decision makers within the public healthcare space identifying their healthcare and cost-saving benefits (Stefano, 2021). During periods of restricted movements, connected health has facilitated the continued provision of healthcare for both screening of acute illness and continued care for the chronically ill through an increased adoption of telemedicine (Omboni et al., 2022). Some of the key areas of healthcare services provided using telemedicine include Consultation, Follow-up, and Caregiver support (Bitar & Alismail, 2021).

While the benefits of connected health are self-evident when the general population is confined to their homes or to a certain radius of said home, it is important to highlight the benefits that connected health provides to those in areas where gaining physical access to a healthcare professional can be difficult. Mobile Health (mHealth) is a field that has come about due to the incredible speed that mobile technology has disseminated throughout the world’s population. As of 2022, the International Telecommunication Union estimated that 5.3 billion individuals have access to the internet (International

Telecommunication Union, 2023b), illustrating the importance of continued research in mHealth.

4.2.3 The importance of a central reference for teams working within Connected Health

Connected health projects find themselves crossing disciplinary lines as feedback from both medical clinicians and information systems (IS) professionals is critical for the success of a connected health system. Both design methodology and case studies that surround the development of connected health systems make specific reference to the multidisciplinary nature of the development process (Harte et al., 2017; McCarthy et al., 2020).

A critical step in ensuring the success of a connected health system is a clear understanding of the existing journey that patients go through as part of their treatment plan and ultimately establish areas of opportunity, or “pain points” within the patient journey where connected health systems can be effectively implemented (Carroll, 2016). To ensure that all team members are clear on both the patient journey as well as areas of opportunity within the patient journey, a visual representation of a patient’s journey used as a reference point can be extremely beneficial for multidisciplinary teams as visual aids are often effective in conveying complex concepts quickly and effectively. Studies suggest that visual aids are very effective within the healthcare sector when conveying risk factors to vulnerable individuals (Garcia-Retamero & Cokely, 2013; Garcia-Retamero et al., 2012).

4.2.4 Patient Journey Mapping

Several tools exist to map the patient's journey (Curry et al., 2006; Simonse et al., 2019). Simonse et al. (2019) proposes a patient journey mapping method designed for integrated services design. This shows a patient journey across an hourly timeline and a clearly noted measure of a patient mood during a procedure. Curry et al. (2006) presents a "*multi-layered patient flow*", that resembles UML modelling techniques to map out a patients flow through a service. This presents the opportunity to map the patient journey in a condensed way, while maintaining accuracy. A standout and well cited tool in this area is that of the "*integrated patient journey mapping tool" (IPJM) (McCarthy et al., 2016)*. This tool is designed to support *"multidisciplinary practitioners in designing healthcare solutions that meet the demands of existing constraints, performance improvement, and patient experience" (McCarthy et al., 2016, p. 354)*. Subsequent research has found that the *"IPJM can support multidisciplinary teams in exploring connected health solutions that consider the 3 pillars of health care quality: patient experience, clinical effectiveness, and patient safety"* (McCarthy et al., 2020, p. 10).

While the IPJM is a robust tool for mapping a patient's journey, its current iteration presents some limitations including difficulty in gaining access to both clinicians and IS professionals at the same time when using focus groups to populate the journey map, and a lack of key performance indicators on the journey map itself. Accessibility limitations are also highlighted, noting that the journey map requires a large screen or large physical page, such as an A2 sized page, in order to effectively illustrate the entire journey map (McCarthy et al., 2020).

4.2.5 Connected Health Supporting Teams Under Pressure

As mentioned above, connected health systems can greatly increase the effectiveness of medical services with limited resources. One area particularly under pressure in the

UK and Ireland is the Child and Adolescent Mental Health Services (CAMHS). Ensuring that children and adolescents have access to high quality and evidence based mental health services is of critical importance. Article 24 of the Convention on the Rights of the Child outlines that *“States Parties recognize the right of the child to the enjoyment of the highest attainable standard of health and to facilities for the treatment of illness and rehabilitation of health” (United Nations, 1989)*. Supporting these services benefits not only the individual, but society as a whole. The World Health Organization highlights that *“The lack of attention to the mental health of children and adolescents may lead to mental disorders with lifelong consequences, undermines compliance with health regimens, and reduces the capacity of societies to be safe and productive” (World Health Organization, 2003)*. It is therefore of the utmost importance that public and private health service providers ensure that these services have access to the most up to date technologies and research to provide the best service possible.

While it is clear that the mental health of adolescents is of critical importance, CAMHS services are struggling to meet demand. Reports indicate an increasing number of adolescents presenting to CAMHS for treatment. Figures from the UK’s NHS show an increase in the number of children (5-19 years old) with a diagnosed “mental disorder” grew from one in eight (12.8%) in 2017 (NHS Digital, 2018) to one in six (16.0%) in 2020 (NHS Digital, 2020) and again to 17.4% in 2021 (NHS Digital, 2018). The Covid-19 pandemic may certainly have played a part in this, however as the world began to return to normality in 2022, figures are still on the rise, with rates standing at 18.0% during 2022 (Newlove-Delgado T et al., 2022). While demands for these services are increasing, the number of staff available to tackle this demand is limited, with Irish CAMHS services falling short of recommended staffing levels in recent years (Health Service Executive, 2013a).

Waiting lists, an indicator of a services ability to meet demand, have presented concerns internationally, with Australia’s National Youth Mental Health Foundation, “Headspace”, reporting waiting times as a concern for almost ninety percent of their centres (headspace., 2019). The Australian private sector is also showing difficulty in managing demand, with one third of private practices closed to new referrals, and an average waiting time of 34-44 days depending on service needed (Mulraney et al., 2021). While Covid-19 has certainly had an effect on mental health service demand, Australia has seen long waiting lists for some time now, with reports of five to nine months waiting time for CAMHS services in Western Australian in 2012 (Stokes, 2012).

Canada is also facing strong demand for youth mental health services, with Children's Mental Health Ontario reporting *"average wait times for counselling and therapy is 67 days and for intensive treatment the average is 92 days" (Children's Mental Health Ontario, 2020)*. This again seems to be an ongoing concern, with a pre Covid study showing only 31.4% of 116 polled Canadian CAMHS service providers able to meet the benchmark waiting list time set by the Canadian Psychiatric Association (Kowalewski et al., 2011).

With limited staff levels and an increased demand for services, connected health systems can play a role in supporting CAMHS services. One area that may greatly benefit from a connected health system is the treatment of Attention-Deficit/Hyperactivity Disorder (ADHD), a common neurodevelopmental disorder that falls under CAMHS area of responsibility within the Irish health service. As ADHD is a lifelong condition, CAMHS are generally responsible for managing treatment of ADHD until the service user turns eighteen, requiring substantial service resources to effectively manage.

4.2.6 ADHD

Attention-Deficit/Hyperactivity Disorder can be defined as "*a persistent pattern (at least 6 months) of inattention and/or hyperactivity-impulsivity that has a direct negative impact on academic, occupational, or social functioning." (World Health Organization, 2019).* ADHD is a common behavioural disorder, particularly in children, with evidence supporting ADHD symptomatology prevalence in approximately 5% of children (Polanczyk et al., 2007). The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) reports rates to be lower at 2.5%. A study carried out in 2011 on the US National Survey of Children Health reported, of the 11% of children with a historical ADHD diagnosis, 8.8% reported currently having ADHD (American Psychiatric Association, 2013). ADHD is noted as having a negative effect on an individual's social, academic, or occupational performance (de Graaf et al., 2008; Loe & Feldman, 2007; Nijmeijer et al., 2008).

The International Classification of Diseases (ICD) 11 (World Health Organization, 2019) highlights the diagnostic criteria for ADHD, noting two key areas of importance, inattention symptoms and hyperactivity-impulsivity symptoms. Inattention symptoms include, but are not limited to, carelessness or lack of attention to detail to work/activities, difficulties keeping attention on task, difficulties in organization, and being easily distracted by extraneous stimuli. Hyperactivity and impulsivity symptoms include difficulties keeping still while sitting, resulting in fidgets or squirms, running, and climbing when not socially appropriate, and an inability to remain quiet during leisure (World Health Organization, 2019).

ADHD has a profound impact on the daily life of individuals with the disorder (Danckaerts et al., 2010). In childhood, it negatively affects children’s school performance (Barry et al., 2002; Loe & Feldman, 2007; Rapport et al., 1999). The negative impact can be substantial, with Loe & Feldman stating that *“Children with ADHD show significant academic underachievement”* (Loe & Feldman, 2007). Individuals with ADHD show a notable decrease in full-scale Intelligence Quotient (IQ), significantly impaired reading and arithmetic ability estimates when compared to a control group of children without the disorder (Biederman et al., 1996). Executive function deficits have also been demonstrated in visuospatial and verbal working memory (Willcutt et al., 2005).

Childhood interpersonal relations and peer relationships are impacted by ADHD. Young people and children with ADHD can display elevated levels of aggression, difficulties when handling interpersonal conflict, and difficulty in reacting to other individuals appropriately (Buhrmester et al., 1992; Grenell et al., 1987; Nijmeijer et al., 2008). These interpersonal issues extend to family relations, with children with ADHD showing more frequent instances of conflict or impaired cohesion with siblings and parents (Biederman et al., 1996). Those with ADHD may also have an increased risk of injury and negative lifestyle habits. Studies suggest that there is a strong link between ADHD and increased risk of injury (Pastor & Reuben, 2006; Schwebel et al., 2011). Those with ADHD have an increased vulnerability to substance misuse (Charach et al., 2011). The literature supports an increased risk of dependence on substances such as nicotine and other addictive substances (Lee et al., 2011; Wilens et al., 2008).

Of most significance Danckaerts et al. (2010) found that children with a diagnosis of ADHD self-reported lower health related quality of life scores than their peers. This illustrates the importance of supporting and delivering consistent high-quality care and treatment to children and young people presenting to services with a diagnosis of ADHD. Early intervention is critical when supporting ADHD, with studies suggesting that early intervention yields positive results for ADHD sufferers, including managing symptoms and improving social functioning, while reducing risk of anxiety, addictive disorders and academic failure among others (Biederman et al., 2019; Feil et al., 2016; Halperin et al., 2012). As mentioned, ADHD left untreated has profound impacts on a person’s life, and it also presents the possibility of producing Adverse Childhood Experiences (ACEs). ACE’s are negative circumstances which occur in a child’s life before the age of eighteen. Early intervention in cases of ACE has also been shown to have positive results, compounding the need to reduce waiting lists to improve patient outcomes by early implementation of best practice treatment plans (Asmussen et al., 2019).

4.2.7 Dundee ADHD Clinical Care Pathway – A Gold Standard for ADHD treatment

While there are several publications that advise on the treatment of ADHD including the National Institute For Health And Care Excellence (NICE) (2018), one that has gained considerable credibility is that of the Dundee ADHD Clinical Care Pathway (DACCP). This pathway, originally used in Scotland, creates a "*clearly structured, evidence based clinical pathway for the assessment and management of children and adolescents with ADHD*" (Coghill & Seth, 2015) and has been identified in a systems review (Maskey, 2022) as the preferred construct for delivery of high-quality ADHD care in Ireland. This pathway identifies 4 stages in the diagnosis and treatment of ADHD.

Stage 1: Referral and pre-assessment screening – This is the initial stage of the pathway where a referral letter is received by a CAMHS service. This, in most cases, is sufficient to determine if a full assessment is required. In some cases, a more in depth, pre-assessment screening is conducted to ensure that a full assessment is warranted. This screening involves an interview and the completion of questionnaires by parents, teachers and other relevant parties who are in a position to provide additional details to the service.

Stage 2: Assessment, diagnosis and treatment planning – The Dundee pathway sets out standard protocols where the majority of clinical information is received and reviewed by specialist nursing staff, with the role of the doctor confined to diagnosis and treatment planning.

- The information gathering stage involves interviews with the child, parents, and other relevant parties. Educational or school reports are used as initial information sources. Medical history is documented, and a full screening of physical and mental health is conducted. Following this, additional information may be requested where deemed necessary.

- Diagnosis and treatment planning – Once information required has been gathered, a report is sent to clinicians to review and conduct a final assessment appointment to discuss diagnosis and treatment planning with parents and the patient. In the absence of an ADHD diagnosis at this point, follow-up care should be arranged to address any other mental health problems that were identified.

Stage 3: Initiating treatment – Treatment usually involves medications for individuals over 6 years of age, with non-pharmacological treatment employed for those below this age and for those whose parents do not consent to prescribing medication. If treatment is of benefit, any additional or remaining difficulties are addressed. If no benefit is clear from treatment, further options are discussed. Methylphenidate is considered the first line treatment in the absence of co-morbidities or clinical contraindications to its use. Dose titration, where the dosage is optimized for each patient, is used to maximize benefits of medication while limiting possible side effects. Several "titration appointments" are recommended, where weight, pulse and blood pressure are monitored to ensure the health of the patient is maintained. Following a four-week period, an additional meeting with a doctor and nurse is conducted to discuss progress and dosage.

Stage 4: Continuing care/monitoring treatment – Following titration, patients are continuously monitored to ensure safety and to avoid adverse effects of treatment. This ensures that any other problems that may arise are identified and treated where required. For patients receiving medication as part of treatment, appointments are typically spaced 6 months apart are held to ensure patients are responding to treatment, and those who are not being actively treated are followed up on annually to ensure that, if difficulties return, they receive appropriate treatment (Coghill & Seth, 2015).

As part of an action plan to modernize and update CAMHS services to ensure continued provision of CAMHS services within Ireland, several recommendations are made within the Maskey report (Maskey, 2022, p. 8), including "*The CAMHS Governance group should* *explore the options available in ICT to improve the governance, effectiveness, efficiency and accessibility of CAMHS"*. Specifically, adopting electronic health records, electronic questionnaires to replace paper-based approach and the use of telemedicine, are recommended within this report (Maskey, 2022). This highlights an opportunity to embed connected health within the CAMHS services as a critically needed digital transformation is in its early stages within the Irish CAMHS service. To effectively address this opportunity, this paper will look to operationalize the IPJM through the lens of the Dundee treatment pathway.

4.3 Methods

To effectively leverage the IPJM within the context of the Dundee pathway, it is prudent to identify the key benefits of leveraging the IPJM in this context, operationalize the IPJM within this context, and finally review the IPJM with a view to improving its accessibility.

This chapter proposes four research questions to be answered, based on the background research of the topics concerned:

1. How is visualizing the Dundee clinical care pathway beneficial to stakeholders when identifying key requirements for a connected health application designed to support the implementation of the Pathway?
2. How can the Integrated Journey Mapping tool be applied within the context of the Dundee ADHD Clinical Care Pathway?
3. How can the Integrated Journey Mapping Tool be updated in order to improve its accessibility?
4. How can connected health applications embedded within the Dundee pathway improve clinician efficiency?

The first research question relates to establishing the rationale behind mapping the pathway onto the IPJM. This ensures that the undertaking of mapping the pathway has tangible benefits to multi-disciplinary teams. The second question follows by mapping the pathway with the final question reviewing how the IPJM can be improved to increase its accessibility, with particular reference to some of the challenges noted in the original publication (McCarthy et al., 2020).

To populate and verify the IPJM with personas of individuals on the Dundee Clinical Care Pathway, it is important to use a robust and rigorous approach that includes input from clinicians with various backgrounds, as well as academics and HIS professionals, to ensure that the completed visualization is true and accurate to the initial publication. To achieve the desired result, a Design Science approach was used to create and iterate the design of a patient journey map artifact (PJMA).

Design Science is an approach involving "*the creation of an artifact and/or design theory as a means to improve the current state of practice as well as existing research knowledge*" (Vaishnavi & Kuechler, 2021, p. 1). Design science focuses on the development of a new artefact, examples being a diagram, mobile application or graph, as well as the study of the use of the newly created artefact.

The distinction between design research and design science research is a critical one. While Design Science Research (DSR) was initially referred to as "Design Research", it quickly became apparent that a name change was needed as design research has a longstanding link to the field of study which focuses on the concept of design itself. This is distinct from DSR in that DSR aims to provide learnings through the design and development of an artifact whereas design research "*is research about design whereas DSR is primarily research using design as a research method or technique*." (Vaishnavi & Kuechler, 2021, p. 6). This presents a clear motivation for differentiation between both terms.

The output of the design science process should be "*something that is interesting to the research community*" (Vaishnavi & Kuechler, 2021, p. 2). "Something of interest" may include work that creates new knowledge where none previously existed, the implementation of existing knowledge to solve a new problem or the refinement of existing knowledge to better service the relevant stakeholders" (Vaishnavi & Kuechler, 2021). This ensures that the resulting research findings are accepted by the research community and subsequently appropriate for academic publications. The research output for this project consists of this a peer-reviewed, published research paper, which highlights the design of a diagram to visually illustrate the Dundee ADHD Clinical Care pathway, with the artefactual output consisting of the diagram itself.

This chapter aims to ensure that both the artefactual output and design theory are represented by clearly defining the design stages of the PJMA, including illustrating all iterations, while also producing the PJMA that has been validated through a rigorous process to ensure the PJMA is a suitable representation of the Dundee ADHD Clinical Care Pathway. A specific design science research approach, known as the design science research methodology or DSRM (Peffers et al., 2007), will be used for the development of the PJMA.

Design science was chosen as the methodology of choice for several reasons:

1. It is a generally accepted methodology within the IS field that has proven to produce academically rigorous results.
2. It facilitates an iterative process which enables feedback from various stakeholders in order to refine the design of the PJMA.
3. It offers transparency in the development of the PJMA as each version is documented and presented as part of the final publication (Hevner et al., 2004).
4. Its iterative approach facilitates an integrative approach, with feedback from each iteration narrowing the result towards a consensus, similar to other healthcare research methodologies, for example, the Delphi study method (Keeney et al., 2010).

For the demonstration, interviews were conducted with individuals whose professional experience would be relevant to the research area, these include Connected Health Consultants, CAMHS clinicians, and Connected Health Researchers. Interviews were scheduled for 1 hour and generally lasted between 30-45 minutes. One participant provided feedback via email. Table 4.1 gives details of the professionals interviewed during the process. As the area of connected health within ADHD is a novel one, the use of qualitative data gathering and analysis in parallel with design science is viewed as an appropriate choice to build a case study in the area and subsequently identify novel theory in the area (Eisenhardt, 1989).

Table 4. 1 Total number of interviews by Interviewee Category.

Interview Category	Number of Interviews
CAMHS Clinician	3
CAMHS Nurse	1
Dundee Pathway Expert (Via Email)	1
Social Worker	1
Connected Health Researcher	2
Connected Health Consultant	2

Following on from the creation of the modified PJMA, the modified patient journey mapping has been applied to a private ADHD diagnosis and treatment service, and subsequently reflective interviews were carried out to establish the successes of the modified patient journey mapping tool. Individuals were selected using opportunistic sampling (Patton, 2002), and are classified as those who had used the tool in the context of the clinic's system development project. Interviewees included the service's

Managing Director, Head of People, Director of Information, along with the external developer’s success manager.

The UCC Social Research Ethics Committee has approved this research. Informed consent was received by all participants prior to the commencement of an interview. This was achieved by way of an information leaflet highlighting the rationale for the study, how findings will be used as well and how the data will be stored and processed. Participants were then asked to sign a consent form to ensure they had read the information leaflet and were happy to participate. See the appendix provided for details.

Due to ethical concerns, patients were not interviewed. CAMHS deal with adolescents and children who are receiving mental health care and, as such, they are classed as extremely vulnerable. This research focused on mapping the pathway from a clinician’s point of view. The implications of this are discussed in section 4.5.

4.4 Visualizing the Dundee Pathway

The results of each step within the DSRM process for the development of the PJMA can be found below, visualized in figure 4.1, starting with identification of the problem and objectives of a solution. Each iteration receives its own design and development, demonstration, and evaluation sub-section and finally a communication sub-section rounds out section 4.4.

4.4.1 Problem identification and motivation

As mentioned, a connected health project consists of a multi-disciplinary team, many of whom will not have the clinical training or expertise required to understand the treatment pathway of a patient. While an intimate knowledge is not required by every member of the team, it is important that each team member has a high-level understanding of the patient journey to ensure the team remains on track and avoids scope creep.

The Dundee ADHD Clinical Care Pathway is regarded as the gold standard for ADHD treatment in Ireland, with recommendations made to implement ICT within the service where possible (Maskey, 2022). This presents a research opportunity to create a visual representation of the pathway to support the development of a connected health application that guides non-clinical experts through the treatment process and ensures that every member of a connected health project team has an appropriate level of understanding of the treatment pathway.

This also presents an opportunity to update the tools available within the IPJM to improve the accessibility of the tool through the exploration of integrating elements from the Unified Modelling Language (UML).

4.4.2 Objectives of a solution

The objective for this research project is to create an accurate visual representation of the "Dundee ADHD Clinical Care Pathway", which can be used as a visual aid for multi-disciplinary teams during the development of a connected health application that supports clinicians in the implementation of the pathway for the treatment of those diagnosed with ADHD. In order for the visual aid to be successful in conveying the Dundee pathway to viewers, it must do the following:

1. Be true and accurate to the pathway as described by Coghill and Seth (2015).
2. Effectively conveys the clinical journey through the pathway to individuals who have little to no clinical experience in treating or working with individuals diagnosed with ADHD.
3. Create an evaluation of IPJM using principles from UML to create a PJMA.

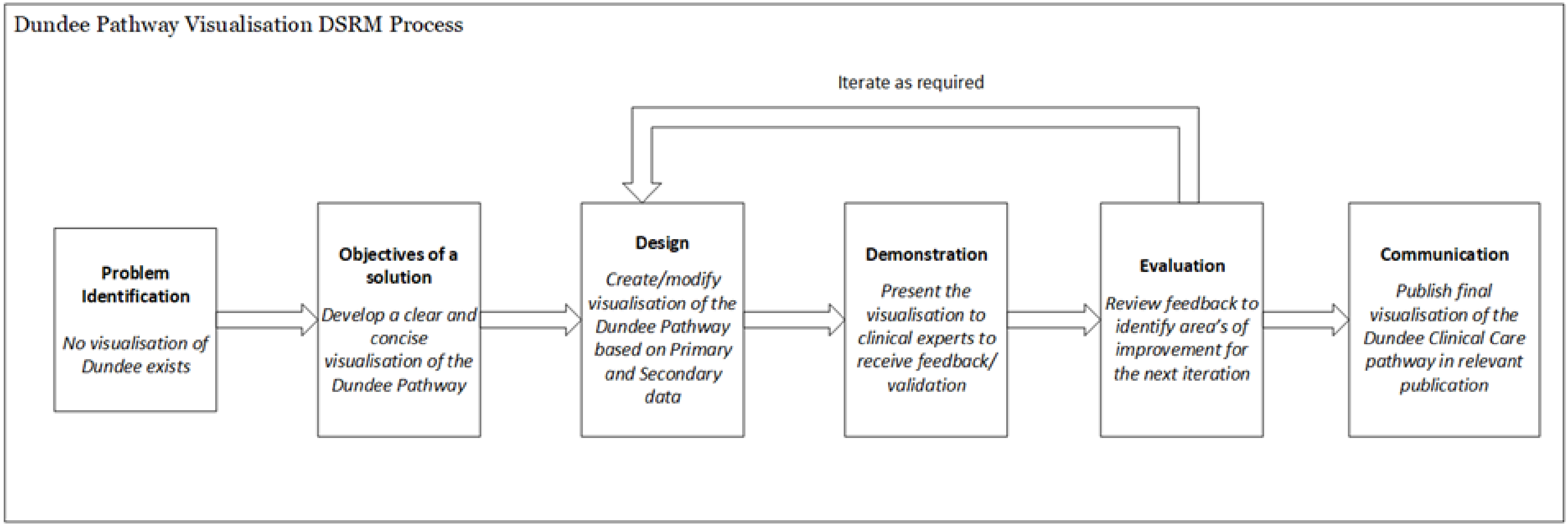


Figure 4. 1 - Design Science Research Methodology as per the project.

4.4.3 Design and Development (Iteration One)

In order to create the initial visualization, two interviews were conducted with a CAMHS clinician and nurse with experience in implementing the Dundee pathway within a clinical setting. These interviews allowed for the gathering of key data that assisted in the development of the first iteration of the visualization. Data collected in this interview, along with a review of both the literature, allowed for the creation of Figure 4.2, the first step in the process of developing a robust and verified PJMA.

The PJMA consists of a number of key areas:

1. The left section of the pathway highlights the patient persona. This iteration of the PJMA contains the patient's name, age, a brief risk profile and a brief summary of the patient's journey.
2. The centre section of the patient journey map highlights encounters that the patient will have with individuals. The individual's relationship to the patient is highlighted on the left, and each point along the journey represents an interaction with an individual or group.
3. The section at the bottom of the map highlights the medical pathway, with details of each interaction to give greater context to each interaction.

Each interaction progresses on to another interaction, with a fork taking place during the "Behavioural Parenting work" to highlight that if this intervention is successful, then the patient may jump straight to the "Continuing Care Appointment" step. If this intervention is not successful, then continuation to titration is highlighted as per the pathway(Coghill & Seth, 2015). The continuing care appointment represents a continuous cycle where periodic check-ins are conducted to ensure the patient remains happy with their treatment. A fork also takes place at the "end of assessment appointment" where if the prescribed medication does not have the desired effect, then an additional round of titration is conducted with a different medication.

Iteration 1 consists of a single persona. Several personas were identified through semi-structured interview with CAMHS clinicians, with the persona in iteration 1 “John” representing a fictitious individual who would engage with every stage of the Dundee pathway. John has no known allergies and has no underlying medical issues. This makes John a suitable persona to illustrate the Dundee pathway in an “ideal” setting. As John has no other medical concerns, it is highly likely that John can progress through the Dundee Clinical Care Pathway as described in the literature, without the need for additional interventions. John does not respond to behavioural techniques but does respond well to the first stimulant tested during titration.

4.4.4 Demonstration / Evaluation (Iteration One)

Demonstration of the first iteration of the PJMA, shown in Figure 4.2, was completed by presenting the PJMA to an expert familiar with the original pathway publication (Coghill & Seth, 2015), and as such, presented an excellent opportunity to ensure the pathway remains true to the original publication. Allowing the author of the pathway to review the first interaction also ensures the PJMA does not misrepresent the original work. Very valuable feedback was received by the author and feedback was generally very positive from the work done. Following an evaluation of the reviewer’s very rich feedback, the following feedback was identified as the key to the accuracy of the diagram:

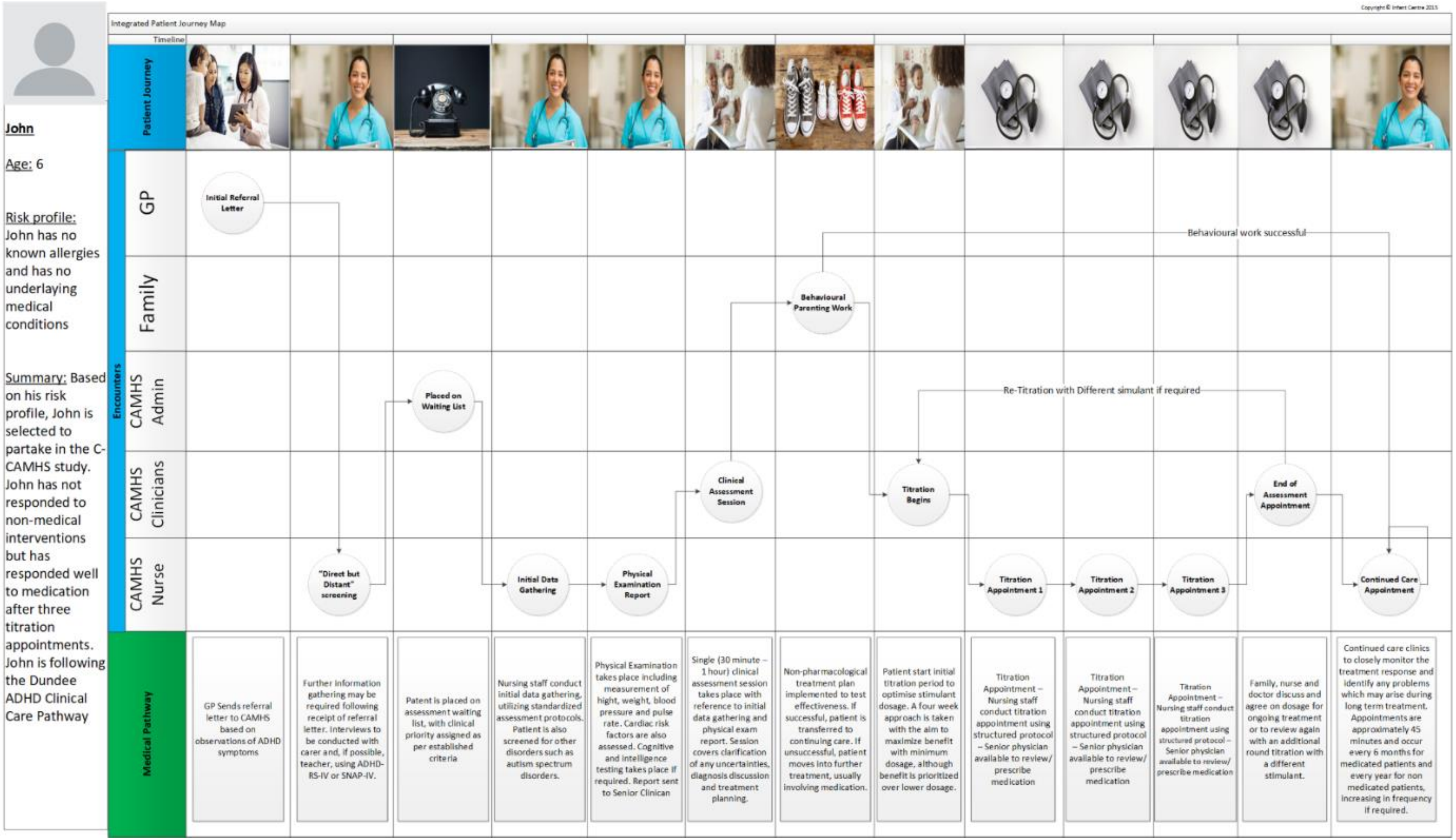
- A lack of enthusiasm towards the pictures used in the “Patient Journey” Section at the top of the Journey map.
- Titration Appointments and continued care appointments were handled by nurses with a “floating doctor” available to assist as required.
- All nurses were referred to as CAMHS clinicians, with very few other allied health professionals including psychologists.
- School information was often gathered through a short but structured narrative report.

- Titration, in reality, was around 4 - 8 weeks.
- "Other problems" appointments are not captured in Iteration 1 of the map, these are ad hoc in nature and are arranged based on things identified during the continued care appointment, or at any stage in the treatment process. The clinician responsible was determined based on the nature of the appointment, including, but not limited to, family or school issues which need to be addressed.

Based on the feedback, it was decided that a second iteration was needed, and the above feedback should be incorporated into the second iteration. General feedback highlights that the PJMA should be streamlined, pictures removed, and ad-hoc appointments should be illustrated in subsequent iterations. Table 4.2 below highlights the interviewees for this Iteration.

Table 4. 2 - Interviews from Iteration 1

Interview Category	**Number of Interviews**
Senior CAMHS Clinician	1
CAMHS Nurse	1
Dundee Pathway Expert (Via Email)	1



John

Age: 6

Risk profile: John has no known allergies and has no underlaying medical conditions

Summary: Based on his risk profile, John is selected to partake in the C-CAMHS study. John has not responded to non-medical interventions but has responded well to medication after three titration appointments. John is following the Dundee ADHD Clinical Care Pathway

GP Sends referral letter to CAMHS based on observations of ADHD symptoms

Further information gathering may be required following receipt of referral letter. Interviews to be conducted with carer and, if possible, teacher, using ADHD-RS-IV or SNAP-IV.

Patent is placed on assessment waiting list, with clinical priority assigned as per established criteria

Nursing staff conduct initial data gathering, utilizing standardized assessment protocols. Patient is also screened for other disorders such as autism spectrum disorders.

Physical Examination takes place including measurement of hight, weight, blood pressure and pulse rate. Cardiac risk factors are also assessed. Cognitive and intelligence testing takes place if required. Report sent to Senior Clinican

Single (30 minute – 1 hour) clinical assessment session takes place with reference to initial data gathering and physical exam report. Session covers clarification of any uncertainties, diagnosis discussion and treatment planning.

Non-pharmacological treatment plan implemented to test effectiveness. If successful, patient is transferred to continuing care. If unsuccessful, patient moves into further treatment, usually involving medication.

Patient start initial titration period to optimise stimulant dosage. A four week approach is taken with the aim to maximize benefit with minimum dosage, although benefit is prioritized over lower dosage.

Titration Appointment – Nursing staff conduct titration appointment using structured protocol – Senior physician available to review/ prescribe medication

Titration Appointment – Nursing staff conduct titration appointment using structured protocol – Senior physician available to review/ prescribe medication

Titration Appointment – Nursing staff conduct titration appointment using structured protocol – Senior physician available to review/ prescribe medication

Family, nurse and doctor discuss and agree on dosage for ongoing treatment or to review again with an additional round titration with a different stimulant.

Continued care clinics to closely monitor the treatment response and identify any problems which may arise during long term treatment. Appointments are approximately 45 minutes and occur every 6 months for medicated patients and every year for non medicated patients, increasing in frequency if required.

Figure 4. 2 First iteration of the PJMA, visualizing the Dundee clinical care pathway as per interview and review of literature – Images under "Patient Journey" provided by Microsoft copyright free, for illustrative purposes only.

4.4.5 Design and Development (Iteration Two)

Creating the second iteration of the PJMA presented the opportunity to include multiple personas in the diagram by implementing UML principles to utilize the encounters as divergence points, or decision nodes, for each persona. It was decided that three personas would be used in the second iteration of the diagram, representing three common patient scenarios, John remains as per iteration one, with Mary and Adam added as additional personas.

- Mary differs from John as she has responded to non-medical interventions and her parents are happy that she does not require medication to manage her ADHD.
- Adam differs from John as he has not responded to non-medical interventions and the initially prescribed stimulant has not had the desired effect, however a second stimulant has proven effective.

To effectively differentiate between each of the personas, colour coding is used to represent each individual on the diagram, John is represented in blue, Mary in pink and Adam in green. Lines in black represent all three personas as the first number of encounters are the same for each persona.

Mary's divergence point is during the "Behavioural work" encounter as this was deemed effective for her and as such was moved straight to "Continued Care". Adam and John continue to Titration where John is successful on his first stimulant, where Adam requires a second round of titration as the first stimulant did not have the desired effect. This is illustrated by "Re-Titration". All three persona's finally reach "Continued Care", which is illustrated by a circular arrow as this is a stage where patients are monitored indefinitely, or in the case of CAMHS until the age of eighteen.

At all relevant stages, an “as required” branch extends out into an “Other Problems Appointment” which illustrates an Ad Hoc appointment that may be necessary to discuss any immediate problems during treatment which may or may not be directly related to the treatment plan in place but may still be of importance to the patient’s overall health and wellbeing.

For iteration two, images were removed from the diagram and replaced with a prominent timeline section. This timeline was identified during the above mentioned semi-structured interviews and represents a best-case scenario for the pathway. Two “wildcards” (X and Y) are included in the timeline. X represents the total number of weeks an individual was undergoing titration, which varies for each patient, and Y which represents an unspecified as/when required timeframe. Encounters have also been updated as per feedback from clinicians. Figure 4.3 highlights iteration 2 in detail.

4.4.6 Demonstration / Evaluation – (Iteration Two)

Evaluation of iteration two took place in two phases. Phase one was clinical verification to ensure the updated visualization was still an accurate representation of the pathway, with phase two involving four interviews of connected health consultants/academics to discussing the merits and drawbacks of the visualization for use as part of a requirements gathering toolset. Table 4.3 below highlights the interviewees for this Iteration.

Table 4. 3 - Interviews from Iteration 2

Interview Category	Number of Interviewees
CAMHS Clinician	2
Social Worker	1
Connected Health Researcher	2
Connected Health Consultant	2

Validation of iteration two came in the form of interviews with two CAMHS clinicians, and a social worker, who has experience working with and/or treating those with ADHD. Overall feedback on the diagram was very positive, with clinicians praising the accuracy and clarity of the diagram. A key theme that was mentioned throughout the interviews was the multidisciplinary nature of CAMHS teams. Several clinicians, including nurses, consultants, occupational therapists, speech and language therapists and social workers are involved in the screening and data gathering process. It is important that these stakeholders are represented in the diagram to ensure their needs are met by any future connected health application.

Another key concern raised is the management of consent. It is critical that informed consent is received at point of referral to ensure that the CAMHS team are given permission to begin the screening process as this involves contacting multiple stakeholders in the patient's life including, but not limited to, teachers, carers, parents or any other relevant care giver. This consent form will need to be well documented in any application in this area. A medication consent form will also need to be produced and signed by the parents at the "Medication Discussion" stage as this protects all parties involved in the treatment process. This medication consent form will also need to be captured by the diagram.

When discussing “behavioural parenting work”, it was noted that many parents do not decide to go down this treatment route as they may have already tried this and concluded that this approach is not a suitable solution for them. As a result, these parents have attended their GP for a referral to CAMHS with the view of beginning pharmacological treatment. This is not, however, the case for all patients and behavioural parenting work may still be a very effective solution for parents when provided with appropriate learning materials and literature.

When discussing the “Other Problems Appointment” encounter, clinicians advise that this appointment generally occurs during treatment, either pharmacological or non-pharmacological, however this can also occur at any stage of the pathway. It was noted that risk is the key driver of these appointments and the relevant clinician responsible and urgency of this type of appointment is directed by the type and severity of the relevant risk. The health and safety of the patient is, as always, the highest priority here.

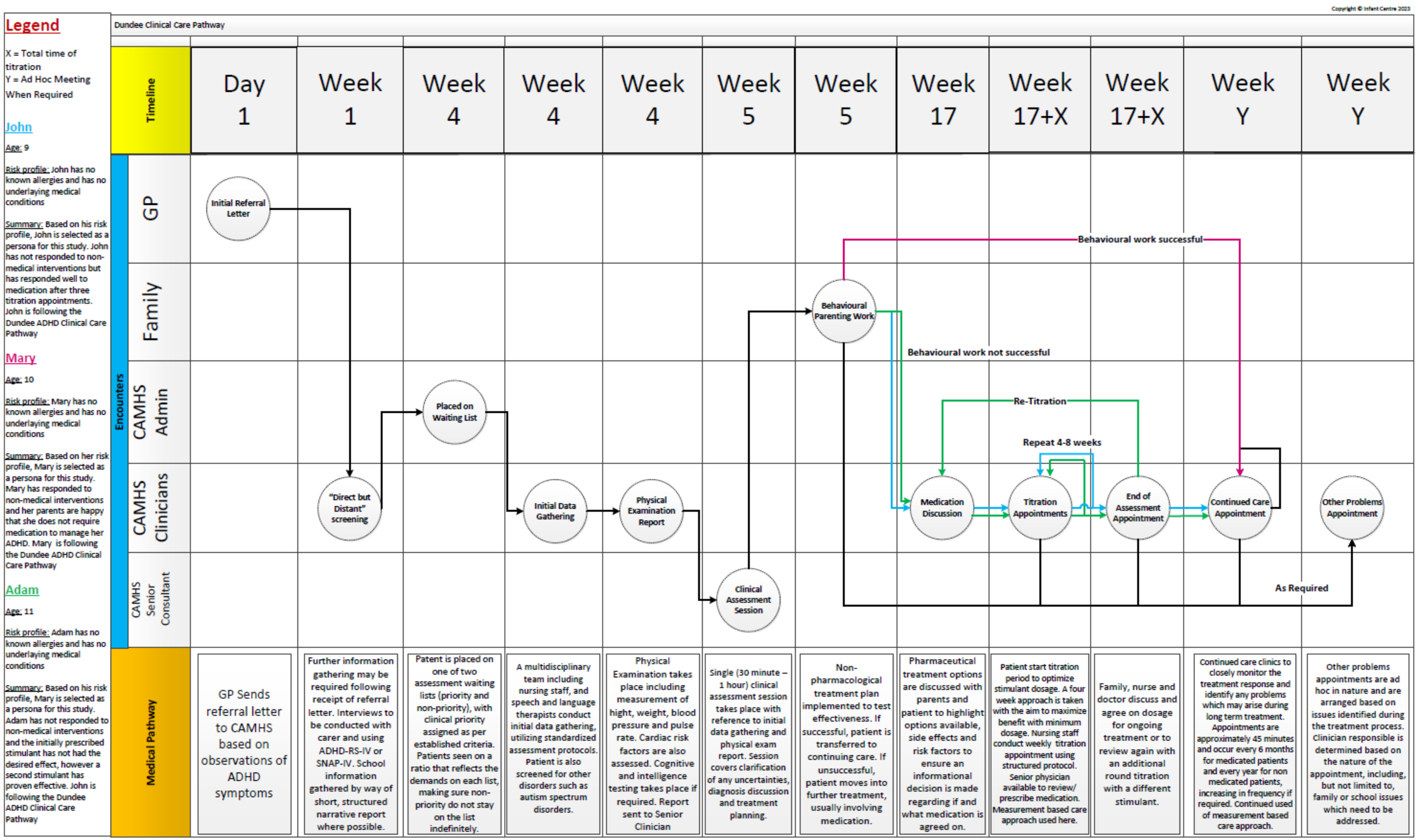
It was highlighted that, if “Behavioural Parenting Work” was successful, typically the patient is discharged from the services instead of being placed on a continued care plan. It was noted that if a patient is discharged in this manner, they can be referred to the service again and would be subject to a much shorter waiting period.

It was noted that patients presenting to CAMHS often have comorbid conditions such as autism spectrum disorder (ASD), which may inhibit the effectiveness of stimulant medications.

Clinicians also advised on the positioning of encounters based on their own clinical practice, with some screening/examinations taking place before or after others depending on the system in place within that specific service. It was, however, agreed that the relevant examinations were identified within the diagrams subject to the above feedback.

Following on from clinical verification of the diagram, the diagram was reviewed by four experts, consisting of connected health consultants and academics to provide feedback and possible areas for improvement. This yielded some very positive feedback, as well as very useful suggestions.

It was noted that the colours for Adam and John personas were quite similar, and hard to distinguish as the shades of blue and green were quite similar. The importance of keeping the visualization to a one-page size was emphasized, as a “one-pager” was viewed as being very powerful from an information conveyance point of view. It was noted that there was a lack of regulatory concerns from a connected health standpoint within the diagram itself. It was suggested that this tool can be used as a multilayered system, where additional information is added on top, similar to “acetate sheets”. It was also noted that this iteration was quite clinically focused, and there is no mapping of the patients “emotional journey” through the service. Use of UML shapes was suggested to highlight where decisions are being made that may change the course of a patient’s journey. The benefits of visualizing the pathway to identify gaps where connected health can be imbedded was mentioned. It was noted that images may be beneficial in visualizing who is responsible for each encounter.



Legend

X = Total time of titration
Y = Ad Hoc Meeting When Required

John

Age: 9

Risk profile: John has no known allergies and has no underlaying medical conditions

Summary: Based on his risk profile, John is selected as a persona for this study. John has not responded to non-medical interventions but has responded well to medication after three titration appointments. John is following the Dundee ADHD Clinical Care Pathway

Mary

Age: 10

Risk profile: Mary has no known allergies and has no underlaying medical conditions

Summary: Based on her risk profile, Mary is selected as a persona for this study. Mary has responded to non-medical interventions and her parents are happy that she does not require medication to manage her ADHD. Mary is following the Dundee ADHD Clinical Care Pathway

Adam

Age: 11

Risk profile: Adam has no known allergies and has no underlaying medical conditions

Summary: Based on his risk profile, Mary is selected as a persona for this study. Adam has not responded to non-medical interventions and the initially prescribed stimulant has not had the desired effect, however a second stimulant has proven effective. John is following the Dundee ADHD Clinical Care Pathway

Timeline	Medical Pathway
Day 1	GP Sends referral letter to CAMHS based on observations of ADHD symptoms
Week 1	Further information gathering may be required following receipt of referral letter. Interviews to be conducted with carer and using ADHD-RS-IV or SNAP-IV. School information gathered by way of short, structured narrative report where possible.
Week 4	Patent is placed on one of two assessment waiting lists (priority and non-priority), with clinical priority assigned as per established criteria. Patients seen on a ratio that reflects the demands on each list, making sure non-priority do not stay on the list indefinitely.
Week 4	A multidisciplinary team including nursing staff, and speech and language therapists conduct initial data gathering, utilizing standardized assessment protocols. Patient is also screened for other disorders such as autism spectrum disorders.
Week 4	Physical Examination takes place including measurement of hight, weight, blood pressure and pulse rate. Cardiac risk factors are also assessed. Cognitive and intelligence testing takes place if required. Report sent to Senior Clinician
Week 5	Single (30 minute – 1 hour) clinical assessment session takes place with reference to initial data gathering and physical exam report. Session covers clarification of any uncertainties, diagnosis discussion and treatment planning.
Week 5	Non-pharmacological treatment plan implemented to test effectiveness. If successful, patient is transferred to continuing care. If unsuccessful, patient moves into further treatment, usually involving medication.
Week 17	Pharmaceutical treatment options are discussed with parents and patient to highlight options available, side effects and risk factors to ensure an informational decision is made regarding if and what medication is agreed on.
Week 17+X	Patient start titration period to optimize stimulant dosage. A four week approach is taken with the aim to maximize benefit with minimum dosage. Nursing staff conduct weekly titration appointment using structured protocol. Senior physician available to review/ prescribe medication. Measurement based care approach used here.
Week 17+X	Family, nurse and doctor discuss and agree on dosage for ongoing treatment or to review again with an additional round titration with a different stimulant.
Week Y	Continued care clinics to closely monitor the treatment response and identify any problems which may arise during long term treatment. Appointments are approximately 45 minutes and occur every 6 months for medicated patients and every year for non medicated patients, increasing in frequency if required. Continued used of measurement based care approach.
Week Y	Other problems appointments are ad hoc in nature and are arranged based on issues identified during the treatment process. Clinician responsible is determined based on the nature of the appointment, including, but not limited to, family or school issues which need to be addressed.

Figure 4. 3 - Second iteration of the PJMA, implementing feedback received from iteration one

4.4.7 Design and Development (Iteration Three)

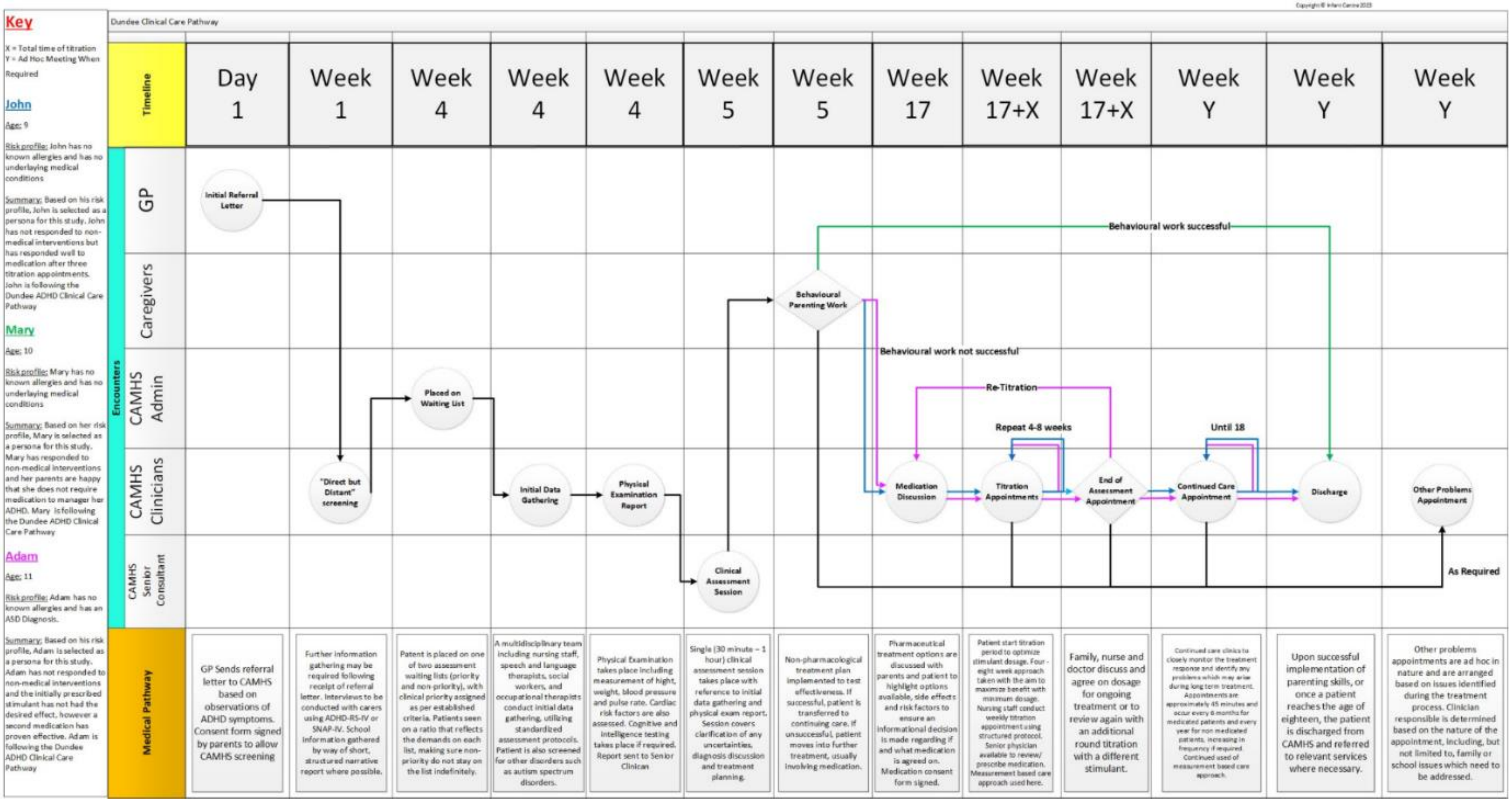
Based on the feedback received from evaluation of iteration two, it was decided that a third iteration of the visualization would be developed. This iteration, as shown in Figure 5.4, has been updated to include the following changes. The Adam persona has been updated to include a comorbid ASD diagnosis; this reflects the commonality of this comorbid diagnosis and likelihood that ASD will impact stimulant performance. Colors of Adam and Mary have been switched to increase the contrast between John and Adam as both occupy similar locations on the diagram. A diamond shape added to illustrate where an individual patient's journey may diverge based on clinical decision making. A discharge encounter added, and an "until 18" note added to the continued care loop to illustrate that patients are discharged after effective behavioural work, or the patient reaches the age of eighteen. Medical pathway section updated to include relevant forms and the multidisciplinary nature of the data gathering process. Legend moved to the top left and highlighted in red to highlight its importance. "Family" encounter updated to "Caregivers" to include teachers, child minders etc.

4.4.8 Demonstration / Evaluation (Iteration Three)

Demonstration of iteration three took the form of email debrief containing Figure 3.3 to ensure that all feedback was taken on board and that participants had the opportunity to present any further feedback. Overall feedback on the third iteration has been very positive and participants have highlighted their anticipation of the full publication of the work. This feedback has given the research team the confidence that the next step for this PJMA is to move on to the "Communication" phase of the design science methodology noted above and compile all iterations, feedback and result into a research piece for consumption by the wider community. Table 4.3 notes the breakdown of individuals receiving a debrief email.

Table 4. 4 - Table of debriefed participants

Participant Category	Number of Interviewees
Senior CAMHS Clinician	1
CAMHS Nurse	1
Dundee Pathway Expert	1
CAMHS Clinician	2
Social Worker	1
Connected Health Researcher	2
Connected Health Consultant	2



Key

X = Total time of titration
Y = Ad Hoc Meeting When Required

John

Age: 9

Risk profile: John has no known allergies and has no underlaying medical conditions

Summary: Based on his risk profile, John is selected as a persona for this study. John has not responded to non-medical interventions but has responded well to medication after three titration appointments. John is following the Dundee ADHD Clinical Care Pathway

Mary

Age: 10

Risk profile: Mary has no known allergies and has no underlaying medical conditions

Summary: Based on her risk profile, Mary is selected as a persona for this study. Mary has responded to non-medical interventions and her parents are happy that she does not require medication to manager her ADHD. Mary is following the Dundee ADHD Clinical Care Pathway

Adam

Age: 11

Risk profile: Adam has no known allergies and has an ASD Diagnosis.

Summary: Based on his risk profile, Adam is selected as a persona for this study. Adam has not responded to non-medical interventions and the initially prescribed stimulant has not had the desired effect, however a second medication has proven effective. Adam is following the Dundee ADHD Clinical Care Pathway

GP Sends referral letter to CAMHS based on observations of ADHD symptoms. Consent form signed by parents to allow CAMHS screening

Further information gathering may be required following receipt of referral letter. Interviews to be conducted with carers using ADHD-RS-IV or SNAP-IV. School information gathered by way of short, structured narrative report where possible.

Patent is placed on one of two assessment waiting lists (priority and non-priority), with clinical priority assigned as per established criteria. Patients seen on a ratio that reflects the demands on each list, making sure non-priority do not stay on the list indefinitely.

A multidisciplinary team including nursing staff, speech and language therapists, social workers, and occupational therapists conduct initial data gathering, utilizing standardized assessment protocols. Patient is also screened for other disorders such as autism spectrum disorders.

Physical Examination takes place including measurement of hight, weight, blood pressure and pulse rate. Cardiac risk factors are also assessed. Cognitive and intelligence testing takes place if required. Report sent to Senior Clinican

Single (30 minute – 1 hour) clinical assessment session takes place with reference to initial data gathering and physical exam report. Session covers clarification of any uncertainties, diagnosis discussion and treatment planning.

Non-pharmacological treatment plan implemented to test effectiveness. If successful, patient is transferred to continuing care. If unsuccessful, patient moves into further treatment, usually involving medication.

Pharmaceutical treatment options are discussed with parents and patient to highlight options available, side effects and risk factors to ensure an informational decision is made regarding if and what medication is agreed on. Medication consent form signed.

Patient start titration period to optimize stimulant dosage. Four - eight week approach taken with the aim to maximize benefit with minimum dosage. Nursing staff conduct weekly titration appointment using structured protocol. Senior physician available to review/ prescribe medication. Measurement based care approach used here.

Family, nurse and doctor discuss and agree on dosage for ongoing treatment or to review again with an additional round titration with a different stimulant.

Continued care clinics to closely monitor the treatment response and identify any problems which may arise during long term treatment. Appointments are approximately 45 minutes and occur every 6 months for medicated patients and every year for non medicated patients, increasing in frequency if required. Continued used of measurement based care approach.

Upon successful implementation of parenting skills, or once a patient reaches the age of eighteen, the patient is discharged from CAMHS and referred to relevant services where necessary.

Other problems appointments are ad hoc in nature and are arranged based on issues identified during the treatment process. Clinician responsible is determined based on the nature of the appointment, including, but not limited to, family or school issues which need to be addressed.

Figure 4. 4 - Third iteration of the PJMA, implementing feedback received from iteration two

4.5 Discussion

This discussion section presents a commentary on each of the research questions, informed by the research conducted in this chapter in the order in which they are asked. Following on from this commentary, recommendations are presented for how connected health systems can be imbedded into the Dundee ADHD Clinical Care Pathway.

4.5.1 RQ 1 How is visualizing the Dundee clinical care pathway beneficial to stakeholders?

Research question one relates to why utilizing IPJM to visualize the Dundee clinical care pathway presents benefits to stakeholders when attempting to identify key areas where connected health can be embedded. Feedback from clinicians and IS professionals suggests that utilizing the modified IPJM diagram as presented in this paper effectively conveys the Dundee pathway to non-clinical audiences, enabling them to assimilate the information and subsequently facilitating more in-depth and focused conversations with clinicians when identifying pain points and opportunities for connected health adoption. Low code/No code (LC/NC) development techniques can be leveraged for rapid prototyping, using journey mapping as a guide, to quickly design and develop relevant connected health applications to embed within the patient pathway. Design science approaches can be used to quickly iterate the design of an application based on feedback and LC/NC can assist in the rapid deployment of updated iterations to support clinical needs.

Based on the feedback received from clinicians and IS professionals, the PJMA diagram as presented was well received by both groups. One may infer that visualizing the Dundee pathway is of benefit to stakeholders who are of a non-clinical background when used as a visual aid to bring them up to speed on how the Dundee Clinical Care Pathway works. Connected health applications are multi-disciplinary in nature and therefore require input and contributions of individuals outside the clinical field. Ensuring all team members working on a connected health project are aware of the standard care pathway is critical to a well-designed connected health application.

4.5.2 RQ 2 How can the IPJM be applied in the context of the Dundee Pathway?

Question two pertains to how the integrated patient journey mapping tool can be implemented utilizing the Dundee Clinical Care Pathway as a use case. Figure 4.4 illustrates the Dundee pathway on a modified integrated patient journey map, whose accuracy is verified by clinicians working in the field. This journey map may serve as a starting point for future research in connected health application design and development by effectively illustrating the Dundee pathway to non-clinical connected health team members, the benefit of which has been highlighted in the answer to research question one.

4.5.3 RQ 3 How can the Integrated Journey Mapping Tool be updated in order to improve its accessibility?

Research question three focuses on how the integrated patient journey mapping tool can be modified to enhance its accessibility. During its original publication, it was noted that the substantial size of the diagrams was a concern. Leveraging UML techniques allows for a more compact view of the patient's journey which facilitates the condensing of the diagram onto a single A4 form factor.

Connected health consultants and academics interviewed particularly noted that the one-page nature of the diagram is extremely powerful when conveying the details of the

Dundee pathway and conveying the complexity of care to the IS professionals working on a potential connected health design and implementation project. It was also noted that visualizing the pathway in this way presents connected health consultants with a clear way to identify gaps where connected health systems can be embedded to provide clinicians with the most effective way to follow the pathway.

The PJMA diagram is a clinical pathway representation and, as such, focuses on the pathway from the point of view of the clinician. There is certainly scope for future research in this area, focusing on the pathway from the patient's perspective, which will certainly yield valuable information in continuing research in this area. Individuals who are using CAMHS services for ADHD treatment fall under multiple vulnerable categories as they are children/adolescents who are receiving mental health services and as a result, the interview of these individuals being impractical at this stage of research due to ethical considerations. This resulted in the diagrams being heavily focused on the clinical and information technology side of the process. The PJMA diagram is a clinical pathway representation and, as such, focuses on the pathway from the point of view of the clinician.

4.5.4 How can connected health applications embedded within the Dundee pathway to improve clinician efficiency?

From a review of the final diagram as shown in figure 4.4, one can identify a number of areas where connected health can be effectively embedded. The "Discreet but Distant Screening" phase presents the opportunity to move from a paper-based approach to a software-based approach. This has the benefit of allowing the system to analyse and produce results visible in a clinician portal. The paper-based screening process takes a substantial amount of time, time which would be available to clinicians to see other patients using the software-based approach. Allowing a patient/ parent to fill in relevant screening information via a connected health application, which offers the opportunity to introduce the individual to an application early in the treatment pathway, creating a sense of familiarity with the application which will prove beneficial during later stages of the pathway.

Another area that presents an opportunity for connected health integration to the pathway is during the “Behavioural Parenting Work” phase. A connected health application can present caregivers with relevant information such as text, audio, or video supports that are provided to support this phase of treatment. An application may also take feedback from the caregiver and feed this information back to clinicians, who can see which techniques yielded positive results and those that did not. This allows clinicians to receive a clear and detailed picture of what is effective and subsequently allows them to make more informed decisions.

The “Continued Care Appointments” Phase presents an opportunity to utilize remote patient monitoring using Bluetooth connected devices such as blood pressure and heartrate monitors as well as smart weight scales. These devices may be connected to the application using established protocols and allow for the readings to be transmitted directly from the device to the connected health application which will subsequently send the information to the clinician portal, eliminating the need for manual entry and thus eliminating the risk of human error when inputting results.

This chapter has presented the Dundee clinical care pathway in a modified Integrated Patient Journey Map, allowing for a visual aid that has assisted in identifying the above opportunities for embedding connected health into the Dundee Pathway. The modified journey map has also addressed some limitations noted in the original publication. Utilizing Unified Modelling Language UML techniques, similar to Curry et al. (2006), and colour coding has allowed multiple personas to be mapped onto one diagram, while also condensing the size of the diagram to a single page representation. This addresses one of the key limitations of the original IPJM publication, which highlighted the need for a larger page/screen to accommodate the entire diagram. The PJMA proposed in this paper can be represented in a smaller page as text on the diagram is set to a minimum of point 12 font size, ensuring readability on a standard A4 sheet. Interviewees made particular reference to the value of the one-page nature of the modified diagram. The UML techniques employed allow for the presentation of clear focal points where clinical decisions divert individual persona’s trajectory on the pathway based on individual patient needs/circumstances.

Presenting multiple personas on the journey map allows for greater scope when examining the pathway. The Integrated Patient Journey Map traditionally captured one persona on each diagram, requiring multiple diagrams to represent multiple personas effectively. The condensed version of the pathway offers several benefits to its users, such as quickly identifying areas where connected health applications can be utilized to best serve individual patients. The single page nature of the modified pathway diagram enables robust conversation between clinicians and information systems consultants to effectively map out a number of patient journeys and subsequently note possible areas for connected health adoption. This tool may also highlight pain points within the process, most notably during interviews where clinicians are free to voice specific issues they are facing at stages within the pathway, subsequently presenting the opportunity for connected health systems to reduce or eliminate the impact of these pain points of the service efficiency.

4.6 Recommendations

This study has also leveraged its findings to make some key recommendations for where connected health may be embedded into the Dundee Clinical Care Pathway. While not an exhaustive list, and there is scope for further research in this area, recommendations made for embedding connected health into the clinical care pathway are as follows:

1. Leverage software-based screening questionnaires to reduce clinician administrative overhead.
2. Utilize software-based teaching materials, including digital content libraries using text, audio and/or video, to assist in the non-medical intervention stages of the pathway.
3. Adopt smart remote monitoring tools, for example Bluetooth blood pressure cuffs, to streamline the continued care process with the aim of reducing the number of required continued care appointments while maintaining a high level of oversight and care for patients.

Figure 4.5 highlights these recommendations in an abstracted view of a potential future connected health application which leverages the aforementioned recommendations. The top layer of this diagram illustrates the web and mobile nature of the proposed connected health application. The subsequent layer represents the operational areas for this application, specifically within the home, community, and ward settings. The third level highlights two distinct touchpoints: the first being the patient-facing application, which gathers vital information from both home and community settings and feeds this data into the connected health architecture. The second touchpoint being the clinician support system, operating in community and ward environments, which assists medical professionals in making informed decisions based on data provided by the connected health architecture. Finally, the base of this illustration highlights the pertinent details associated with the Connected Health application. These include digital health records, questionnaire results, blood pressure readings, and patient information resources

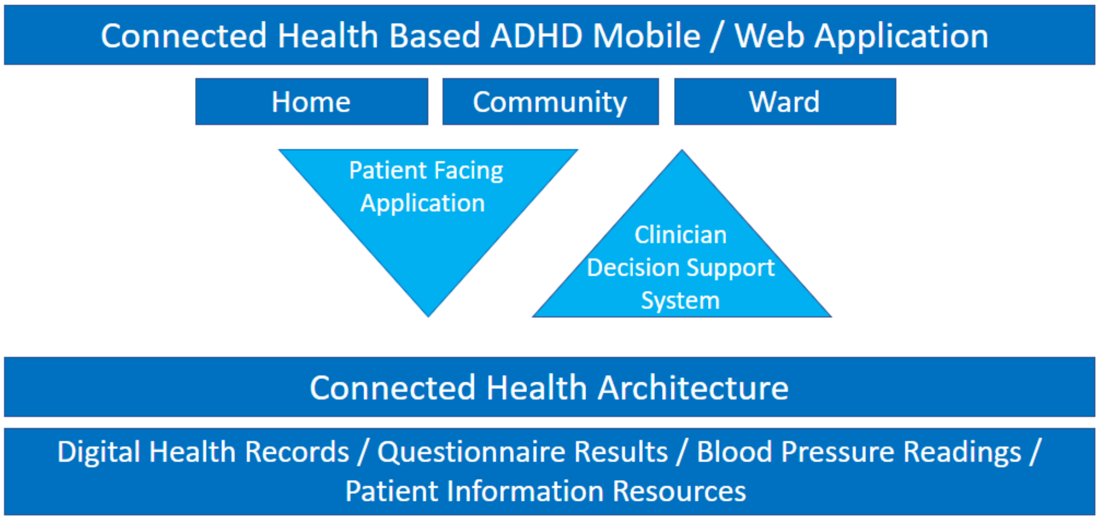


Figure 4. 5 - Abstract view of potential connected health application leveraging recommendations. Modified from (Harris et. al, 2022)

4.7 Practical Applications of Clinical Journey Mapping

To review the practical effectiveness of the patient journey mapping tool identified in this chapter, it was utilized to map out key requirements for an electronic health record system for a private mental health service (Company A). Company A seeks to implement an electronic health record management system. This system is essential for effectively managing patient records, providing clinical guidance, and supporting clinical decision-making.

This process involved mapping the patient's journey through various stages within the service using the modified integrated journey mapping tool. The resulting journey map was then presented to an external software engineering team (the implementation partner) to convey the pathway's complexity, thus ensuring their system could capture all pertinent information and accurately reflects the service's flow. This system is provided by a leading software-as-a-service provider and thus requires numerous configurations to ensure it accurately reflects the patient journey and captures all required information at various stages. It is therefore critical that implementation partners have a clear understanding of the patient journey to ensure successful implementation and adoption of the system.

The initial step involved designing the patient journey map to convey system requirements. This map was created through internal meetings and included all pertinent encounters, device touchpoints, details, timelines, and points of divergence, noted as diamond shapes. Once created, the artifact was presented to the implementation partner. This presentation aimed to convey both the nuances of the patient journey and the system requirements, while also serving as a discussion aid for addressing any areas of concern and establishing key system requirements based on the journey map.

Subsequently, reflective interviews were conducted to evaluate the relevance and effectiveness of using the integrated patient journey mapping tool for discussions and requirements gathering. The interview protocol, detailed in the appendix, includes ten questions related to the general experience of using the journey mapping tool as a requirements conveyance tool. These questions addressed understanding, clarity, usability, engagement, effectiveness in requirements gathering, comparison with previous methods, improvement suggestions, and future use.

Reflective interviews were conducted with internal parties from Company A including the managing director, director of information, and head of people along with the implementation partner’s client success manager. Interviews were analysed using reflexive thematic analysis (Braun & and Clarke, 2019) to ensure insights were appropriately identified and categorized, accurately presenting each interviewee's perspective.

The interviews revealed a highly positive perception of the integrated patient journey mapping tool from all participants, with participants noting that implementing the patient journey map for both requirements gathering and conveyance was highly effective. There was consensus that the tool, when applied during the requirements gathering process, provided significant value across several key requirement areas identified by the interview questions in the protocol. While the general feedback was overwhelmingly positive, several suggestions for improving future implementations of the patient journey mapping tool were noted and will be discussed in this section.

4.7.1 Pilot Study Findings

A number of key themes emerged throughout the interviews. Firstly, it was deemed essential for a facilitator to be present during the integrated patient journey mapping exercises. Participants noted that the facilitator's role is to guide participants through the process and provide context on effectively utilizing the tool, while ensuring participants remained on task. A number of quotes from interviewees underscore this theme and highlight the facilitator's importance, as noted below:

“Where there is facilitated sessions, like in terms of mapping to create the map, I think that's where the secret sauce is” - Interviewee 3

“What I go back to you Richard, it was I think it was your you needed to be there ... there needs to be that person with that. If I had gone on it myself, let's say I would have really struggled.” - Interviewee 4

"It was people who were very much experts, leading the process and so the engagement with it was very well facilitated. And I wonder if it was being brought to a team who had less experience with it or less expertise with it. Would it be as effective? Would there be? Potential obstacles for them engaging with it." - Interviewee 2

Another prominent theme was that the diagram fostered a shared understanding of the patient journey among all participants. The journey mapping tool facilitated consensus by serving as a central point where comments and concerns could be raised and debated within the requirements gathering team.

"The opportunity to discuss that gets easier and the ability the ability for us to build a shared understanding gets easier. Inviting people into the conversation is easier." – Interviewee 3

"Yeah, I mean the diagram in terms of that, that journey sort of enhanced well, now I'm going to change this significantly enhanced our understanding of the patient journey." – Interviewee 1

"Building that shared understanding, you can see how it works really well when visualized and displayed and obviously interacted with. That's really good." - Interviewee 3

"Maybe imagining what it would look like bringing it to other stakeholders to say this is our system. This is our pathway. I think it really clearly outlines what that process looks like" – Interviewee 2

Participants noted the iterative nature of the diagram was very powerful for both engagement and collaboration. It was found that the diagram significantly enhanced both aspects. It allowed individuals to comment on specific parts of the diagram, fostering debate and ensuring that any issues or concerns were addressed.

"So, if you are iterating and people are coming together on multiple occasions will then engagement is almost happening by design." – Interviewee 3

I liked that it was very. Iterative... it was something that could kind of as we had different meetings around it and kind of gathered more information or clarified something or realised that something needed to kind of be changed, that there could be different versions of it that kind of updated with us as we went along the process. – Interviewee 2

"It really did facilitate, I would say, focused discussions and encourage stakeholder participation around a clear structured conversation around specific stages of the patient journey" – Interviewee 1

The ease of understanding and engaging with the journey mapping exercise across various iterations was also highlighted. Participants found it straightforward to resume discussions after breaks, as the diagram provided a clear reference point for continuing valuable conversations efficiently.

"It's very easy to remember or to continue on from where you stopped, even if that was only before a lunch break, after a lunch break...I think the one thing you do get is you know where you've stopped, and you know where you can continue from." – Interviewee 3

From the implementation partner's perspective, feedback on using the diagram as a requirements gathering tool was also very positive. Typically, they gather much of this information themselves; however, in this pilot study, the integrated patient journey mapping tool streamlined this process before their involvement. The implementation partner emphasized that having a facilitator conducting this work greatly benefits the project overall. Although there is a cost associated with hiring a qualified facilitator, this expense was viewed as an investment rather than a cost, highlighting its net positive impact on project development and delivery within a healthcare organization.

"I would say it more changing that word to investment. It would have, it'd be an investment having somebody that has these capabilities and real you know understanding of what that looks like." – Interviewee 1

Additionally, it was noted that the diagram was easy to understand for software engineers who were not directly involved in the requirements gathering process. The iterative nature of the diagram allowed for ongoing discussion and modification to reflect changing system requirements. This iterative process facilitated engagement and helped identify gaps and pain points that needed addressing in the new system.

Overall, these insights underscore both the strengths and potential enhancements for future implementations of the integrated patient journey mapping tool in requirements gathering processes within healthcare organizations.

" it was shared. Uh internally...... 3-4 people say they get it and it does this and it does that. But different people with different personalities and different of processing information. Might see things slightly differently or have different questions and that did not happen It was very clear. So what that tells me is that I should tell you is that that should be shared or could be shared in a number of different arenas." - Interviewee 1

For improvement, one suggestion was to adopt a layered approach to add more context to the diagram. For instance, incorporating icons into action bubbles or decision points could illustrate device touchpoints driving specific engagements. An example given was using a WhatsApp icon to indicate communication via WhatsApp with clients and service users.

"Within the patient journey map that might allow you to introduce certain icons and those icons could potentially further enrich aspects of, we'd say a process or a step. Or an activity that you're calling out in a particular cell...... Or if we were maybe using a particular set of technologies that they could be icons maybe.....In our case, for instance, WhatsApp is an element of something that gets done, so you might have the icon of maybe WhatsApp." – Interviewee 3

Additionally, an interactive layer could provide further context when users click on specific action bubbles, offering detailed documents that elaborate on particular actions without cluttering the main diagram. It was also noted that, while the journey mapping tool was very useful within an iterative setting, it would be of less benefit if used in a single event setting.

"you might even click on a click on one of, you know, one of the what you want to call it squares one of the boxes, let's say in that diagram. And it populates this text. This rich text that captures an awful lot of detail about that.....minimize it or maximize it, something like that" – Interviewee 4

"But if you decided to use your tool only once in a single sitting. I think engagement could be lesser." – Interviewee 3

4.7.2 Pilot Study Findings

Based on the pilot study, it can be inferred that using integrated patient journey mapping has the facility to stimulate debate within a multi-disciplinary team, create a shared understanding of a complex patient journey by visualizing the journey in a condensed yet insightful manor, and creates an environment where system pain points can be identified and discussed to ensure a future connected health system can effectively meet these needs.

4.8 Conclusions

The multi-disciplinary nature of connected health projects requires resources be made available to allow non clinically focused members of the team to effectively get up to speed with the clinical requirements of a particular project. Clinical journey mapping provides a way for team members to get both up to speed on clinical practices, while also presenting a way for teams to identify key gaps where connected health systems can be embedded in the pathway to facilitate better use of clinical resources and ultimately provide better patient outcomes. Pilot study results indicate that the use of modified integrated patient journey mapping presented in this chapter have tangible benefits from both a requirement gathering and conveyance perspective.

Continued research in this area is welcome as continued progress in youth mental health, as well as healthcare as a whole, is of upmost importance to the success of future generations. Specifically, research into the design and implementation of the connected health systems which will embed themselves into the Dundee ADHD treatment pathway will be critical for the continued development of, and success of, Youth mental health services supporting those with ADHD around the world. Research in the area of software-based screening questionnaires, remote vital sign monitoring, and software-based teaching materials to support those with ADHD and their families.

4.9 Future Research

The PJMA diagram is a clinical pathway representation and, as such, focuses on the pathway from the point of view of the clinician. There is certainly scope for future research in this area, focusing on the pathway from the patient's perspective, which will certainly yield valuable information in continuing research in this area. Individuals who are using CAMHS services for ADHD treatment fall under multiple vulnerable categories as they are children/adolescents who are receiving mental health services, ethical concerns resulted in the interview of these individuals being impractical at this stage of research. The research team has subsequently focused on the clinician and information technology side of the process. The PJMA diagram is a clinical pathway representation and, as such, focuses on the pathway from the point of view of the clinician. Due to the formative nature of this research, further work in this domain from the point of view of the patient may yield additional value.

Further case studies of the modified patient journey mapping tool may be beneficial to establish its applicability over a wider use case. The possibility of applying the modified patient journey map for other services, for example for acute mental health issues or adult ADHD treatment, presents itself. The mapping process may yield tangible benefits for services specialising in these areas when conducting a digital transformation or EHR adoption.

Chapter 5: Risk-Benefit of Connected Health-Led Digital Transformation: A Case Study in Child and Adolescent Mental Health Service Clinical Decision-Making Support

A condensed version of this chapter has been published as *Harris, R., Murray, D., & Adam, F. (2024). Risk-Benefit of Connected Health-Led Digital Transformation: A Case Study in Child and Adolescent Mental Health Service Clinical Decision-Making Support. Journal of Decision Systems – supplemental issue 1, 1-12.* https://doi.org/10.1080/12460125.2024.2336272

Richard Harris (RH) Statement of Contribution: RH conceptualized and designed the chapter, reviewed and revised the chapter as per feedback and guidance from supervisors (FA and DM), and peer reviewers of the above publication. RH gathered and analyzed all primary research data under the guidance of supervisors.

5.1 Abstract

A digital transformation within a health service presents unique risks and benefits when compared to other organisations (Thakkar & Davis, 2006; Upadhyay & Hu, 2022). This case study aims to identify the key risks and benefits of a connected health led digital transformation within Irish community Child and Adolescent Mental Health Services (CAMHS). Qualitative analysis, consisting of interviews with clinical personal within the CAMHS service, was carried out to identify and analyse the key risks and benefits which are discussed in this chapter. Key areas of concern include electronic health records (EHR), telemedicine, and mHealth adoption within the CAMHS service. Twenty-one benefit factors were supported by 98 mentions (average = 4.7 mention per factor). Twenty-nine risk factors were supported by 76 mentions (average = 2.62). While the information presented offers little that is unexpected, they are critical for empirical

validation of these factors through interviews with key stakeholders in the CAMHS domain which underpins the research presented in this thesis.

5.2 Introduction

The area of telemedicine, and its recent focus on connected health solutions, has the potential to deliver solutions to long-lasting, particularly thorny problems faced by modern societies through digital transformation. Arising from the development of these new applications of technology and their applications to clinical contexts, the potential to deliver decision support systems that serve the greater good is evident *(World Health Organization, 2011)*.

Whilst the impact of digital transformation has been demonstrated in a number of areas of public life, it remains to be seen whether connected health solutions can deliver solutions that are a good fit in the medical area, given its acute requirements in terms of confidentiality, robustness and ethics (Thakkar & Davis, 2006; Upadhyay & Hu, 2022)

To explore the risk and benefits arising from connected health solutions, we focus on the area of Child and Adolescent Mental Health Services (CAMHS) and conduct interviews with a panel of experts to tease out the potential for positive and negative impacts of the digital transformation of these acute services.

CAMHS was selected as it is a critical service in the mental health domain and one which is under incredible pressure at the current times, with waiting lists (Finnerty, 2023) that are not compatible with the quality of care which the population of modern economies are entitled to (Maskey, 2022; United Nations, 1989). Crucially, the area of CAMHS is one where delayed treatment decreases the likelihood of positive outcomes. Therefore, using connected health solutions, in this area, seems like it could deliver crucial benefits; however, there is also a need to understand the risks that could arise from their application, especially in situations where the possibility of harm is high (World Health Organization, 2003).

Thia chapter first considers the mechanisms of digital transformation, particularly as they apply to the healthcare area. The methodology employed in this research project is then presented. In the following section, the findings arising from our interviews with experts are analysed. The chapter concludes that, given a proper understanding of the context of use, the application of connected health to CAMHS is the right way to go.

5.3 Background

Digital Transformation, as defined by Vial, *is "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies"* (Vial, 2019). When viewing digital transformation within the healthcare domain, several key technologies come into focus, including telemedicine, mHealth, eHealth, and electronic health record systems. (Kraus et al., 2021). These technologies also form the basis of connected health systems, with connected health being defined as encompassing "*terms such as wireless, digital, electronic, mobile, and tele-health and refers to a conceptual model for health management where devices, services or interventions are designed around the patient's needs, and health related data is shared, in such a way that the patient can receive care in the most proactive and efficient manner possible" (Caulfield & Donnelly, 2013, p. 704)*.

As mentioned, there are a number of connected health solutions that drive digital transformation within a connected health context. Electronic Health Records (EHR) play a key part in the successful implementation of a digital transformation in the healthcare context. EHRs are systems that contain the results and details of both clinical and administrative contacts between the service provider and the service user, including information such as medication, progress notes, and lab results (Ambinder, 2005; Menachemi & Collum, 2011). EHRs provide the clinical decision-making team with a central source of truth to access, review and share clinically relevant information in a timely manner, a critical component of connected health (Caulfield & Donnelly, 2013; Upadhyay & Hu, 2022). Benefits of EHRs include real-time access to patient data, reduced time spent on paper documentation, effective report generation, facilitating effective audit, effective exchange of clinical information between staff, and reduced costs (Thakkar & Davis, 2006; Upadhyay & Hu, 2022). Some risks identified include technical issues preventing access to patient data, security, overreliance on EHR, inaccurate data entry, overwhelming complexity of the system, and decreasing face-to-face time with patients (Thakkar & Davis, 2006; Upadhyay & Hu, 2022).

An effectively implemented EHR system also facilitates the use of other health technology systems such as mHealth. The WHO has defined mHealth as "*medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices (World Health Organization, 2011, p. 6).* With modern mobile phone adoption rate at approximately seventy-three percent worldwide (International Telecommunication Union, 2022), and the rate of internet access increasing from approximately forty percent in 2015 to over seventy percent in 2023 (International Telecommunication Union, 2023b). This growth in internet connectivity is particularly prevalent in the United Nations "Least Developed Countries" list, with broadband connections growing substantially from 1.3 per 100 people in 2011 to 42 per 100 people in 2022 (International Telecommunication Union, 2023a)

mHealth applications have proven to be effective in continued monitoring of patients in high income countries like Ireland; where for example, the Learning to Evaluate Blood Pressure at Home (Leanbh) study has shown positive results when applying remote blood pressure monitoring for the detection of pre-eclampsia (Harris et al., 2022).

With the increasing adoption of both Internet and mobile phone ownership, telehealth is becoming a more viable option for many service providers in areas with limited resources. The WHO defined mobile telemedicine as "*the communication or consultation between health professionals about patients using the voice, text, data, imaging, or video functions of a mobile device" (World Health Organization, 2011)*. Mobile telemedicine can also be used in the management of chronic diseases, as well as providing care to those who are in underserved areas where resource shortages prevent or restrict access to specialised care. Patients, community health workers and physicians across urban and rural areas can be connected via mobile telemedicine, ultimately increasing healthcare quality and reducing referrals (World Health Organization, 2011).

One area that could benefit from the reduction of referrals is the Child and Adolescent Mental Health Service (CAMHS). CAMHS is responsible, as the name suggests, for the provision of mental health services to those under the age of eighteen within the Republic of Ireland. Article 24 of the Convention on the Rights of the Child notes *"States Parties recognize the right of the child to the enjoyment of the highest attainable standard of health and to facilities for the treatment of illness and rehabilitation of health."* (United Nations, 1989). The World Health Organization highlights the need for adequate mental health services, stating that *"The lack of attention to the mental health of children and adolescents may lead to mental disorders with lifelong consequences, undermines compliance with health regimens, and reduces the capacity of societies to be safe and productive." (World Health Organization, 2003)*. It is therefore critical that both state-run and private health services have access to the best and most up-to-date technologies to support them in the provision of adolescent mental health care.

A prevalent diagnosis within CAMHS is Attention-Deficit/Hyperactivity Disorder (ADHD), defined as "*a persistent pattern (at least 6 months) of inattention and/or hyperactivity-impulsivity that has a direct negative impact on academic, occupational, or social functioning." (World Health Organization, 2015, 2025).* ADHD is a somewhat common behavioural disorder, and while figures differ, reports indicate a 5% prevalence in children (American Psychiatric Association, 2013; Polanczyk et al., 2007), with the US National Survey of Children's Health indicating a rate of 7.9% with a current ADHD diagnosis (HRSA, 2014). ADHD is noted as harming an individual's social, academic, or occupational performance (de Graaf et al., 2008; Loe & Feldman, 2007; Nijmeijer et al., 2008). Individuals with ADHD have been shown to have a notable decrease in full-scale IQ, with significantly impaired reading and arithmetic ability, with executive function defects also present (Biederman et al., 1996; Willcutt et al., 2005)

With a rising demand for services, Irish CAMHS have struggled to meet recruitment targets to keep on top of the rise, with the service falling short of recommended staffing levels (Health Service Executive, 2013a). To tackle the shortfalls of the CAMHS services, the *Maskey* report (2022) highlights "*The CAMHS Governance group should explore the options available in ICT to improve the governance, effectiveness, efficiency and accessibility of CAMH" (Maskey, 2022).* Recommendations for the implementation of Telemedicine, adoption of electronic health records, and utilisation of electronic questionnaires are all recommended in the report.

5.4 Methodology

The implementation of connected health solutions and decision support in the area of CAMHS is quite a difficult endeavour, due to the significant ethical and clinical considerations involved: CAMHS patients, as well as being an underage population, are also amongst the most vulnerable groups of patients in the clinical realm. Given the very limited scope for experimentation as even observational studies are very difficult to set up from an ethical approval perspective, given the extremely vulnerable population, with participants being adolescent under the care of a mental health service, it was decided to rely initially on expert opinion to investigate what people at the core of the CAMHS services. This was considered to be an appropriate way to identify opportunities and risks inherent in the digital transformation of services dedicated to the mental health care of young patients.

Seven clinicians were interviewed to identify key areas of benefit and concern when implementing connected health-led digital transformation, with specific reference to telemedicine, EHR and mHealth (Comprising remote patient monitoring, digital questioners and digital content library). Interviewees were selected based on their professional experience and all had clinical expertise in the area of child and adolescent mental health services. Interviewees were based in Ireland and available for remote interview. Table 5.1 provides a list of the experts interviewed for this research study.

Table 5. 1 - List of interviewees

Interviewee	**Title**
1	Senior CAMHS Registrar Trainee
2	Senior CAMHS Registrar
3	Senior CAMHS Registrar Trainee
4	CAMHS Consultant Psychiatrist
5	CAMHS Consultant Psychiatrist
6	CAMHS Consultant Psychiatrist
7	Adolescent Psychiatrist

To ensure the capture of relevant opinions, we approached experts acting in different capacities and playing complementary roles within a regional CAMHS service. Table 2 shows the demographics of our sample of experts with respect to the role they play in CAMHS. The addition of practitioners with various levels of expertise allowed the consideration of potential issues that could emerge with less experienced practitioners, but the majority of informants were quite senior in CAMHS.

Table 5. 2 -Demographics of the expert sample

Title	Number of Participants
CAMHS Consultant Psychiatrist (CCP)	3
Senior CAMHS Registrar (SCR)	1
Senior CAMHS Registrar Trainee (SCRT)	2
Adolescent Psychiatrist (AP)	1

Interviews were recorded and transcribed systematically to allow for a complete thematic analysis of the data captured. This yielded just under 200 pages of text which were analysed using a colour-coded system with two raters involved. The author of this thesis acted as the primary rater, with a supervisor offering reflection and guidance as required.

Reflexive thematic analysis (Braun & and Clarke, 2019) of the data was conducted to identify the relevant risks and benefits described in the interviews. Further analysis allowed us to gather these factors in a number of categories. The review of the entire corpus revealed relevant risk or benefit categories which were coded in a risk-benefit matrix, where each point of interest can be presented, and commonalities identified and visualised. The analysis and the matrix are presented in the next section.

5.5 Analysis of the interviews

5.5.1 Examination of the Benefit factors

Thematic analysis (Braun & and Clarke, 2019) of the interviews yielded a total of 21 benefits listed under three broad categories (see table 3). These were related to: the implementation of an Electronic Health Record (EHR) based system (6 benefit factors), the general concept of Telemedicine (4 benefit factors) and the reliance on m-Health (11 benefit factors).

The m-Health category was the most discussed with a total of 11 factors which were further categorised under three sub-headings: remote screening questionnaires, remote vital signs monitoring and software-based teaching and education material.

Across all the matrix, benefit factors received from 7 mentions (meaning that all interviewees mentioned it) to one single mention (where only one interviewee mentioned it). In consideration of the fact that statistical significance was not a feature of the research study and that the important feature was that a broad range of views from expert holding relevant positions in the CAMHS environment be collected, we did not discriminate amongst factors based on the number of mentions, although table 3 is ranked in decreasing order of the number of mentions, to analyse the extent to which a particular factor was universally considered important.

Table 5. 3 - Reported benefits of connected health solutions in CAMHS

	SCRT 1	**SRT 1**	**SCRT 2**	**CCP 1**	**CCP 2**	**CCP 3**	**AP**	**Total**
Benefit								
EHR (6 Benefits)								
Standardised Structure	X	X	X	X	X	X	X	7
Connected (Streamlined Transfer of Information)	X	X	X	X	X	X	X	7
Records not going missing/damaged	X	X	X	X	X	X		6
Bad Handwriting Removed	X	X	X	X	X	X		6
Greater Oversight		X	X	X		X	X	5
Remote Prescriptions	X				X			2
Telemedicine (4 Benefit)								
Accessibility (Patients access to clinicians)	X	X	X	X	X	X	X	7
Time Saved (Stable Patients)	X	X	X			X	X	5
Connectivity with Other Clinicians	X		X	X				3
Approachable for Technology Literate individuals	X		X					2
MHealth Applications (11 Benefits)								
Remote Screening Questionnaires								
Time Saved (Automatic Grading)	X	X	X		X		X	5
Prevents loss of form	X	X			X		X	4

Speed of Return (Reminders)	X	X			X		X	4
Software Based Teaching Material								
Flexibility	X	X	X	X	X	X	X	7
Access to trained clinicians	X	X		X	X			4
Time Saved (Decreased number of queries)					X			1
Remote Vital Sign Monitoring								
Time savings (Data is transferred directly without appointment)	X	X	X	X	X	X		6
Progress charts	X		X	X	X	X	X	6
Accessibility	X	X	X	X	X			5
Greater Adherence to best practice	X			X	X		X	4
Accuracy (Less stress at home)						X	X	2

In respect to the first category – Electronic Health Record – the benefits mentioned were related to the increased robustness afforded by an essentially paperless digital system. The existence of a standardised and structured and streamlined process was noted as a positive. One clinician noted *"I think actually putting this structure on the workflow, obviously in keeping with best clinical practice is really positive to support clinicians"*.

Permanent records and no more handwritten material was perceived to be a critical benefit, one clinician noted that clinicians have "appalling handwriting" with another noting situations like *"People not be able to read handwriting pages, (Pages) falling out, files being lost, even damage and fire and stuff like that."* . It was also noted that EHR can assist with increased scrutiny and greater oversight on patients, with a clinical noting *“They've also got advantages in terms of accuracy and Audit trails and all the rest of It”*

The data processing advantages of being able to issue remote electronic prescriptions was also noted. These are prima facie “ERP-like” advantages which could be identified in the implementation of any large-scale integrated system and can be characterised in terms of the healthcare system catching up with other industries where ERP applications have been implemented to date.

Under the general telemedicine heading, interviewees noted that the increased connectivity afforded by connected health solutions was a clear benefit. The possibility of accessing up to date, even near real time data on patients and their evolution and reactions was a game changer. The further possibilities of inter-clinician communication, synchronous or asynchronous, across medical facilities (where patients need to access different services at the same time), were also recognised as facilitating the proper execution of treatments and accelerating their adaptation to changing conditions.

It was noted that, particularly for patients on medication, the use of telemedicine would be useful for monitoring patients, one clinician noted that telemedicine, in combination with other treatment approaches, can be used to *“check in with them to make sure that they're not having some obvious side effects, and I think you could save a huge amount of time”*.

The m-Health category listed factors related to the development of specific features built into specific mobile applications, based on recommendations made in chapter 4. The remote monitoring of vital signs was noted as it can be a lead indicator of patient evolution and can mean that patients can be in the community, at home, or treated by their GPs rather than confined to hospital wards for part of their treatment. One clinician noted “*So I mean yes, so advantage would be that you know we can get a more* *longitudinal clinical information, not just one snapshot in the clinic*". Another clinician noted the benefits of remove monitoring tools *"through their interactions with all their systems and through wearables and all of that sort of interesting stuff, which is very early days, and that whole idea of digital biomarkers and all, and that can then be integrated with electronic record system data and all that stuff."*

The use of on-line / app-based screening questionnaires was also flagged as critical. It can be used as a mechanism to accelerate the triage of patients, leading to the faster identification of acute cases. One clinician noted that there would be *"massive time saving."*. This is particularly important where long waiting lists exist, in a medical specialty where delays in implementing a treatment plan can lead to rapid further deterioration.

One further area was mentioned by most interviewees, that of software-based educational material, which included the possibility to get immediate access to senior clinicians to respond to acute cases. The flexibility that this afforded was recognised by all informants.

In all, while the benefits listed in table 1 do not contain novel elements within the context of connected health literature, it was useful to see them validated by expert clinicians and furthermore to realise that there was a keen interest in and detailed understanding of the role a connected solution could play in the delivery of a CAMHS service. In order to avoid the hype sometimes associated with IT and the digitalisation of processes, it was imperative to ensure that the key actors in CAMHS understood the potential of connected health and agreed that digital transformation is worthy of consideration. One clinician noted that *"If you had the software right, having this technology right, I don't see why ADHD ever would need to darken the door of the clinic"*

It does not mean however that the implementation of such solutions is without problem or difficulties, as the examination of the risks perceived to be associated with connected health in CAMHS indicates. These are examined in the next section.

5.5.2 Examination of the Risk factors

The thematic analysis of the interviews yielded a total of 29 risks listed under the same three broad categories as were used to categorise the risk factors (see table 4). The use of the same headings facilitated the emergence of a rigorous risk / benefit analysis pertaining to the implementation of connected health solutions in CAMHS.

Table 5. 4 - Reported Risks of connected health solutions in CAMHS

Risks	**SCRT 1**	**SRT 1**	**SCRT 2**	**CCP 1**	**CCP 2**	**CCP 3**	**AP**	**Total**
EHR (7 Risks)								
Electronic Data Protection (Hackable)	X	X	X	X	X		X	6
Adoption/Buy-in (Parent or Staff)	X	X	X	X	X			5
IT Support	X	X		X	X		X	5
Technology Availability /Literacy (Digital Divide)				X	X	X	X	4
Project Scale		X	X		X			3
Duplication of data		X						1
Risk of Data loss during transition		X						1
Telemedicine (9 Risks)								

Lack of view to body language	X	X	X	X	X	X	X	7
Difficulty making connections	X		X	X	X		X	5
Quality Internet Connection		X	X	X		X		4
Lack of direct access in case of necessary intervention (Self harm etc...)	X		X	X				3
Lack of Direct Social Interaction	X				X			2
Possible lack of empathy	X						X	2
Lack of Cultural Awareness (Fully Remote)	X							1
Recording without consent	X							1
Patient Acceptance of Telehealth				X				1
MHealth Applications (13 Risks)								
Remote Screening Questionnaires								
Ease of use / Design	X			X		X		3
Lack of paper trail (Teachers need hard copy of documents sent)					X	X		2
Software Based Teaching Material								
Moderation (Correct/ Up to date Information)	X	X	X	X				4
Interaction Needed		X	X					2
Confidentiality	X							1

Parents Perception of Education	X							1
Bias of choices based on order of material seen				X				1
Patients not Creating Connections through meeting in person						X		1
Remote Vital Sign Monitoring								
Accuracy (Erroneous Readings)	X					X		2
Scale of trials required (To establish correct norms)				X		X		2
Governance				X			X	2
Practicalities of working with Children with ADHD (Keeping monitor on at home ETC etc)				X				1
BP Reading Tolerances (Child BP readings harder to detect and establish norms)				X				1

Likely reflecting the critical nature of the care provided in CAMHS and the vulnerability of the patients accessing such services, there were more risk factors than benefit factors mentioned in our interviews. Under every category, more risk factors were mentioned by the interviewees, although some of these factors are less broadly supported (ie: not mentioned by as many interviewees) than the benefit factors listed. The 21 benefit factors were supported by 98 mentions (average = 4.7 mention per factor) whereas the 29 risk factors were supported by 76 mentions (average = 2.62). This indicate a more diffuse perception of the risks involved in comparison of the benefits sought, which seemed to be obvious to a greater proportion of experts. This can be viewed as reflecting of a cautious approach towards a transformation which has the potential to result in radical changes for a critical service. Other research has identified that, whilst the potential benefits of digital transformation in healthcare are evident, it is taking time to achieve them due to resistance to change and the need to present a clear business case, and demonstrable positive impacts on health outcomes before any changes can be implemented (Iyanna et al., 2022).

Under the EHR heading, the experts expressed worries pertaining to the robustness of digital solutions in the face of malicious attacks. When discussing a recent cyber-attack, one clinician noted *"if they were electronic (patient records), we would have found it very difficult and not been able to access any of the patient records"*. Interestingly, while the risk of a cyber-attack does present a risk, the lack of EHR's within CAMHS actually protected the service during a cyber-attack *"We experienced the cyber-attack in the HSE and ironically we didn't have much trouble with it really because our system is behind the curve, not being electronic"* This presents a case for ensuring there is a non-electronic record backup system.

They were also concerned that connected health solutions might face issues with staff and patient adoption, especially where technophobia might be present, which may aggravate underlying symptoms of stress and anxiety. *"they (parents) might not be much into smartphones and digital learning some have, you know, poor skills on how to navigate through different software"*. As with any implementation of IT, they feared that the lack of familiarity with certain technologies might have a bearing on the efficacy of digitally enabled solutions.

Overall, the issue of IT support and IT resilience was a concern for many of the experts interviewed. Such concerns are likely to be related, at least in part, to the recent experiences of the Irish healthcare systems with a malicious attack which, as noted above, paralysed the majority of the sector for weeks in 2022 (Health Service Executive, 2023a). Such a scenario arising within a CAMHS service at national level would be a disaster and this was on the mind of interviewees. Lessons from previous experiences of digital transformation failure within the Irish heath service, such as the "Personnel, Payroll, and Related Systems" (PPARS) system implementation failure (Sammon & Adam, 2008), must also be examined to ensure that a repeat such failings does not happen again. Such failures can have large scale consequences for public organisations, such as parliamentary inquires, as was the case with PPARS (Sammon & Adam, 2008). The high profile nature of public project or service failures can have large scale impacts on the public's trust of a service, which in the case of CAMHS, has already been diminished as a results of the Maskey report (Maskey, 2022).

Under the general heading of telemedicine, the experts interviewed referred to the potential risks already listed in existing literature on the implementation of IT in medicine. The introduction of mediating technologies, the lack of direct contact and the potential distance introduced between clinicians and their patients were all commented upon. It is certain that the need for empathy and direct intervention, ever present in the medical field, is particularly significant in the CAMHS area and therefore, any connected health solution implemented in the care of CAMHS patients requires specific design features in this respect, as well as a high grade of resilience, for instance, access to high speed, reliable internet connections.

The m-health category offered the greatest fragmentation, only one factors being mentioned by at least 4 interviewees and 11 of the 13 factors mentioned by only 1 or 2 informants. This fragmentation is likely to be due to the lack of a precise vision of how a connected solution application – one that would focus on ADHD for instance – would operate in the real context of a CAMHS service. To the extent that such applications do not exist as of yet, it is natural that even experts may be drawn to speculation about the potential impact of solutions that have yet to be conceptualised.

In the detail of the concerns expressed, some of them are clearly related to fear about the resilience and safety of the technology itself, whereas others, perhaps more important for the future of connected heath solutions, are related to the difficulties inherent in designing the functionalities of such systems. Of particular note is the concern expressed over the size of the trials that would be required to properly establish the effectiveness of the would-be technology enhanced care pathways. The case of younger patients, whose treatment needs particularly fine titration was raised as one which could present impossible challenges for connected health solutions.

5.6 Discussion

The findings from these interviews align with existing literature (Iyanna et al., 2022; Raimo et al., 2023) focusing on digital transformation within healthcare. They are, however, critical, as they arise from our interviews with experts in the CAMHS area, the focus area of this thesis and, as such, ensure that the nuance of the CAMHS service is capture when establishing risks and benefits within the service. Whilst CAMHS is an area where enhancements in the care pathways are needed, as indicated by the long waiting lists, and whilst experts are well aware of the potential for connected health solutions to deliver such improvements, there remains a level of concern and uncertainty in relation to the development and implementation of such solutions. While there is strong support for connected health-lead digital transformation within the service, there are key risk factors that clinicians are cognisant of, and which ultimately, may lead to a reduction of digital technology within a certain section of the service. The following sections provide a commentary on each of the noted technologies (EHR, Telemedicine and mHealth mobile applications).

5.6.1 Electronic Health Records.

Those interviewed identified several risk and benefits of EHR’s, and there appears to be the most consensus from participants when discussing this particular element of a digital transformation. The most noted concern from clinicians was that digitization of records presents the risk of data breaches as vectors of attack are opened when exposing records in a digital format. The Irish health service is acutely aware of this issue as it has been subject to a wide scale cyber-attack (Health Service Executive, 2023b) in 2021 which resulted in 90,000 individuals being contacted regarding the breach of information. This has naturally caused an increased hesitation for the adoption of digital records as paper records are viewed as “unhackable” due to their non digitized nature.

Other key issues of note were the lack of IT support within the Irish Health Service at present, with participants noting that current support systems in place would not be capable of managing such a large-scale digitisation. Users buy-in issues were also noted, with a number of Irish health service staff employed to manage and maintain paper-based records, with a view that resistance from these employees may hinder the ability for successful implementation of a EHR within CAMHS. Some participants also note that there may be some clinical staff who may not be technologically literate enough to effectively use the new services, which may lead to resistance and pushback should a new system be mandated, putting additional pressure on an already overstressed service.

While there was consensus on the risks of an EHR implementation within CAMHS, there was also clear consensus on the associated benefits of EHR implementation. A streamlined and consistent structure of records was noted as the most cited benefit of EHR implementation, as participants noted that current, paper-based record keeping is often fragmented with some records deviating from standards established. A EHR system was noted as having the ability to enforce standards, ensuring records are captured effectively, ensuring no required information points are missing and that records fall within established ranges.

Participants also noted the benefits of being able to access patient records from anywhere within the Irish Health Services network. It was noted that many clinicians travel between surgery/community centres and that, should a record not be available in the location required, the clinician may have to request the file be moved, or in more urgent cases, retrieve the file themselves. Having access to a patient record as required allows clinicians to plan for patient interactions effectively and ensure they can remain effective during an ever-changing CAMHS environment.

Another benefit of note was the removal of handwriting from the patient record, ensuring that information is not miss-interpreted. This can be critical when dealing with medications for young individuals as a miss-interpreted order may have serious consequences. Participants also noted that EHR's add the ability for greater governance and oversight during periods of review as traditionally, paper-based records needed to be painstakingly reviewed to ensure the effectiveness of the service during an audit. With EHR, an oversight/audit committee can be granted access to the relevant system as required to conduct a review, without the need to manually review paper-based records. This issue was also highlighted during the Maskey report as a number of non-digitised records were lost before the look back review team had the chance to digitise them (Maskey, 2022). Such loss could have been avoided with a properly implemented EHR.

5.6.2 Telemedicine

When prompted by the notion of telemedicine within CAMHS, a key area of concern of those interviewed was the loss of the ability to immediately intervein if a particular service user has a deterioration in their mental state. When in person, should such a deterioration occur, intervention can be immediate and appropriate. During remote sessions, by the very nature of the technology used, the clinician is not physically present and, as such, limited in the types and speed at which interventions can be implemented. Similarly, those interviewed noted that there is a distinct lack of viability of facial and/or body language ques that are fundamental to the diagnosis process of certain mental health conditions, with particular reference to ADHD and anxiety disorders. Interviewees note that these cues can be suppressed or hidden during a remote intervention/ appointment and subsequently may make the process of diagnosis difficult.

In the case of telemedicine, it is therefore suggested that, due to the nature of the risks identified, that telemedicine may not be appropriate for initial consultations with patients and during initial diagnosis appointments. It is clear that clinicians require in person appointments, where interventions can be immediate and subtle cues can be identified, in order to provide a safe and effective clinical process. Other risks noted include a lack of ability to form therapeutic relationships/connections and the lack of empathy that can form from an online appointment also support the unsuitability of telemedicine during initial appointments.

Clinicians did however note that telemedicine is very effective when communicating with individuals who have an established treatment protocol and relationship with their clinical team. This suggests that telemedicine can be used as a form of “Continued Care” tool as many service users remain service patients until the age of eighteen, when they are subsequently discharged. As such, should a patient be on a stable treatment plan from the age of twelve, this presents six years of follow up/ monitoring from CAMHS until discharge in the case of medicated patients. Telemedicine can decrease the burden of such monitoring by ensuring patients do not have to travel to community care facilities to be effectively monitored, and clinicians have the ability to work remotely in any setting with suitable privacy and internet connectivity.

5.6.3 mHealth

Within mHealth, three particular interventions were discussed in order to frame the discussion. These where remote patient monitoring, a digital learning space for parents and digitised screening questionnaire. These three areas were identified from recommendations from the Maskey report, and recommendations made in chapter four. This particular section was the most fragmented, from both a risk perspective, with only one factor reaching four mentions. This may highlight that the service may not have a coherent understanding of the impact mHealth can have. This appears to be a natural consequence of an underdeveloped ICT infrastructure and culture within the Irish Health Service.

There is, however, a good level of consensus from when conceptualising benefits for mHealth within the service, with nine out of eleven identified benefits having four or more mentions. This suggests a positive outlook among clinicians as to the possible advantages that connected health systems can bring to CAMHS within the Irish Health Service.

When presented with the implementation of digitised screening questionnaires that form part of the ADHD diagnosis process within CAMHS, benefits identified related to the speed and accessibility of the information. Participants identified that, as a potential mobile application has the ability to automatically grade screening questionnaires, that there would be a timesaving benefit for clinicians who would implement this potential application. It was also noted that, as the app is a digital application and not a physical paper questionnaire, service users would not lose access should an individual piece of paper be mislaid.

When discussing software-based teaching materials, the key benefit identified by participants was that of its flexibility. It presents the opportunity for parents to take advantage of learning materials at a time and place that suits them.

Remote vital sign monitoring can be a key element of mHealth applications, and this concept was also discussed with participants. Time saving and the ability to create progress charts were identified by most participants as key benefits of remote patient monitoring. The ability to request vital signs remotely from patients provides clear timesaving benefits from clinicians as they do not have to go to the process of booking and attending an appointment for what can be seen as routine checking of vital signs such as blood pressure and heartrate. It was also noted that this benefit also extends to service users, as they do not need to travel to the clinical site for this appointment. This travel time can often be measured in the hours and naturally may add stress to the service user and subsequently reduce compliance with appointments. Remote monitoring has the potential to greatly reduce this risk and increase compliance with regular vital sign monitoring.

While there are fragmented views on the risks involved in using mHealth, some notable risks identified. The need to keep all material up to date and ensure no information is regarded as outdate, ensuring the accuracy of remote vital sign readings, and issues surrounding governance were noted as possible risks.

In a paradoxical way, areas where improvements are most needed are sometimes the areas where patients are the most vulnerable and where radical changes, for instance digital transformation enabled changes, are the riskiest. The usual technology related fears – adoption issues, technology literacy, fear about resilience and malicious attacks – are very present in the mind of practitioners. These are added to other concerns relating to the uncertainties that remains in relation to the design of specific applications, which surface as soon as the discussion shifts from a general view of connected health towards specific applications, focused on specific conditions – eg: ADHD or other mental health conditions.

Crucially, experts point out that, even where excellent designs are proposed, there would remain unsurmountable difficulties in ascertaining the exact norms to build into applications. It is not only technological solutions that are needed: it is also the redesigned underlying care pathways that complex multidisciplinary teams must come together to develop. The ethical difficulties inherent in such analysis and design work cannot be overstated and one isolated point made by one of the experts interviewed illustrates this: referring to the provision of app-delivered questionnaires for the assessment of young patients in the 12 month waiting list which characterises CAMHS services in Ireland, one expert commented that it would inconceivable to mention the concept of suicidal ideation to a child or teenager on-line, as this would more than likely be the first time they are exposed to it explicitly and the impact of this would be totally unpredictable. Given greater visibility on acute cases that are lost in the queue and should be treated as a matter of urgency is immediately attractive to CAMHS experts, but the practicalities of implementing this visibility are not yet understood. Ethical considerations preclude any experimentation in this regard. No relevant category of patients could safely be involved in such experimentation.

5.7 Conclusion

Connected health systems, within the broader telemedicine / m-Health area, have the potential to help attenuate the effect of the “perfect storm” (Harris et al., 2022) facing healthcare systems around the world. The CAMHS area is one where the storm is particularly strong and where the impact of patients having to wait for treatment aggravate the severity of their symptoms, as well as complicating their recovery.

Experts are convinced about the potential of digital transformation in the area of healthcare generally, but they have many concerns about the practicalities of implementing connected health solutions in CAMHS, due to a combination of fears attaching to the resilience of technology in general and the difficulties associated with defining the requirements of connected health solutions in CAMHS and of discovering the scientific evidence required to prove the positive impact on health outcomes and underpin the new, redesigned care pathways. The expertise to build such applications is extremely diverse, rare and indeed, some of it does not yet exist.

Chapter 6: Towards a Sustainable Approach to No Code Development of Connected Health Application: A Case Study in Adolescent ADHD Care

A condensed version of this chapter is planned for submission to an appropriate academic journal.

Richard Harris (RH) Statement of Contribution: RH conceptualized and designed the chapter, reviewed and revised the chapter as per feedback and guidance from supervisors (FA and DM). RH gathered and analyzed the majority of primary research data under the guidance of supervisors, the exception is observational study data for DMH-H. This study was designed and carried out by Dr Mohd Faisal as clinician with RH designing DMH-H system architecture and developing the DMH-H app.

6.1 Abstract

The Child and Adolescent Mental Health Services (CAMHS) within the Republic of Ireland are under immense pressure to manage patient loads while ensuring the highest standard of care. The Maskey and Finerty reports have highlighted a number of deficiencies within the services that have exposed service users to unnecessary risk. The Maskey report highlights the need for ICT implementation within the CAMHS service to bring the service up to 21st century standards. The objective of this chapter is to attempt to provide an understanding of the applicability of no code development platforms to assist in the digital transformation required within the CAMHS service. A design science research approach has been used to create a case study artifact, Connected Child and Adolescent Mental Health Services (C-CAMHS), following the design science research methodology highlighted by Peffers et al (Peffers et al., 2007). Interviews and focus groups were used as the primary information gathering techniques, along with the use of the System Usability Scale. Overall, findings suggest that the use of a dual platform no

code application design process can prove both effective and efficient in creating connected health applications to assist in the digital transformation within a community mental health service. A second case study application, Digital Mental Health – Hub, was created to test the effectiveness of no code platforms in a clinical environment, yielding positive results. No code platforms provide researchers with the ability to quickly create and iterate design science artifacts within a connected health setting, giving rise to a subgroup of citizen developers, “citizen researchers”. Further research is needed to quantify the benefits in a more tangible manner; however, the results of this work appear promising.

6.2 Introduction

Connected Health, as described by Caulfield and Donnelly, is “*a conceptual model for health management where devices, services or interventions are designed around the patient’s needs, and health related data is shared, in such a way that the patient can receive care in the most proactive and efficient manner possible*” (Caulfield & Donnelly, 2013, p. 704). From this definition, three pillars emerge: interventions, services, and devices. Connected health systems leverage each pillar of the connected health ecosystem to provide the best quality care possible for patient by ensuring the smooth transfer of information between all relevant health care provision stakeholders (Cathal Doyle et al., 2013; Harris et al., 2022; McCarthy et al., 2020). For connected health to be as successful as possible, services need to be designed with connected health in mind, ensuring that IT devices are integrated directly into the service offering (Caulfield & Donnelly, 2013; Harris et al., 2022). When discussing connected health from an information technology (IT) point of view, key systems that come to the fore, include mobile health, telemedicine, Internet of Things (IoT) for healthcare, and health information systems (HIT) (Caulfield & Donnelly, 2013; Colorafi, 2016; Dey et al., 2017)

6.2.1 Telemedicine

Telemedicine is an “umbrella term that encompasses any medical activity involving an element of distance” (Wootton, 2001). It involves leveraging telecommunications networks to provide healthcare when the patients’ physical presence is not required. Telemedicine has been leveraged throughout high income countries, with the UK’s “NHS 111” urgent call line providing 24-hour access to a trained healthcare adviser (National Health Service, 2019).

6.2.2 Mobile health

Mobile health (mHealth) is the use of mobile devices to facilitate communication and healthcare service provision and is found within the connected health ecosystem. The WHO, through the Global Observatory for eHealth, has defined mHealth as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices” (World Health Organization, 2011). mHealth applications have been leveraged across the world, with Apple, Google and others providing smartphone users with an array of healthcare focused applications. One way to increase the rate at which connected health applications can be produced is through the use of Low-Code Development Platforms.

6.2.3 Low-Code Development Platforms

Low-Code Development Platforms (LCDP), as the name suggests, are platforms that provide users with a suite of tools that allow for the creation of software applications, while keeping code writing to a minimum. These platforms are generally targeted at those who have little practical coding knowledge/experience, often referred to as ‘citizen developers’ (Carroll et al., 2021). This is achieved through the use of graphical user interfaces that utilize visual diagrams, drag and drop features, and declarative language to create a high level of abstraction from the source code (Alamin et al., 2021; Gomes & Brito, 2022; Khorram et al., 2020). Gartner group highlights that LCDP’s, at minimum, must include ‘Low-code capabilities’ (through model-driven or graphical programming approaches) to develop a complete application; support for interfaces, business logic, workflow, and, data services, as well as simplified application development, testing and deployment should be present (Vincent et al., 2022)

While the citizen developer is a key target for LCDP’s, it is not the only group that can benefit from the platform, with experienced developers also benefiting from the speed and ease at which applications can be developed using these platforms, with Gartner highlighting that software engineering leaders must *“accept the march of progress to higher abstraction levels for application development and embrace low-code to accelerate professional application development”* (Vincent et al., 2022).

The benefits of LCDP’s for developers include quicker development time to market to meet demands, a reduction in bug fixing measures and improved system quality, as well as lower deployment efforts. (Alamin et al., 2021; Gomes & Brito, 2022). While the benefits of low-code solutions are quite clear in existing literature, it is also important to note some of the disadvantages and fears that these platforms present. Vender lock in, defined as “the situation where customers are dependent (i.e. locked-in) on a single cloud provider technology implementation and cannot easily move in the future to a different vendor without substantial costs, legal constraints, or technical incompatibilities" (Opara-Martins et al., 2016), is a key fear for organizations using low-code platforms. A high learning curve, pricing and lack of detailed customization of out of the box features are also key limitations (Gomes & Brito, 2022; Khorram et al., 2020).

Thus, LCDP's address a common cause of software development delays by reducing or eliminating the gap between domain requirements and developers' understanding. This gap is a key concern in the domain of connected health, where large multi-disciplinary teams were traditionally utilized to bridge this knowledge gap. (Alamin et al., 2021; Harris et al., 2022).

6.2.4 No Code Platforms

No Code Development Platforms (NCDP) differ from LCDP's in that low code reduces hand-coding whereas no code eliminates it (Käss et al., 2022). Similarly, Carroll et al. notes that NCDP's "provide a fully visual interface with drag-and-drop tools and pre-configured templates, eliminating the need for any coding and related skills" (Carroll et al., 2024).

While low code and no code platforms may be referred to together, for example as "low code/no code platforms" (Rokis & Kirikova, 2022; Yan, 2021), some argue there is a distinction between the two. A disagreement exists within the literature as to whether NCDP's are their own concept, or a subset of LCDP's (Lethbridge, 2021; Prinz, 2021). This thesis will take the view that NCDP's are a subset of LCDP's and therefore NCDP's fall under the LCDP category.

No code development platforms are suitable for "straight forward" applications, such as digitation of paper-based materials. In contrast, low-code platforms provide an additional layer for custom development and thus may be suited for more complex applications (Carroll et al., 2024). Within a connected health context, the literature on the applicability of no code development platforms is limited, with the majority of the research in the area mainly seen in recent years.

No code development offers researchers the ability to "create multiple versions of an app to evaluate their effectiveness in various conditions" (Liu et al., 2022). This ability to create multiple versions of an artifact and evaluate its effectiveness presents an opportunity to utilize the DSRM highlighted by Peffers et al. (2007), as the DSRM relies on the ability to iterate an artifact based on demonstration and feedback.

6.3 Methods

To effectively leverage the no code development platforms within the context of the Dundee Pathway (Coghill & Seth, 2015), a case study mobile application, known as "C-CAMHS" will be designed as a proof-of-concept application, where its design leveraging the DSRM will provide an answer to the below research question:

Is the use of a dual platforms low code/no code development approach suitable for creating connected health applications within the CAMHS domain?

To create an application that will suit the needs of CAMHS in Ireland, a design science approach will be adopted, the DSRM (Peffers et al., 2007). The design science approach is *"the creation of an artifact and/or design theory as a means to improve the current state of practice as well as existing research knowledge"* (Vaishnavi & Kuechler, 2021). The DSRM approach facilitates the creation of an artifact by way of an iterative design approach, where an artifact is created based on a set of objectives, feedback is sought from potential users/domain experts, and the feedback is subsequently used to enhance the next iteration of the artefact. As noted by Liu et al. (2022), the strengths of no code platforms lie in its ability to quickly instantiate an artifact based on learnings from previous iterations. This presents an opportunity for synergy, as the strengths of no code platforms provide the opportunity for efficient implementation of a DSRM study.

For the purposes of this chapter, the artifact in question will be the “C-CAMHS” mobile application which aims to streamline the process of diagnosing and/or monitoring those with ADHD. During a review of the literature, one key issue identified was vendor lock-in (Opara-Martins et al., 2016). To address this, a two-platform approach was adopted for application development, ensuring that both platforms use industry-standard communication protocols. This approach allows for the possibility of substituting vendors without disrupting the application's structure and architecture. Figure 6.1 illustrates where each vendor is implemented within the application's architecture, demonstrating how a two-vendor approach can effectively mitigate vendor lock-in. The front end is provided by “Thunkable” while the back end is provided by “Xano”.

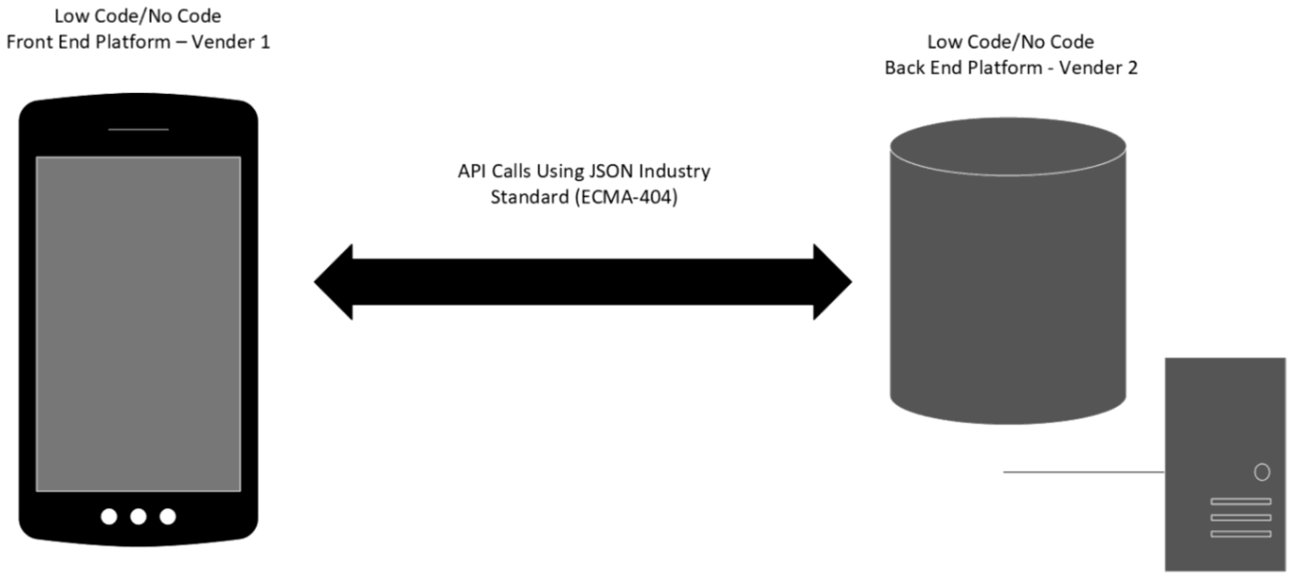


Figure 6. 1 - Two Vendor approach to low code/no code development

The output of design science research should be something that is interesting to the research community (Vaishnavi & Kuechler, 2021). In the case of the C-CAMHS project, the “Something of interest” is envisioned to include both the artefactual output, being the C-CAMHS proof of concept app, as well as the learnings found from the implementation of no-code development platforms to create a connected health application within the Irish CAMHS domain.

Feedback on the application will be sought from clinicians who work in the area of CAMHS ADHD treatment. Connected health researchers and specialists in the area of digital transformation will also be asked to review the application and provide feedback on its design and its implementation. Finally, primary school teachers with experience in both completing ADHD questionnaires and working with children with ADHD will be asked to provide their feedback.

Feedback will be obtained from three cohorts, first being clinicians within the CAMHS service. These participants will inform the effectiveness of the application by providing feedback on what is needed, what is implemented well, and what needs to be improved from a functionality perspective. The second cohort, the connected health researchers and digital transformation experts will be in a position to advise on the efficiency of the application, by reviewing the application’s design and commenting on its structure from a technical perspective. This will be augmented with feedback from the research team on the perceived level of difficulty in implementing recommendations from participants.

Finally, teachers and special needs assistants specialized in teaching and supporting those with disabilities within a primary school setting will be asked for feedback to ensure that the views and opinions of those who will be using the app are accurately represented. This will take the form of a focus group. The System Usability Scale (SUS) is an industry standard usability questionnaire, providing participants with 10 questions on the usability of a system. Responses are promoted from participants using a Likert scale, and overall results are calculated to establish an overall usability score for a system.

Informed consent from all participants was received by way of the provision of an information sheet advising the purpose of the interview, how the information will be processed and stored, and how the results of the study will be used. All participants are over the ages of eighteen with the capacity to provide informed consent.

During interview, participants were provided with an emulated version of the mobile application which can be opened on their desktop or mobile web browser via a link provided. This allowed them to engage with the application and provide feedback based on their experience. This was facilitated using the "publish web app" feature provided by Thunkable, and allowed users to engage with the application in an emulated environment. Users were provided with user login and password during interview in order to log in and access features of the application. Upon completion of the interview, the emulated environment was shut down to prevent others from accessing the application. A screenshot of the emulated environment can be seen in the appendix of this this thesis.

Interviewees were presented with the application by way of an emulated mobile environment where, following a brief introduction to the application and explanation of its overall purpose, they were given the opportunity to use the application and provide feedback on its design and functionality. Participants were encouraged to voice any positive or negative thoughts on each aspect of the design or functionality and raise any concerns or missing functionality.

Interview transcripts were subsequently reviewed to ensure all relevant design feedback was captured, with particular attention paid to any comments concerning clinical risk/ patient safety, as these are of utmost importance when creating a connected health application.

Due to ethical concerns, children with ADHD and their parents will be excluded from the participant scope at this stage, however it is envisioned that a future clinical trial of C-CAMHS will be conducted once the clinical case for such an application has been demonstrated. This demonstration is a requirement for any clinical trial to be undertaken in the medical domain. The findings from this chapter, along with chapters four and five, are targeted at providing this demonstration.

To address these ethical challenges, the use of proxies has been employed to ensure the study gains an appropriate level of understanding of the end user's needs (patients and parents) without the need to directly interact with these groups, as per the ethical challenges discussed. These proxies, as noted above (clinicians and teachers / special needs assistants), are professionals with relevant experience in the clinical space who can speak to the needs of end users based on their experience to date. These individuals have a wealth of experience dealing with a wide number of potential end users and thus their inclusion presents the opportunity to gain access to a large pool of knowledge about individual cases they have experienced via engagement with a single participant.

The experience of proxies was validated by way of their clinical or professional expertise, proxies must articulate an appropriate level of clinical/professional expertise, provided via response to interview questions or via identification of relevant experience via review of professional social media prior to interview. It is assumed that all individuals are providing an honest and true account of their experience in response to questions at interview or on their professional, public facing social media.

6.4 Creation of C-CAMHS

To effectively create C-CAMHS, the rigorous implementation of the steps of the DSRM is key to success. The results of each step within the DSRM process for the development of the C-CAMHS can be found below, starting with identification of the problem, highlighted in section 6.1.4, and objectives of a solution, highlighted in section 6.4.2. Section 6.5 provides each iteration its own design and development, demonstration, and evaluation sub-sections.

6.4.1 Problem identification and motivation

The first step of the process is problem identification. As mentioned, CAMHS services in Ireland are behind the standards of other developed countries when it comes to data management. The Finnerty report (2023) highlighted the clear need for modernizing CAMHS processes, and the Maskey report (Maskey, 2022) has shown that there is clear consequences to not doing so. For the purposes of this project, the problem statement is that "Irish Child and Adolescent Mental Health Services lack efficient and effective ICT systems to support the prevision of the services, resulting in risks to service users". The risk outlined highlights the need to modernize the service to ensure compliance with the UN declaration of human rights of the child, with particular reference to article 24.

6.4.2 Objective for a solution

Based on the problem statement outlined above, it is clear that modernization of CAMHS ICT services is critical to ensure that the needs of the services are met. To that end, the objective of this research is to create an artifact that can effectively assist in the digital transformation of the CAMHS service. C-CAMHS is the artifact that will be used as the lens to review how no code platforms can be used to assist in this much needed digital transformation of CAMHS, while also providing an artefactual output that may be adopted within the service to support their transition from a paper-based service to a digital first service.

6.5 Design and Development

6.5.1 Design and Development (Iteration One)

Iteration one of C-CAMHS has been created based on a review of the Dundee pathway, as highlighted in Chapter 4 and the risks associated with implementing connected health systems within a CAMHS setting, as highlighted in Chapter 5. It was decided that connected health applications are best suited for the early screening process and remote monitoring of patients during the continued care process. This is based on recommendations made by both Maskey (2022) and Chapter 4 of this thesis. Appropriate mHealth implementation identified include remote screening questionnaires, software-based teaching materials, and remote vital sign monitoring.

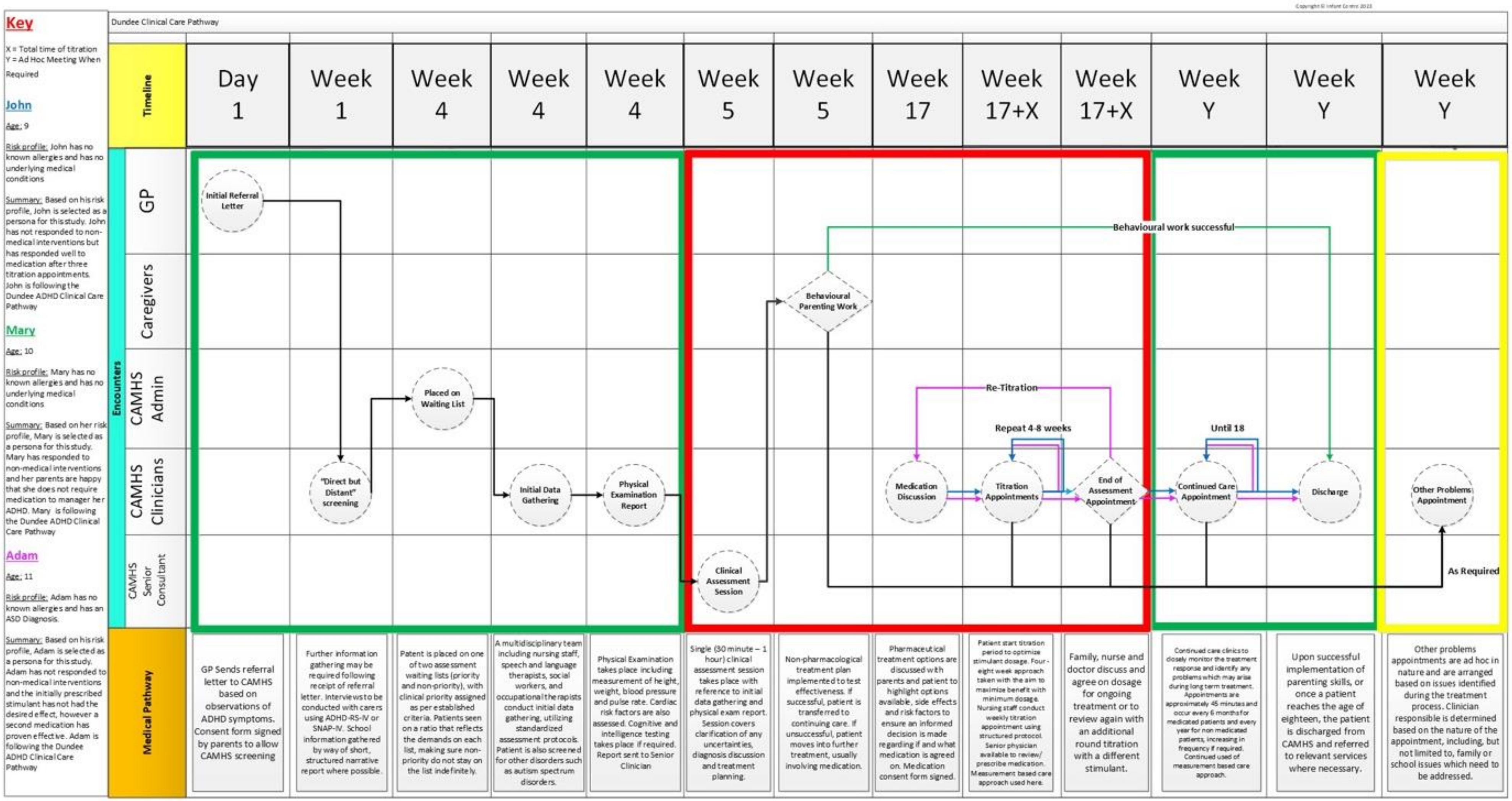
As discussed in Chapter 5, there is a lack of consensus among clinicians regarding the specific risks involved in the aforementioned mHealth implementations, suggesting either a lack of awareness of the risks or the possibility that these risks may be limited or may, in fact, not exist. Compared to the presence of a general consensus of risks in electronic health records and telemedicine implementation, the sporadic nature of risks identified in the mHealth categories implies they are less known and thus presents an opportunity for research.

In contrast to the early stages screening process of questionnaire completion or monitoring of patients on establish treatments, the initial assessment and titration sections of the Dundee pathway require direct communication with clinicians. This presents the opportunity to leverage telemedicine. However, in contrast to the risks of mHealth, the risks associated with telemedicine in the context of CAMHS assessment are better defined and more widely agreed upon, as seen in Chapter 5, likely due to experiences gained during the COVID-19 pandemic. These risks include limited visibility of body language and difficulties in establishing connections with clients or service users. It was also noted that there is a difficulty or inability to quickly intervene in the event of a mental health incident, as identified in chapter 5.

Given these considerations, using telemedicine for direct clinical assessments with adolescents presents risk that may not be justified at this stage of research. This, in the researcher's opinion, excludes the use of remote patient monitoring and telemedicine during this critical stage of the treatment pathway for risk management reasons.

Consequently, it was deemed appropriate to implement connected health in the early stages of the Dundee pathway. This includes gathering information and initial screening of individuals, as well as utilizing remote vital sign monitoring to streamline continued care after diagnosis and treatment plans are established. The lack of risk identification or consensus among participants interviewed in Chapter 5 suggests that these risks may not be significant. However, it is clear that there is no consensus on the risks associated with leveraging remote screening questionnaires and vital sign monitoring at this time. Figure 6.1 highlights where C-CAMHS may be used in green and where it would not be suitable for thus research project in red. This figure visually represents the arguments made above.

The yellow denotes that the nature of the appointment dictates if it is appropriate to use C-CAMHS. For example, if the ad-hoc appointment is requested to ask some follow up questions in a non-emergency situation, telemedicine may be appropriate. However, in a crisis management situation where the mental health of the child/adolescent is deteriorating and there is an identified risk of self-harm, an in-person appointment may be appropriate due to the lack of direct access to the child in a telemedicine setting, the ability to render appropriate interventions is limited or completely removed in a remote setting.



Key

X = Total time of titration
Y = Ad Hoc Meeting When Required

John

Age: 9

Risk profile: John has no known allergies and has no underlying medical conditions

Summary: Based on his risk profile, John is selected as a persona for this study. John has not responded to non-medical interventions but has responded well to medication after three titration appointments. John is following the Dundee ADHD Clinical Care Pathway

Mary

Age: 10

Risk profile: Mary has no known allergies and has no underlying medical conditions

Summary: Based on her risk profile, Mary is selected as a persona for this study. Mary has responded to non-medical interventions and her parents are happy that she does not require medication to manager her ADHD. Mary is following the Dundee ADHD Clinical Care Pathway

Adam

Age: 11

Risk profile: Adam has no known allergies and has an ASD Diagnosis.

Summary: Based on his risk profile, Adam is selected as a persona for this study. Adam has not responded to non-medical interventions and the initially prescribed stimulant has not had the desired effect, however a second medication has proven effective. Adam is following the Dundee ADHD Clinical Care Pathway

GP Sends referral letter to CAMHS based on observations of ADHD symptoms. Consent form signed by parents to allow CAMHS screening

Further information gathering may be required following receipt of referral letter. Interviews to be conducted with carers using ADHD-RS-IV or SNAP-IV. School information gathered by way of short, structured narrative report where possible.

Patent is placed on one of two assessment waiting lists (priority and non-priority), with clinical priority assigned as per established criteria. Patients seen on a ratio that reflects the demands on each list, making sure non-priority do not stay on the list indefinitely.

A multidisciplinary team including nursing staff, speech and language therapists, social workers, and occupational therapists conduct initial data gathering, utilizing standardized assessment protocols. Patient is also screened for other disorders such as autism spectrum disorders.

Physical Examination takes place including measurement of height, weight, blood pressure and pulse rate. Cardiac risk factors are also assessed. Cognitive and intelligence testing takes place if required. Report sent to Senior Clinician

Single (30 minute – 1 hour) clinical assessment session takes place with reference to initial data gathering and physical exam report. Session covers clarification of any uncertainties, diagnosis discussion and treatment planning.

Non-pharmacological treatment plan implemented to test effectiveness. If successful, patient is transferred to continuing care. If unsuccessful, patient moves into further treatment, usually involving medication.

Pharmaceutical treatment options are discussed with parents and patient to highlight options available, side effects and risk factors to ensure an informed decision is made regarding if and what medication is agreed on. Medication consent form signed.

Patient start titration period to optimize stimulant dosage. Four - eight week approach taken with the aim to maximize benefit with minimum dosage. Nursing staff conduct weekly titration appointment using structured protocol. Senior physician available to review/ prescribe medication. Measurement based care approach used here.

Family, nurse and doctor discuss and agree on dosage for ongoing treatment or to review again with an additional round titration with a different stimulant.

Continued care clinics to closely monitor the treatment response and identify any problems which may arise during long term treatment. Appointments are approximately 45 minutes and occur every 6 months for medicated patients and every year for non medicated patients, increasing in frequency if required. Continued used of measurement based care approach.

Upon successful implementation of parenting skills, or once a patient reaches the age of eighteen, the patient is discharged from CAMHS and referred to relevant services where necessary.

Other problems appointments are ad hoc in nature and are arranged based on issues identified during the treatment process. Clinician responsible is determined based on the nature of the appointment, including, but not limited to, family or school issues which need to be addressed.

Figure 6. 2 - Patient journey map, presented in chapter four, modified based on risks and benefits identified in chapter five

Based on the above noted recommendations and associated risk areas, two possible implementation opportunities emerge, the first focusing on pre diagnosis screening and the second being remote patient monitoring during the continued care process. Iteration one therefore implemented both screening questionnaire and remote blood pressure monitoring functionality within the application. The Snap 26-point parent/teacher questionnaire was chosen as the questionnaire that would be digitized as it is a proven questionnaire, and the copyright was available to facilitate digitization.

A login screen has been created for iteration one leveraging JSON web tokens (JWT) authentication, this process can bee see in appendix 1 and 4 of this thesis. The login page consists of 2 input fields, one for username and one for password. Two buttons are also present, one for actioning a login and one for opening the registration screen. The registration screen shows the privacy policy and subsequently refers the user back to the research team for registration in the study.

Once a user selects log in, user credentials are passed to the server via an API where their provided password is compared to that on file. A JWT is generated if the login is successful and sent back to the user’s mobile device and is used to both identify them and enable them to submit to other API’s on the Xano back-end service.

Iteration one of the applications facilitates the auto marking of these questionnaires based on the existing instructions for users and stores the results of the questionnaire for each element in a database for later review by clinicians. While other screening questionnaire are available, copyright was not available to digitize these as part of this study and therefore could not be included. It was confirmed during an interview on iteration one that the Snap-26 parent teacher screener was an appropriate questionnaire to implement, and its effectiveness is on par with the Conners ADHD screener.

Users are presented with each question individually, and each response is saved on the device, once the final question is answered, the result is calculated and sent to the backend server, along with their JWT stored on device for verification. This approach is highlighted in appendix 3.

Remote blood pressure monitoring is implemented by manual input of results and image capture for verification to ensure accurate readings have been input. Figure 6.2 shows the login screen, figure 6.3 shows the home screen, figure 6.4 shows an example of a questionnaire question, with figure 6.5 showing the blood pressure input screen. System flow for this functionality is highlighted in appendix 2.

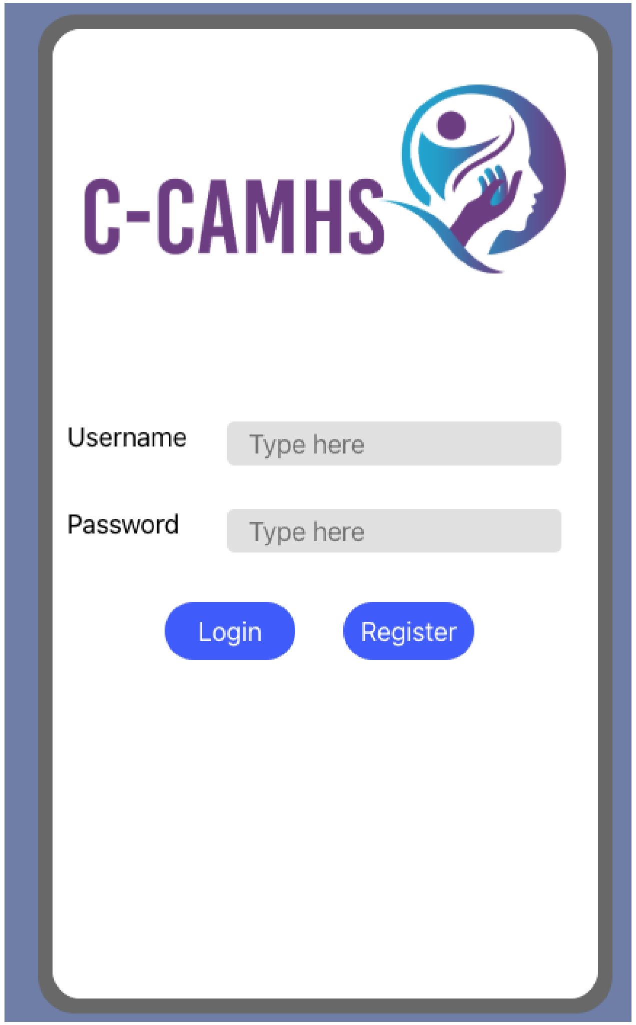


Figure 6. 4 - Initial Login Screen

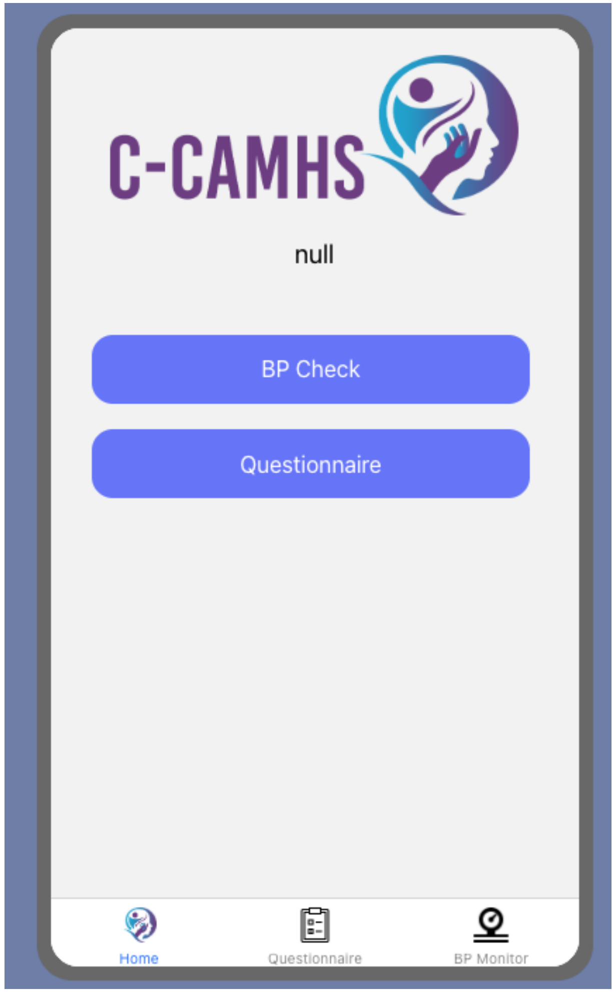
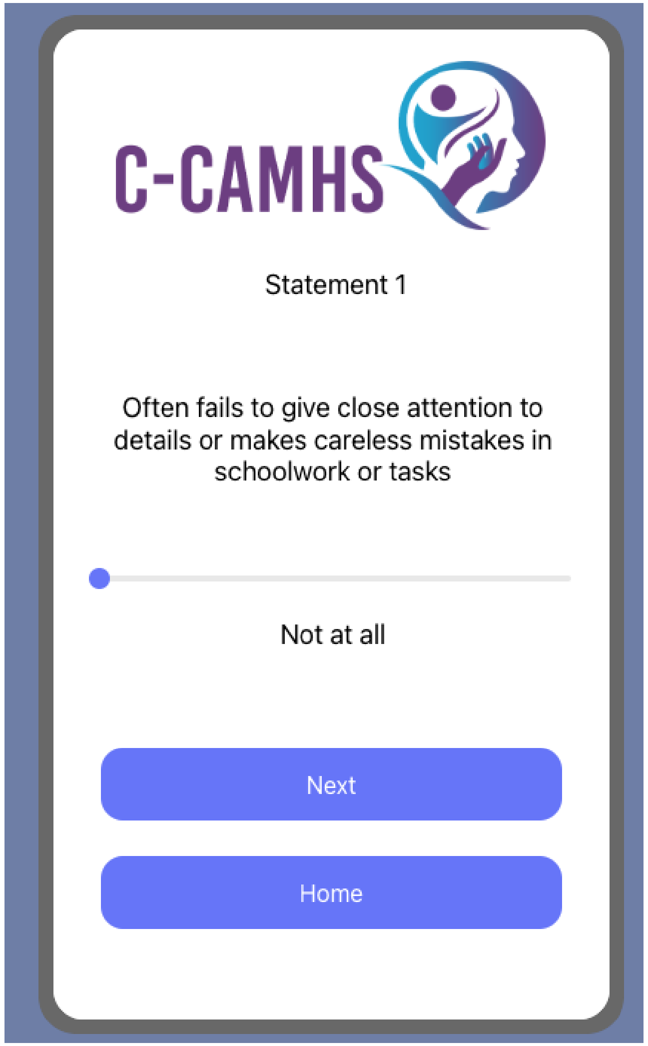


Figure 6. 3 - Home Screen

As mentioned above, Iteration one of C-CAMHS was created by combining two no code providers, one providing front end components, and one combining back-end components. This approach facilitates the possibility of transferring from one back-end provider to another as all communication between the front and back end is handled via industry standard API calls. This ensures that the application is not reliant on one service provider to remain in operation and can be transitioned to another front or backend provider as the needs of the application change over time. Logins are secured via industry standard JSON web token, ensuring that users only have access to their information and not the information of others.

Questionnaire implementation, see figure 6.4, follows a single question per page approach. This was chosen as feedback from ADHD experts during interviews identified that individuals with ADHD often have parents who also may have diagnosed, or undiagnosed, ADHD. As such, the application was created in such a way as to ensure that the needs of these parents were met. Clinicians noted that a questionnaire page that presents multiple questions at once may be overwhelming, and a single question per page approach may be an appropriate approach to take when digitizing the Snap-26 questionnaire. This feedback informed the design of iteration one, where each question is presented on its own page.

During interviews, blood pressure was noted as a key vital sign that must be monitored regularly, to that end, users can enter blood pressure readings taken at home, see figure 6.5. The accuracy of the reading is confirmed by asking users to take a picture of their blood pressure cuff results after taking a reading, ensuring that readings are taken correctly. While blood pressure cuffs that sync via Bluetooth exist, they are often using proprietary protocols for communication that low code/ no code platforms may not have the capacity to engage with.

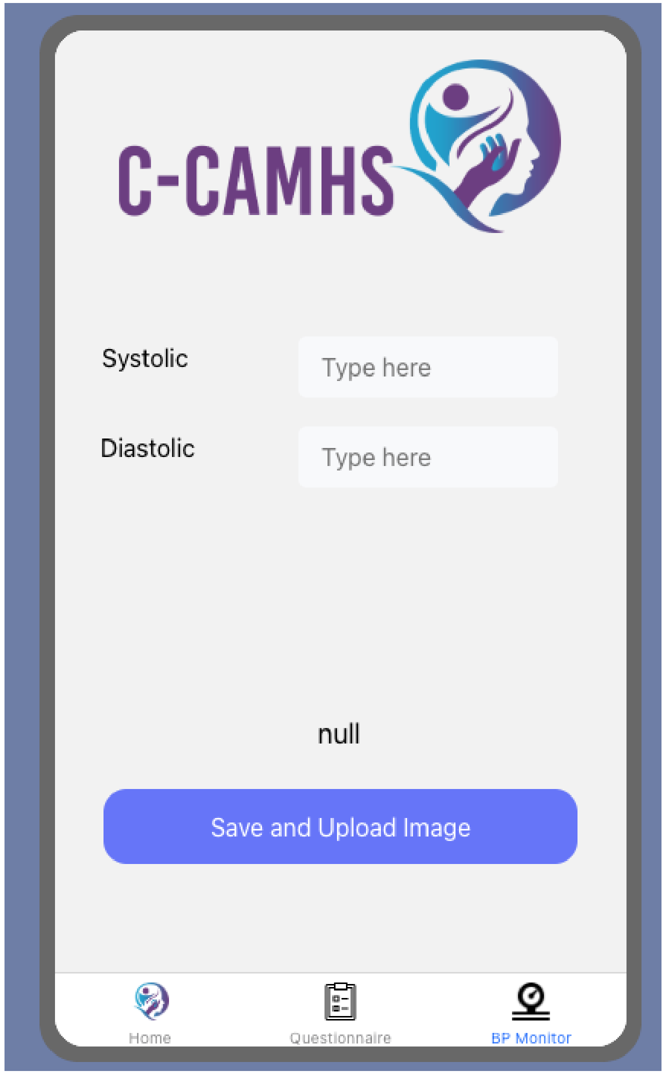


Statement 1

Often fails to give close attention to details or makes careless mistakes in schoolwork or tasks

Not at all

Figure 6. 4 - Questionnaire Question Example



Systolic: Type here

Diastolic: Type here

null

Figure 6. 5 - Blood Pressure Input Screen

6.5.2 Demonstration / Evaluation (Iteration One)

Following the creation of iteration one, as shown above, four experts were interviewed and asked for their feedback on iteration one based on their expertise. These experts consist of the following: A connected health researcher, a digital transformation specialist, a CAMHS consultants and CAMHS senior registrar trainee.

Key insights from clinicians were that the implementation of the questionnaire was to a high standard, and clinicians were satisfied with the design of the app, however the clinicians requested that the results from each question are also stored on the server alongside the final survey results, allowing the clinician to drill down into the responses to gain a more detailed understanding of each respondent. It was suggested by one interviewee that the *"Global Assessment of Functioning*" (GAF) scale be implemented into the app, however this is an adult scale and, while a child version exists, it is under copyright, thus precluding its inclusion without permission from the author. In addition, the implementation of the GAF was ultimately deemed out of scope due to its lack of inclusion within the Dundee Pathway, however it presents the opportunity for further research.

Clinicians liked the ability to take blood pressure remotely, but also requested that, in addition to the blood pressure reading, that heart rate also be noted as this is provided by the blood pressure cuff during the reading. Clinicians also requested additional information be taken from the patient based on any side effects of medication being taken. These include readings on mood, sleep, appetite, dizziness, headache and an area to enter any other details the patient/ carer deems appropriate to enter. Weight and height were other metrics that the app should capture.

Overall feedback on the app was very positive, and there was a clear consensus that this app was needed and that it would be of great benefit to the CAMHS service if it was to be expanded and brought into the service. Based on this feedback, it was decided to continue with this approach of using two service providers for the front and back end, and to expand the apps capabilities based on the feedback from the interviews.

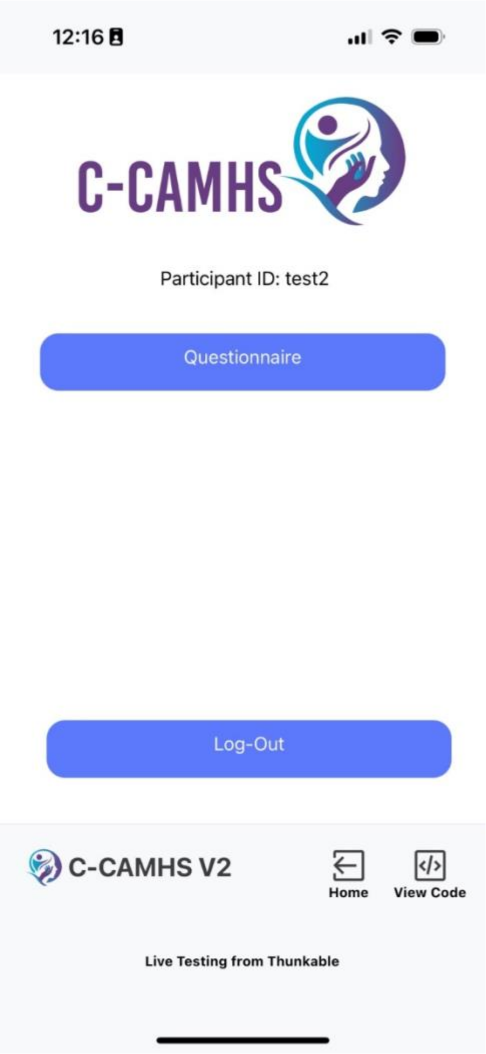
6.5.3 Design and Development (Iteration Two)

As mentioned, while feedback was very positive overall, there were improvements that can be made to the app, specifically expanding the key information points that clinicians need in order to assist them in making a diagnosis/ managing patient. It was decided that iteration two would integrate a number of these information points and present a second iteration of the application for another round of feedback. Along with the key points noted above, it was decided that two user profiles were to be created, one for a user without a diagnosis (Figure 6.6), which only has access to the screening questionnaire, and second version for a user with an established diagnosis (Figure 6.7), which would have access to all the remote monitoring tools. This was to ensure that users entering the service would only see functionality that was relevant to them, and that functionality can be unlocked over time based on the user's progression along the treatment pathway.

As feedback from the questionnaire section was very positive overall, the design has not changed in iteration two, however the information that is being sent to the server now includes the answer to each individual question, allowing clinicians to see the response to each question. The blood pressure readings page (Figure 6.8) has been expanded to include heart rate readings, and the input method has been changed from textual to numeric only to better suit the input expected from the user.

A weight and height page (Figure 6.9) has been added allowing users to enter their weight and height for reference by the clinician. A side effects page (Figure 6.10) has also been added to ensure that common side effects from ADHD medication are noted if this occurs, these include mood, sleep and appetite levels, check boxes if dizziness or headache occurs, and a free text box allowing users to enter any non-urgent information they feel their clinician may need at their next check-in.

Due to the number of additional pages added, the navigation bar at the bottom of the page has been removed as this was viewed as too condensed. The flow of the app has been updated as such to ensure users are not stuck on any one screen.



12:16

Participant ID: test2

Questionnaire

Log-Out

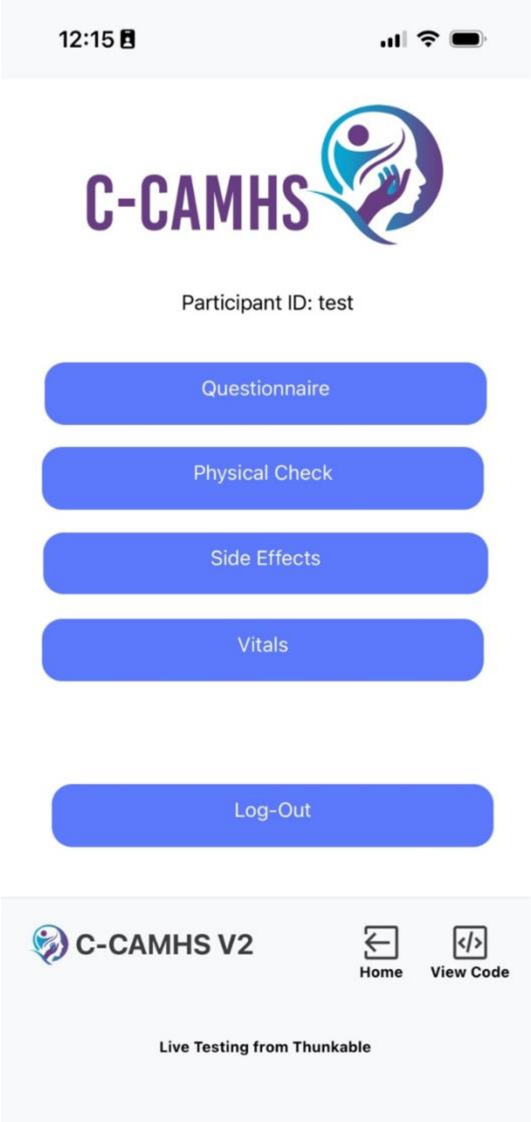
C-CAMHS V2

Home

View Code

Live Testing from Thunkable

Figure 6. 6 User Without a Diagnosis Home Page



12:15

Participant ID: test

Questionnaire

Physical Check

Side Effects

Vitals

Log-Out

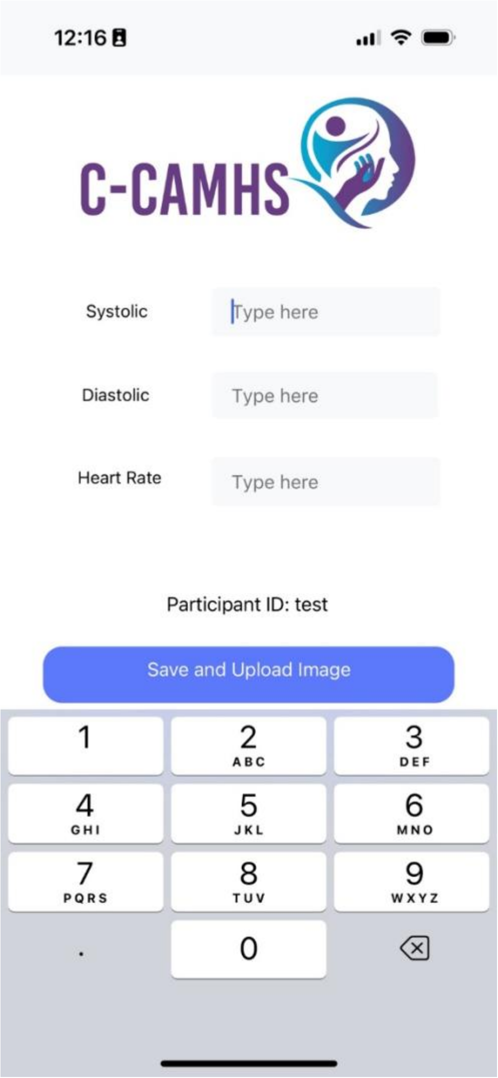
C-CAMHS V2

Home

View Code

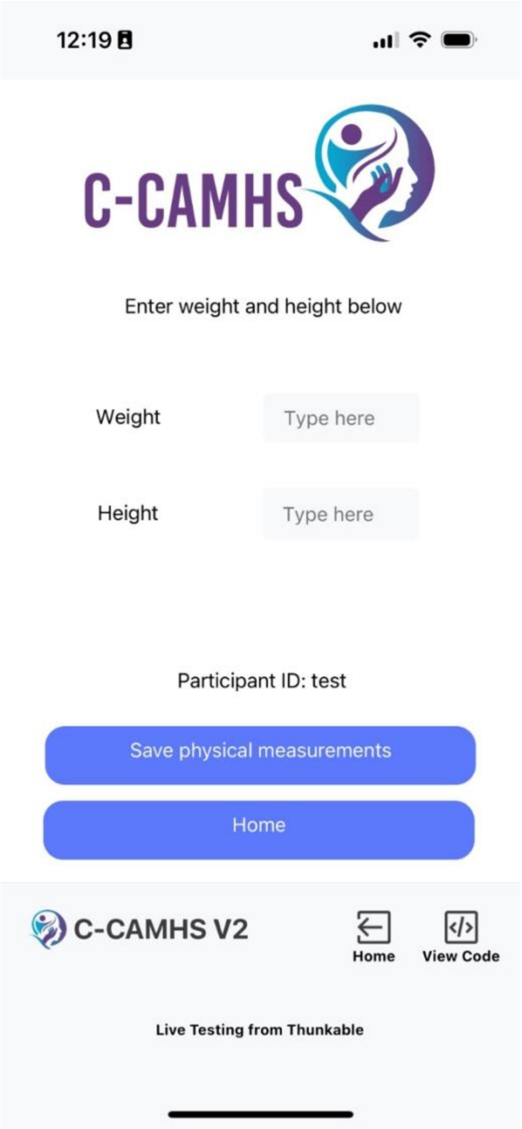
Live Testing from Thunkable

Figure 6. 7 User With a Diagnosis Home Page



Participant ID: test

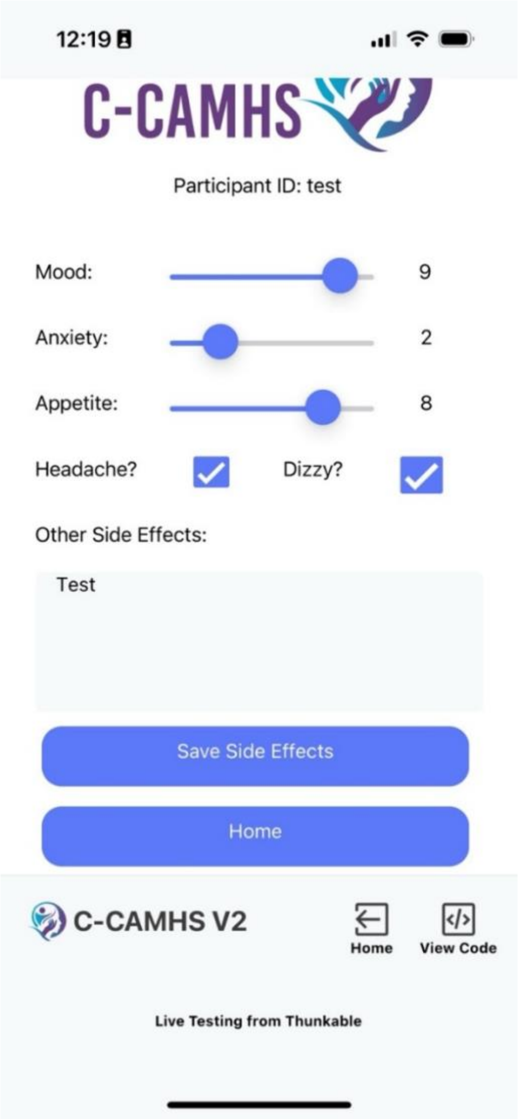
Figure 6. 8 - Blood Pressure Reading Page



Enter weight and height below

Participant ID: test

Figure 6. 9 - Weight and Height Page



Participant ID: test

Mood: 9

Anxiety: 2

Appetite: 8

Headache? ☑ Dizzy? ☑

Other Side Effects: Test

Figure 6. 10 - Side Effects Reading page

6.5.4 Demonstration / Evaluation (Iteration Two)

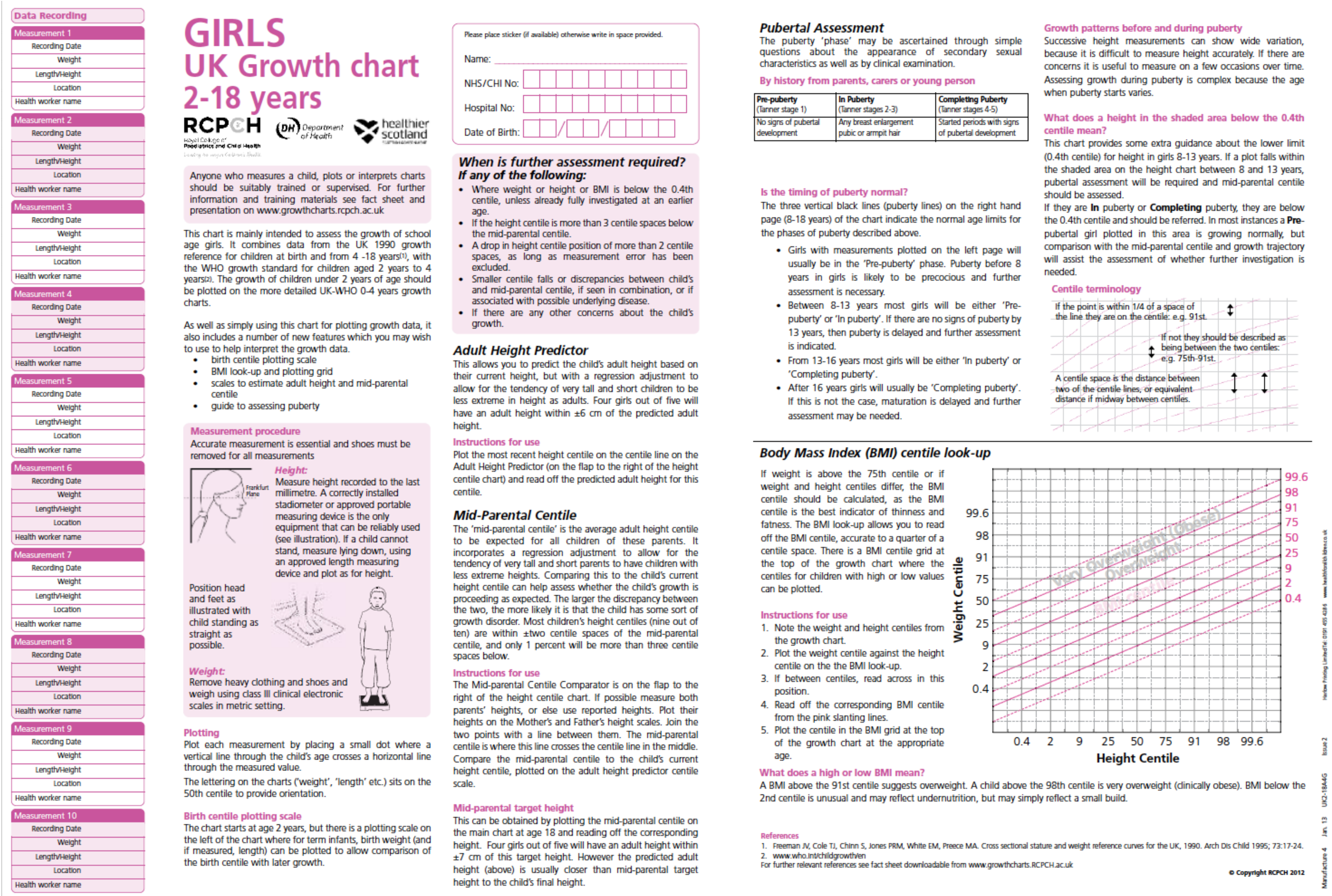
Feedback from iteration two was gathered via three interviews with experts in the field. An ADHD Care Coordinator, Consultant adolescent psychiatrist and a Child & Family Support Network Coordinator were interviewed and presented with the mobile app for review. Feedback on the design of the app was very positive, with comments such as the application being “sleek” and that the app did not look like a form, which was a noted as being a positive for parents as completing a large number of forms was noted as being fatiguing for parents.

The side effects page was noted as not being comprehensive enough, and a recommendation to use a standardised questionnaire to assess side-effects was recommended. Upon investigation, the Pittsburgh Side-effects Rating Scale (Pelham Jr, 1993) was an appropriate questionnaire to digitise. Medication compliance was also noted as an important data point to capture.

It was noted by one participant that the minimalist nature of the application was a positive. However, another participant notes that the questionnaire section may not provide users with enough information to inform their decisions. It was noted that in order for parents to make an informed response, all options should be presented to them. This is not the case in iteration two as options only present themselves as the user scrolls across the answer bar. As seen in Figure 6.4, only one response is visible, that being the "not at all" response, however the Snap 26 Screening questionnaire offers four distinct choices, "not at all", "Just a little", "Quite a bit", and "Very much" as response options for any given prompt. While the label will update as the user scrolls the selector across the bar to show each of the four options depending on the selectors position along the bar, the lack of all four options being immediately available to participants was noted as having the possibility to bias responses.

It was noted that while gathering the weight and height for the patient is needed, these also needed to be plotted as a "centile". This is currently done manually by filing out a UK-WHO Growth Charts (Health Service Executive, 2024b), see figure 6 11 and 6 12. It was noted that a potential application would need to calculate this centile for it to provide efficiencies for clinicians.

It was also noted that showing the metrics for the weight and hight labels was also critical to provide context on responses given. It was decided that there was enough information gathered to initiate a third iteration of the C-CAMHS application .



Data Recording

Measurement 1
Recording Date
Weight
Length/Height
Location
Health worker name

Measurement 2
Recording Date
Weight
Length/Height
Location
Health worker name

Measurement 3
Recording Date
Weight
Length/Height
Location
Health worker name

Measurement 4
Recording Date
Weight
Length/Height
Location
Health worker name

Measurement 5
Recording Date
Weight
Length/Height
Location
Health worker name

Measurement 6
Recording Date
Weight
Length/Height
Location
Health worker name

Measurement 7
Recording Date
Weight
Length/Height
Location
Health worker name

Measurement 8
Recording Date
Weight
Length/Height
Location
Health worker name

Measurement 9
Recording Date
Weight
Length/Height
Location
Health worker name

Measurement 10
Recording Date
Weight
Length/Height
Location
Health worker name

GIRLS
UK Growth chart
2-18 years

RCPCH Royal College of Paediatrics and Child Health
DH Department of Health
healthier scotland

Anyone who measures a child, plots or interprets charts should be suitably trained or supervised. For further information and training materials see fact sheet and presentation on www.growthcharts.rcpch.ac.uk

This chart is mainly intended to assess the growth of school age girls. It combines data from the UK 1990 growth reference for children at birth and from 4 -18 years(1), with the WHO growth standard for children aged 2 years to 4 years(2). The growth of children under 2 years of age should be plotted on the more detailed UK-WHO 0-4 years growth charts.

As well as simply using this chart for plotting growth data, it also includes a number of new features which you may wish to use to help interpret the growth data.

- birth centile plotting scale
- BMI look-up and plotting grid
- scales to estimate adult height and mid-parental centile
- guide to assessing puberty

Measurement procedure

Accurate measurement is essential and shoes must be removed for all measurements

Height:
Measure height recorded to the last millimetre. A correctly installed stadiometer or approved portable measuring device is the only equipment that can be reliably used (see illustration). If a child cannot stand, measure lying down, using an approved length measuring device and plot as for height.

Position head and feet as illustrated with child standing as straight as possible.

Weight:
Remove heavy clothing and shoes and weigh using class III clinical electronic scales in metric setting.

Plotting

Plot each measurement by placing a small dot where a vertical line through the child's age crosses a horizontal line through the measured value.

The lettering on the charts ('weight', 'length' etc.) sits on the 50th centile to provide orientation.

Birth centile plotting scale

The chart starts at age 2 years, but there is a plotting scale on the left of the chart where for term infants, birth weight (and if measured, length) can be plotted to allow comparison of the birth centile with later growth.

Please place sticker (if available) otherwise write in space provided.

Name: ______________________________

NHS/CHI No: ☐☐☐☐☐☐☐☐☐☐

Hospital No: ☐☐☐☐☐☐☐☐☐☐

Date of Birth: ☐☐/☐☐/☐☐☐☐

When is further assessment required?
If any of the following:

- Where weight or height or BMI is below the 0.4th centile, unless already fully investigated at an earlier age.
- If the height centile is more than 3 centile spaces below the mid-parental centile.
- A drop in height centile position of more than 2 centile spaces, as long as measurement error has been excluded.
- Smaller centile falls or discrepancies between child's and mid-parental centile, if seen in combination, or if associated with possible underlying disease.
- If there are any other concerns about the child's growth.

Adult Height Predictor

This allows you to predict the child's adult height based on their current height, but with a regression adjustment to allow for the tendency of very tall and short children to be less extreme in height as adults. Four girls out of five will have an adult height within ±6 cm of the predicted adult height.

Instructions for use

Plot the most recent height centile on the centile line on the Adult Height Predictor (on the flap to the right of the height centile chart) and read off the predicted adult height for this centile.

Mid-Parental Centile

The 'mid-parental centile' is the average adult height centile to be expected for all children of these parents. It incorporates a regression adjustment to allow for the tendency of very tall and short parents to have children with less extreme heights. Comparing this to the child's current height centile can help assess whether the child's growth is proceeding as expected. The larger the discrepancy between the two, the more likely it is that the child has some sort of growth disorder. Most children's height centiles (nine out of ten) are within ±two centile spaces of the mid-parental centile, and only 1 percent will be more than three centile spaces below.

Instructions for use

The Mid-parental Centile Comparator is on the flap to the right of the height centile chart. If possible measure both parents' heights, or else use reported heights. Plot their heights on the Mother's and Father's height scales. Join the two points with a line between them. The mid-parental centile is where this line crosses the centile line in the middle. Compare the mid-parental centile to the child's current height centile, plotted on the adult height predictor centile scale.

Mid-parental target height

This can be obtained by plotting the mid-parental centile on the main chart at age 18 and reading off the corresponding height. Four girls out of five will have an adult height within ±7 cm of this target height. However the predicted adult height (above) is usually closer than mid-parental target height to the child's final height.

Pubertal Assessment

The puberty 'phase' may be ascertained through simple questions about the appearance of secondary sexual characteristics as well as by clinical examination.

By history from parents, carers or young person

Pre-puberty (Tanner stage 1)	**In Puberty** (Tanner stages 2-3)	**Completing Puberty** (Tanner stages 4-5)
No signs of pubertal development	Any breast enlargement pubic or armpit hair	Started periods with signs of pubertal development

Is the timing of puberty normal?

The three vertical black lines (puberty lines) on the right hand page (8-18 years) of the chart indicate the normal age limits for the phases of puberty described above.

- Girls with measurements plotted on the left page will usually be in the 'Pre-puberty' phase. Puberty before 8 years in girls is likely to be precocious and further assessment is necessary.
- Between 8-13 years most girls will be either 'Pre-puberty' or 'In puberty'. If there are no signs of puberty by 13 years, then puberty is delayed and further assessment is indicated.
- From 13-16 years most girls will be either 'In puberty' or 'Completing puberty'.
- After 16 years girls will usually be 'Completing puberty'. If this is not the case, maturation is delayed and further assessment may be needed.

Growth patterns before and during puberty

Successive height measurements can show wide variation, because it is difficult to measure height accurately. If there are concerns it is useful to measure on a few occasions over time. Assessing growth during puberty is complex because the age when puberty starts varies.

What does a height in the shaded area below the 0.4th centile mean?

This chart provides some extra guidance about the lower limit (0.4th centile) for height in girls 8-13 years. If a plot falls within the shaded area on the height chart between 8 and 13 years, pubertal assessment will be required and mid-parental centile should be assessed.
If they are **In** puberty or **Completing** puberty, they are below the 0.4th centile and should be referred. In most instances a **Pre-**pubertal girl plotted in this area is growing normally, but comparison with the mid-parental centile and growth trajectory will assist the assessment of whether further investigation is needed.

Centile terminology

If the point is within 1/4 of a space of the line they are on the centile: e.g. 91st.

If not they should be described as being between the two centiles: e.g. 75th-91st.

A centile space is the distance between two of the centile lines, or equivalent distance if midway between centiles.

Body Mass Index (BMI) centile look-up

If weight is above the 75th centile or if weight and height centiles differ, the BMI centile should be calculated, as the BMI centile is the best indicator of thinness and fatness. The BMI look-up allows you to read off the BMI centile, accurate to a quarter of a centile space. There is a BMI centile grid at the top of the growth chart where the centiles for children with high or low values can be plotted.

Instructions for use

1. Note the weight and height centiles from the growth chart.
2. Plot the weight centile against the height centile on the the BMI look-up.
3. If between centiles, read across in this position.
4. Read off the corresponding BMI centile from the pink slanting lines.
5. Plot the centile in the BMI grid at the top of the growth chart at the appropriate age.

What does a high or low BMI mean?

A BMI above the 91st centile suggests overweight. A child above the 98th centile is very overweight (clinically obese). BMI below the 2nd centile is unusual and may reflect undernutrition, but may simply reflect a small build.

References

1. Freeman JV, Cole TJ, Chinn S, Jones PRM, White EM, Preece MA. Cross sectional stature and weight reference curves for the UK, 1990. Arch Dis Child 1995; 73:17-24.
2. www.who.int/childgrowth/en

For further relevant references see fact sheet downloadable from www.growthcharts.RCPCH.ac.uk

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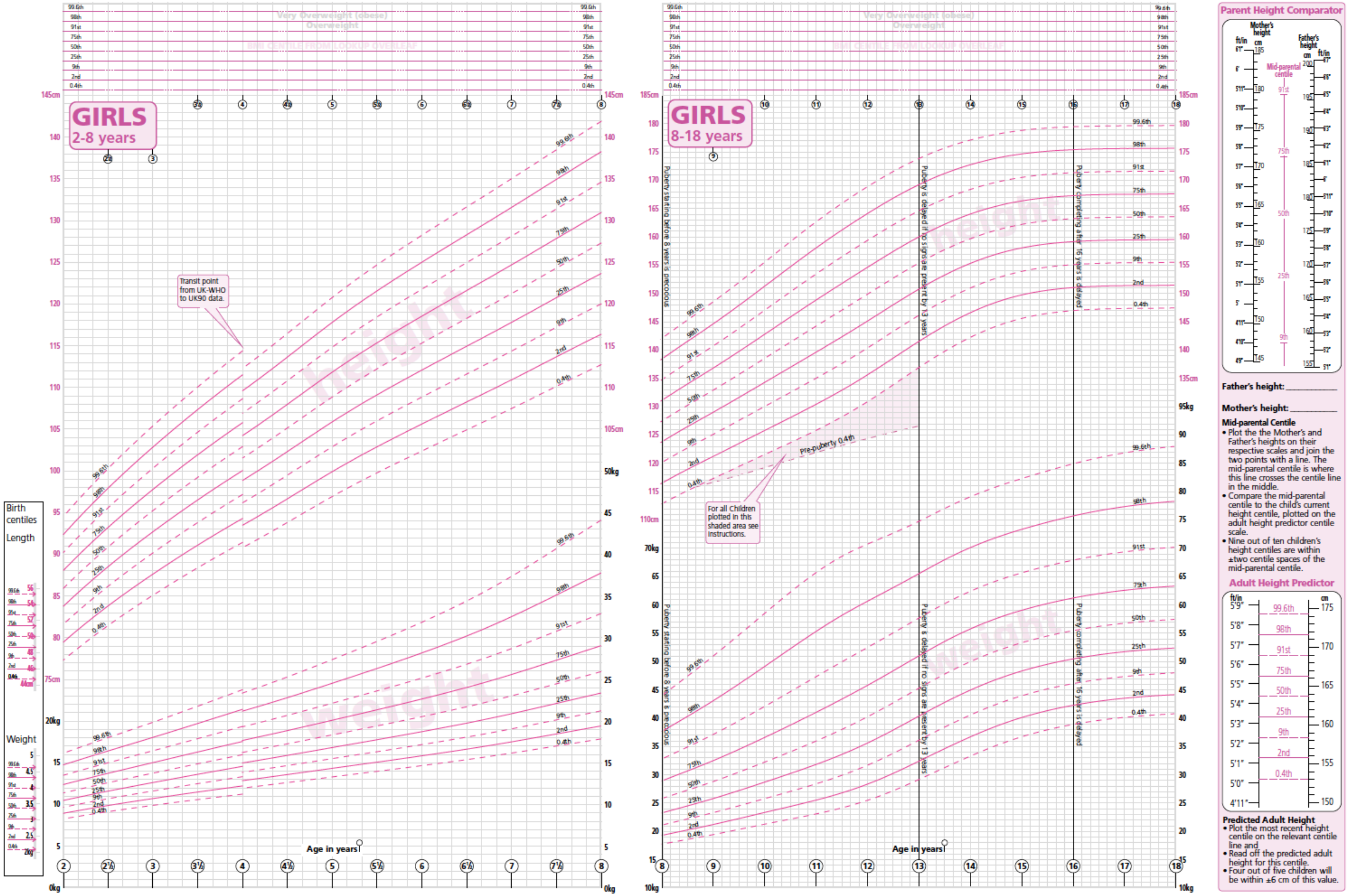
Figure 6. 11 - Relevant Centile Chart front page



Father's height: ____________

Mother's height: ____________

Mid-parental Centile

- Plot the the Mother's and Father's heights on their respective scales and join the two points with a line. The mid-parental centile is where this line crosses the centile line in the middle.
- Compare the mid-parental centile to the child's current height centile, plotted on the adult height predictor centile scale.
- Nine out of ten children's height centiles are within ±two centile spaces of the mid-parental centile.

Predicted Adult Height

- Plot the most recent height centile on the relevant centile line and
- Read off the predicted adult height for this centile.
- Four out of five children will be within ±6 cm of this value.

Figure 6. 12 - Relevant centile chart second page

6.4.5 Design and Development (Iteration Three)

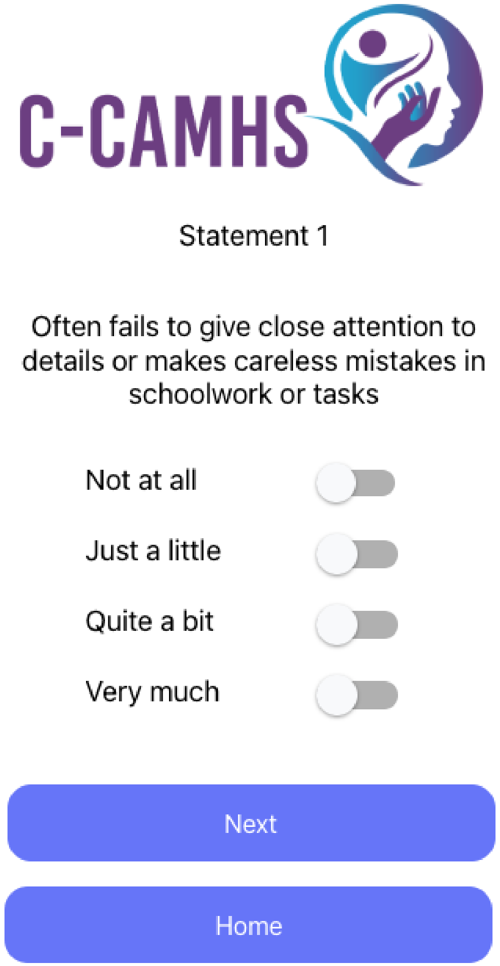
Feedback was quite positive for iteration two, but as mentioned above, there are a number of key points noted that should be represented in the application, thus a third iteration is warranted. This iteration focused on implementing features/ updates noted in the evaluation of iteration two, specifically looking at updating the questionnaire to be more descriptive by showing each answer to the user, see figure 6 13.

Iteration three also focused on the implementation of centile calculations based on the UK-WHO Growth Charts (Health Service Executive, 2024b). These charts are originally provided by the Royal College of Paediatrics and Child Health (Royal College of Paediatrics and Child Health, 2025b), who also provide a clinically accurate API endpoint for calculating the centile (Royal College of Paediatrics and Child Health, 2025a). This API functions by taking information such as the birth date, date of reading, value of the readying, sex of the child and type of measurement (weight/height). This API can also take into account details such as bone age and gestation at birth, however these are optional parameters and do not need to be passed to get a result. These factors are also not captured on the above chart and are therefore out of scope. Below is an example of the API call that takes place:

```
curl --location --request POST
'https://api.rcpch.ac.uk/growth/v1/uk-who/calculation' \
--header 'Origin: https://growth.rcpch.ac.uk/' \
--header 'Subscription-Key: YOUR_PRIMARY_API_KEY_GOES_HERE' \
--header 'Content-Type: application/json' \
--data-raw '{
    "birth_date": "2015-05-12",
    "observation_date": "2025-01-12",
    "observation_value": 20,
    "sex": "female",
    "measurement_method": "weight",

}'
```

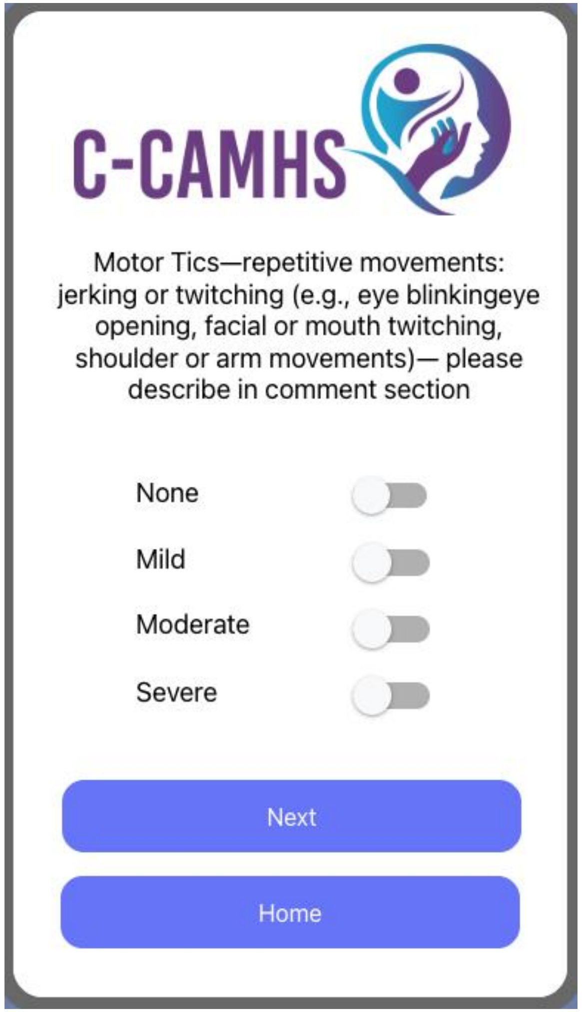
Figure 6. 13 - API Call Structure



Statement 1

Often fails to give close attention to details or makes careless mistakes in schoolwork or tasks

Figure 6. 14 Questionnaire example as per iteration three



Motor Tics—repetitive movements: jerking or twitching (e.g., eye blinkingeye opening, facial or mouth twitching, shoulder or arm movements)— please describe in comment section

Figure 6. 15 Updated Side Effects Questionnaire Sample

This API is called from the server upon receipt of a weight and height reading, with the relevant information retrieved from the user account to populate details such as the date of birth and sex of the child. Observed value is passed directly from the user request, and observation date is populated based on the current date time, formatted in the YYYY-MM-DD format to consist with API requirements shown above.

As mentioned in the feedback for iteration two, while it was important to gather side effects of medication, iteration two did not capture enough variety of possible side effects. The Side-effects Rating Scale (Pelham Jr, 1993) is used for screening side effects for CAMHS patients on ADHD medication and will subsequently be digitised in place of the existing side effects questions in iteration two. This ensures that an appropriate breath of possible side effects is screened for when reviewing medication use.

6.5.6 Demonstration / Evaluation (Iteration Three)

Demonstration of iteration three took place via a focus group of potential users. It was identified that teachers and special needs assistants within a primary school setting (children between the ages of 5-12) were most likely to engage with the application and therefore were ideal candidates to receive feedback from.

The focus group consisted of ten individuals from the above-mentioned groups. All individuals were asked to review the applications usability and design, by using the application themselves or, in the case of internet connectivity issues, by observing another user use the application. Each user was asked to open each function of the application and asked to provide any feedback or questions they had on the functionality of the application. After all participants used each functionality, a system usability scale (SUS) questionnaire (example shown below) was answered by each participant to capture some qualitative data to ensure the overall opinion of the group was effectively captured. The SUS is scored between 0-100, with 0 constituting a very poor design and 100 being excellent.

The overall feedback on the app's usability was positive. The system usability scale results for 10 participants is highlighted in table 6 1. There are some issues that emerged during the use of the system, one being related to login difficulties. This issue may be related to the app itself or may be due to the technological literacy of the participants or internet connectivity issues. This may be addressed from the applications perspective by implementing a QR code login system, where a user is provided with a QR code with login credentials embedded, allowing for a simplified scan and login approach.

Regarding overall usability, feedback was very positive. Special Needs Assistants (SNAs) and teachers noted that filling out the Connors form is often overwhelming, but this system made the process significantly easier to follow. Another key point was that teachers typically discuss issues using pen and paper with a form passed between them as needed, due to difficulties in gathering all teachers in one place simultaneously. Thus, it may be beneficial to provide a form that staff members can leverage prior to filling out surveys or side effect questionnaires to facilitate this workflow. This information can also be stored in school records accessible to both parents and teachers.

Particularly concerning school record management, it was noted that completed questionnaires should be kept on file at the school for audit purposes. Additionally, feedback is currently delivered to clinicians via parents, this presents inefficiencies. The use of connected health systems would allow teachers to interact directly with clinicians, subject to parental consent for direct interaction. This consent may need to be incorporated into the standard onboarding procedure in both private and public sector health services.

It was also noted that the logout frequency was quite aggressive when issues arose. The system is designed to automatically log out if it encounters any errors. While this wasn't highlighted as a major frustration in the focus group as there is an understanding that sessions should be logged out for data protection reasons when errors occur. However, this could become a source of frustration with ongoing use. It may need to be reviewed to ensure a frictionless experience while still adhering to best practices in data protection and security.

As noted, the SUS will be used to gather overall sentiment from the focus group. To score the SUS, one must find the contribution score for each item. Contribution will range from 0 to 4. As per the SUS scoring systems, odd number items (Questions 1,3,5,7, and 9) are scored by taking their scale position and removing 1 (Likert scale score -1). For even number questions (Questions 2,4,6,8 and 10) are scored by removing their Scale position from 5 (5 - Likert scale score). Contributions for each of the ten questions are then added together, and the result multiplied by 2.5 to provide a score out of 100.

Table 6. 1 - Breakdown of SUS Results

Participant ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Evens	Odds	Total	Total Adjusted
Participant 1	5	1	5	1	5	1	5	1	5	1	20	20	40	100
Participant 2	5	1	5	1	5	1	5	1	5	1	20	20	40	100
Participant 3	5	1	5	1	5	1	5	1	4	1	20	19	39	97.5
Participant 4	5	1	5	1	4	1	5	1	5	1	20	19	39	97.5
Participant 5	5	1	1	1	5	1	5	1	5	1	20	16	36	90
Participant 6	5	1	5	1	5	1	5	1	4	2	19	19	38	95
Participant 7	5	1	5	1	5	2	4	1	5	1	19	19	38	95
Participant 8	5	1	5	1	5	1	5	1	4	2	19	19	38	95
Participant 9	5	1	5	1	5	1	5	1	5	1	20	20	40	100
Participant 10	5	1	5	1	5	1	5	1	5	1	20	20	40	100

Based on the results of the system usability scale questionnaire provided to all focus group participants, the app is highly user-friendly. Participants noted the design is clear, concise, and easy to use. This demonstrates the effectiveness of low code/no code platforms in creating user-friendly mobile applications. This is critical for systems within a connected health service delivery environment.

The system usability questionnaire yielded a total average score of 97 with a rage of between 90 and 100. This is a very positive result, and in combination with the overall positive qualitative feedback received from the interview, shows the application is well suited for use in its intended environment.

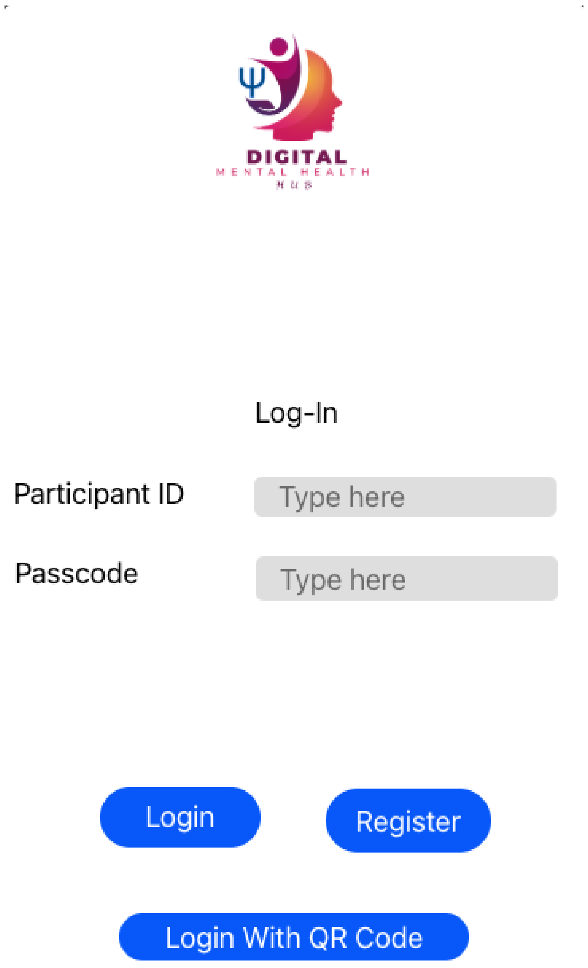
To this point, the use of a dual platform approach to no code connected health application development has been theoretical in nature, with no applied testing of C-CAMHS in a clinical setting to validate its long-term usability and stability. Over the course of this thesis, a number of opportunities emerged to test C-CAMHS, however due to staff turnover rates in key clinical positions, and other issues such as extended leave of absence of key clinical staff, it was not possible to organise a study during the four-year period of this thesis. An opportunity did, however, present itself to leverage the dual platform approach to create an application for another study taking place, The Digital Mental Health – Hub (DMH-H) study.

6.6 Clinical Application of Dual Platform Low Code/No Code

This section focuses on evaluating the effectiveness of a two platform no-code approach for creating connected health research mobile applications in a clinical setting. To evaluate the effectiveness of this development approach, a case study approach will be implemented, with the design of the app DMH-H documented and its effectiveness reviewed by implementation in an observational study.

To review the applicability of this two-platform approach to no-code development for clinical research mobile applications, the case study application DMH-H was created. The DMH-H study's objective was to analyse the link between anxiety and mood levels, and exercise levels of adults with intellectual disability who also had a mental health diagnosis.

The DMH-H application was a companion app for the study and was designed to facilitate the input of a user's mood and anxiety levels and log a date and time for the input. The app was designed to be fully usable without keyboard input, acknowledging the varied abilities of individuals with intellectual disabilities. This accessibility ensures effective data entry while accommodating a wide range of user needs. To remove the need for manual typing of usernames and passwords, a QR Code sign-in system was created to allow users to scan a provided QR code to sign in, as seen in Figure 6.16. To facilitate the recording of anxiety and mood levels, a slider scale was introduced to allow for a dynamically updating scale to record both levels, as illustrated in figure 6.17.

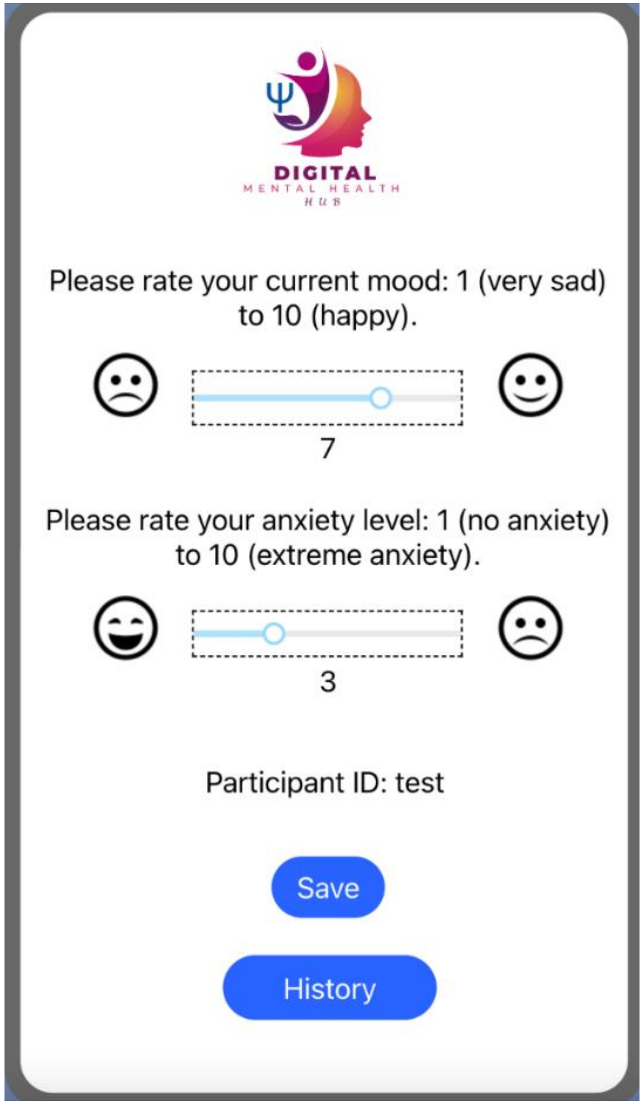


Log-In

Participant ID: Type here

Passcode: Type here

Figure 6. 16 DMH-H Login Screen



Please rate your current mood: 1 (very sad) to 10 (happy).

7

Please rate your anxiety level: 1 (no anxiety) to 10 (extreme anxiety).

3

Participant ID: test

Figure 6. 17 - Digital Mental Health Hub Input Screen

Figure 6.17 highlights the data structure of database tables with figure 6.18 highlighting the system flow of the application, beginning with the user's login. If the user clicks register, they will be shown a copy of the application’s privacy policy and subsequently advised to contact the research team for registration. When the user clicks login, they must enter their details, generating an API call to the back-end vendor to verify existing records. If no match is found, an invalid login message will be generated, and the user will be asked to log in again. If a match is found, a JSON Web Token (JWT) is generated for the session and sent to the mobile application client. This token will authenticate all subsequent API calls from the client-side application.

Once authenticated, all user information is retrieved from the database using JWT to validate and subsequently display the user’s information on the client-side application. The user is then prompted to enter their mood and anxiety levels as shown in Figure 6.17. After entering these figures and pressing save, the application sends these results, along with the JWT used for authentication, to the back-end vendor. If authenticated, the data is stored in the measurement database table. If data storage is successful, a success message is shown to the user, followed by wiping all measurements and user information from the client-side, and logging out the client. If data storage fails, an error message advises the user to contact the research team for further investigation.

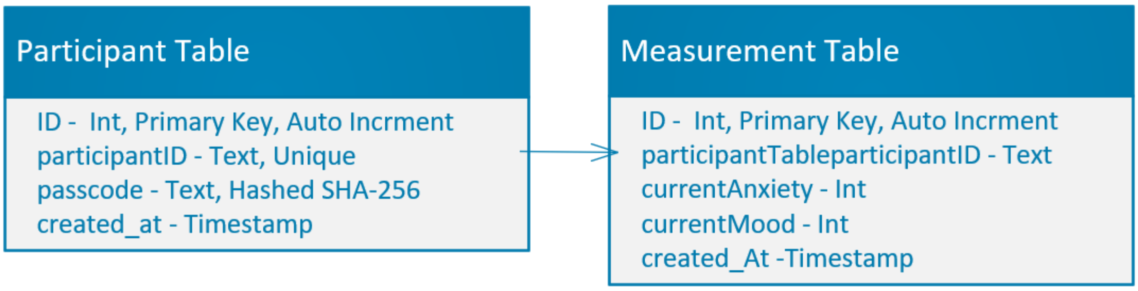


Figure 6. 18 Database table structure.

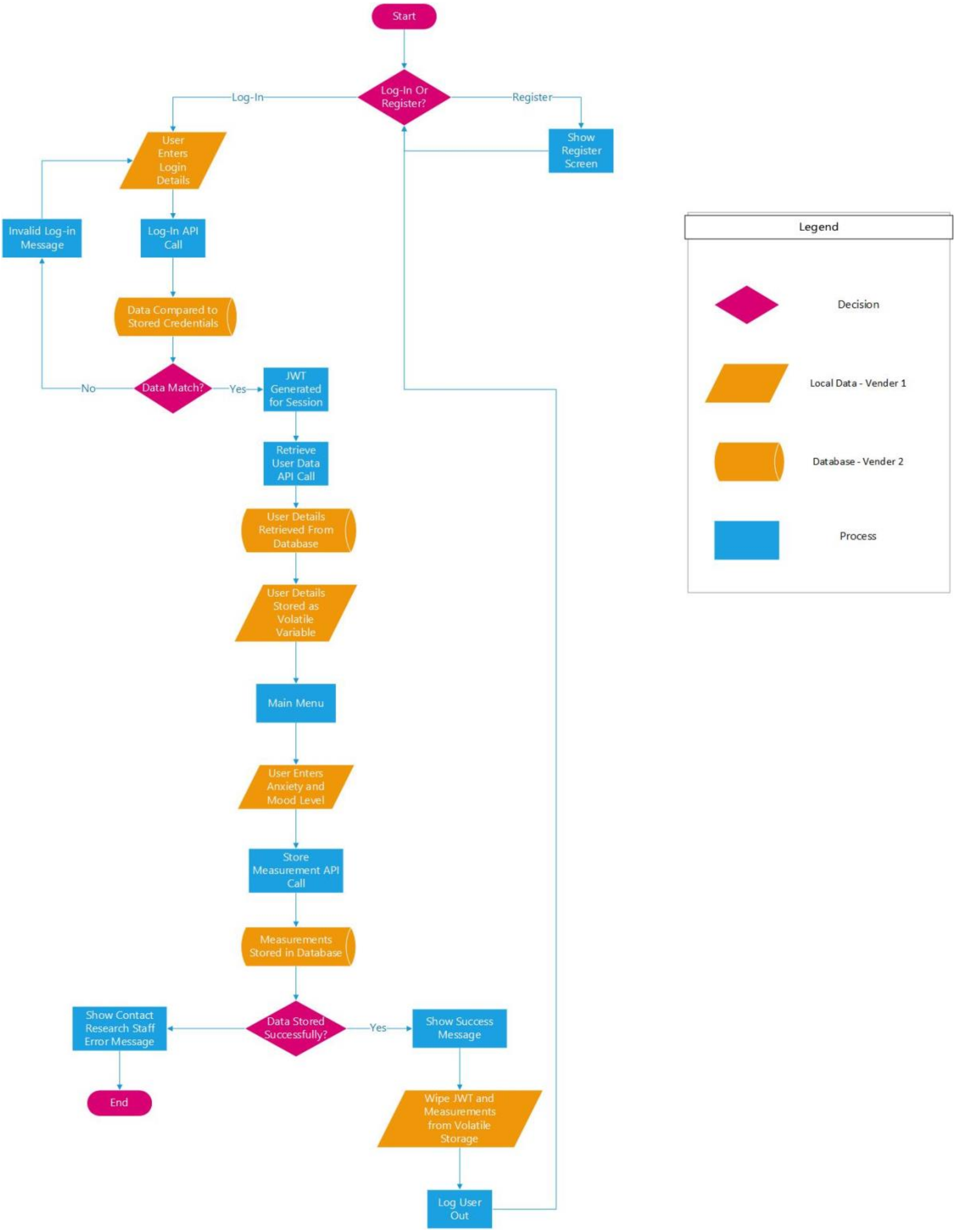


Figure 6. 19 - System Flow of DMH-H

6.6.1 Observational Study

The observational study of DMH-H took place in a clinical environment for the care of adults with intellectual disability. The study as a whole was to leverage digital monitoring tools to measure the activity levels of participants and log their mood and anxiety levels against these activity levels. Readings for anxiety and mood were recorded both on paper, serving as the control, and via the DMH-H. This study received ethical approval from the relevant clinical ethics board where the trial took place. Ethical approval can be found in the appendix of this thesis. This study was administered by a senior registrar, with appropriate qualifications to conduct the study. No personal identifiable information was stored on the DMH-H app, as only a participant ID was used to identify any individual user account. The key for each account was stored separately by the clinician responsible for conducting the study. Ten individuals were recruited for this phase of the clinical trial. Mental health nurses were responsible for taking readings and using the DMH-H app on a day-to-day basis.

6.6.2 Results

Results from the first phase of the clinical trial are very promising. Feedback received from mental health nurses using the app indicated that the app was very easy to use, and very fast to log results. Overall, the nurses were very happy to use the app, however some suggestions for improvement were made.

One suggestion was to implement a free text box where app users could provide some context as to why a particular result was entered in order to provide context to the entry, particularly in cases where a deterioration in mental state has occurred. Nurses also noted that, while the app was generally very easy to use, occasionally there was difficulty in selecting the correct measurement on the sliding scale, this suggests that increasing the size may yield a better user experience.

In terms of reliability of the app, all paper-based results were present within the app, indicating that there was no loss of data when compared to paper control. Nurses did not report any instance of the programmed error message appearing, indicating that all entries received a 200 (OK) response from the server indicating successful entry. Nurses did note that, due to a lack of a confirmation message, they were unsure if the result was entered correctly, resulting in a small number of duplicate entries. To address this, a future iteration of the app can include a confirmation screen before user logout to confirm to users that the reading was entered correctly.

In terms of accuracy, results were within margin of error when compared to control, with any discrepancies attributable to human error when entering results. Mean Absolute Error (MAE) for mood was set at approximately 0.084765 and anxiety at 0.050847, implying a margin of error of less than 1% for each measurement as values are measured between 1 and 10.

6.6.3 Conclusions from Study

Based on results from the clinical trial, the use of a two-platform approach to no code development appears to have produced a reliable, effective and efficient research application for connected health research. The two-platform approach has the advantage of reducing the risk of vender lock in, as both front and backend platforms can be substituted as required due to the industry standard protocols employed for communication between platforms. This also presents the possibility of streamlining the onboarding process of a particular mobile application into a health services central IT network, as should the service wish to adopt a particular application, the relevant API end points can be updated to point to the services internal IT services, replacing the no code backend provider if required. As mentioned, the application was easily deemed to be easy to use, while also showing no data loss and data input within margin of error. Based on these findings, this thesis views this phase of the DMH-H observational study, and by extension the use of a two-platform development approach, as a success. This ultimately provides positive indications that the use of a two-platform development approach can produce reliable mHealth applications for larger scale clinical trials and ultimately adoption within a health service.

6.7 Discussion

This chapter contributes novel insights in several ways. Firstly, it investigates the domain of connected health systems within the context of child and adolescent mental health services, with a specific focus on the utilization of mobile applications to CAMHS for ADHD diagnosis and treatment. As highlighted in Chapter 5, clinicians do not fully understand the risks and benefits associated with these technologies, as evidenced by the absence of a consensus on these matters. Consequently, this chapter presents a unique opportunity provide an appropriate artifact for identifying possible risks and benefits.

The C-CAMHS proof-of-concept application lays the groundwork for developing a larger-scale mobile application to support CAMHS. Furthermore, it demonstrates an approach to leveraging low-code, no-code platforms within a design science-led research project, which has been deemed to be a viable method for creating applications suitable for clinical trials and subsequent adoption. The employment of the Thunkable front-end solution enabled users, in this case user proxies, to interact with an emulated mobile environment for testing and feedback purposes. This approach proved highly beneficial as the vast majority of research participants found the emulated environment straightforward to use, evidenced by an absence of frustration or technical issues during interviews. This scenario offers an opportunity to explicitly evaluate the use of a no-code platforms for user testing purposes. Although not explicitly reviewed in this study, an implicit conclusion can be drawn that this approach is suitable for research in design elements, as indicated by the lack of technical problems or concerns raised by participants.

The term citizen developer, as noted above, refers to an individual who may lack technical or coding skills but possesses the business knowledge to effectively plan and design mobile applications. In applying a no-code development platform within a design science research project, as presented in this chapter, an intriguing dynamic emerges. The use of no code platforms in the context of a DSRM project has presented the possibility of the creation of what may be known as a *"citizen researcher"*. Citizen researchers may include members of the academic community, such as researchers or PhD students. These individuals may have the theoretical knowledge to conceptualize a mobile application but lack the technical skills or time to fully develop one for design science research purposes.

Design science research, as discussed, provides a methodology for individuals to create artifacts that can be reviewed by experts. The feedback from these artifacts can then be leveraged to gain insights into effectively solving the identified research problem. The iterative nature of design science research benefits greatly from the ability to quickly and effectively create tangible artifacts for review. This chapter highlights how no-code development platforms can be leveraged within a DSRM study to action participant feedback while obfuscating the majority of code from the developer. This is especially beneficial for researchers who may lack the time or skills to develop a mobile application via traditional software development approaches.

While these platforms provide individuals with a streamlined way of creating research applications, there may be an inherent obstacle in their large-scale adoption by a health service. As noted in section 6.2.3, vender lock in is a key obstacle that must be overcome when leveraging no code platforms. No code platforms provide a "one stop shop" for producing applications but subsequently lock application functionality within their ecosystem. A no code platform targeting clinical studies noted that, at time of contact (24 July 2024), they did not have the ability to connect their applications to a researcher's back-end infrastructure via API. This indicates that vender lock-in may be a risk when using this platform. In the event of a clinical trial being successful, health services may wish to adopt the application. When created on a traditional no code platform, the research team may be faced with the possibility of recreating the application from scratch using traditional software development tools in order to gain the flexibility needed to integrate with an organization EHR.

The two-platform approach employed in this chapter appears advantageous as it prevents vendor lock-in. If either the front-end or back-end provider becomes insufficient for current/future needs, they can be replaced with a different vendor. This flexibility is ensured as the development approach uses industry-standard connectivity between the front-end and back-end. It also provides the ability for the front-end of the research application to be migrated from targeting the research study back end, to a health service organization back end, streamlining the adoption process, as all communications between front and back end are handled via standard encrypted API calls. The clinical team provides the application data structure to the EHR team within the adopting organization and the EHR team provides the API address to send data to. This is particularly beneficial for the Irish CAMHS service as an application designed using a dual platform approach may be able to “stand on its own”, as discussed in section 6.6, until such a time as CAMHS has access to a robust EHR system, which can then serve as the back end infostructure for C-CAMHS.

However, it's important to acknowledge some limitations with low code/no code platforms, particularly regarding downtime. While the modular design of the application avoids vendor lock-in in the medium to long term, there is a short-term risk of a service provider going down at a critical point during a project or research endeavour. For instance, during the creation of iteration 3, the no code platform employed presented an issue where modifications were not saved and reverted to a previous version even after explicitly saving updates. This was frustrating, and although the issue was resolved quickly, it highlights the concern of relying on a third-party platform for critical research services.

Despite these risks, the argument can be made that the benefits of leveraging a dual platform no code development approach outweigh the potential drawbacks compared to traditional software development processes for creating research applications.

Leveraging no-code platforms has greatly benefited the design science research in this chapter. The no-code platform used has the capability to deploy applications to various endpoints like web, Android, and iOS applications. This allows researchers to reach many users who can give valuable feedback for evaluation. C-CAMHS, the primary case study artifact for this chapter highlights the efficiency of the use of no code platforms to create and iterate artifacts for user testing, culminating in the creation of an application noted as having extremely high usability scores. This shows the efficiency of the use of no-code platforms using design science research within a connected health setting.

The DMH-H case study app highlights how no code applications can be leveraged in a clinical environment to produce applications that may be relied upon to capture data from research participants, which highlights the effectiveness of no code platforms using design science within a connected health setting.

When attempting to understand and articulate the underlying implications of the use of a no code approach to connected health systems design and development, one may draw upon Gibsons “Affordance Theory” (Gibson, 1986), which articulates that value of a particular environment can be directly perceived. In the case of IS, affordance may extend to the technical context of a particular artifact. Norman articulates the notion of applying affordance in the context of technology by referring to affordance as *“the relationship between a physical object and a person (or for that matter, any interacting agent, whether animal or human, or even machines and robots)”* (Norman, 2013, p. 11). This relationship, in this case between the user proxy and the C-CAMHS artifact, is one that can be directly observed through the use of the no code platform thunkable and the ability to directly view the participants interaction with the artifact by way of Microsoft Teams screensharing functionality.

In the context of the use of no code platforms to develop connected health systems, a number of affordances, as described by Norman (2013), emerge. C-CAMHS “affords” the remote monitoring of vital signs, remote screening via SNAP-26 point screener, remote side effect reporting, and remote monitoring of weight and height centiles. These affordances must be directly “discoverable” or “perceivable”, according to Norman (2013), and the use of an emulated environment, as described in section 3 of this chapter, provides the avenue for this discovery. Participants have repeatedly articulated the benefits the application can provide to their service, and how it can streamline their patient interactions. This articulation of benefits, combined with the observations made of the participants ability to effectively navigate the system with little prompting, shows tangible benefits to potential users.

6.8 Conclusions

No-code platforms, as applied in this research leveraging a dual platform approach, appear to provide tangible benefits to healthcare providers undertaking a digital transformation, and are suitable for the creation of connected health mobile applications. As the CAMHS in Ireland continues its connected health led digital transformation, no-code platforms offer researchers the ability to create design science research artifacts, in the form of connected health mobile applications, efficiently and effectively.

Employing a two-platform approach ensures that applications are built in a modular way from inception, through initial design and usability testing, and subsequently prime an application for clinical trials and future adoption within a health service. C-CAMHS illustrates how efficient the use of no-code platforms can be in creating a connected health application for CAMHS in the Irish health service. It also illustrates how no-code platforms can be used within the context of a design science research project to generate tangible and demonstrable artifacts for evaluation, giving rise to what one may refer to as a "citizen researcher".

DMH-H highlights how no-code systems may be relied upon to collect data in a healthcare setting/ research study. Information gathered via DMH-H confirmed to traditional data collection, pen and paper, within the acceptable margin of error. DMH-H was also stable in its use, with the research team not encountering errors when using the system.

This work has employed proxies to gain access to the participants and subsequent data needed to develop this proof-of-concept application in an ethical manner, given the financial constraints and timelines of a PhD thesis. Future research is needed to derive insights from direct user interaction with the prototype. This will typically take the form of an observational or possibly clinical study where the presented prototype is tested within a CAMHS environment to review both its effectiveness and efficiency in supporting CAMHS. While proxies provide a valid approach to prototype creation, the engagement with real end users is a critical step in the development of a complete, production ready system.

Future research may also be completed to compare and contrast different no-code front and backend providers to identify industry leaders in the context of connected health, the results from this formative piece of research are certainly promising and may pave the way for future, large scale research studies in both design and clinical settings. This chapter has leveraged thunkable as the front-end provider and Xano as the backend provider, however other providers may be more suitable to the "citizen researcher" approach noted in this chapter. Future work is warranted to answer this question.

Chapter 7: Discussion

This thesis speaks to, and builds on, the findings of the Maskey and Finnerty reports which have highlighted inefficiency and shortcomings of the CAMHS service within the Republic of Ireland. Chapters four, five and six present individual research works conducted and have presented findings in relation to specific elements of a digital transformation within the CMAHS service. It is critical, however, that the overall contribution of this thesis be discussed as each chapter represents a building block to what is an overall research project.

The aim of the thesis overall is to provide a pathway, or avenue, for connected health researchers looking to create applications within the mental health domain, that seek to leverage low code/ no code platforms as developments tool for creating said interventions. The use and study of low code/ no code platforms within the connected health domain appears to be a relatively new phenomenon, with no code platforms focused on connected health being a relatively new offering (Liu et al., 2022). These platforms do however, as discussed by both Liu et al. (2022) and in chapter 6, show potential to provide tangible benefits to healthcare organizations looking to perform a digital transformation and embrace the principles of connected health to improve their service offerings and patient experiences. Research in the area has the potential to open new avenues for the rapid development of the applications that are needed to reform the clinical pathways that are under the most pressure in modern healthcare systems. The benefits of connected health for both the patient and the health service provider are well documented in existing literature, however the use of low code/no code platforms within connected health appears, as mentioned, to be a new territory for researchers.

This chapter will provide a discussion of the totality of research conducted during this PhD research project. To effectively frame this work, design science will be used to both present and validate the approaches and outcomes of the individual research outputs achieved in the papers underpinning this research, and to provide a unified canvas to represent the entire thesis.

7.1 Research Questions

This thesis thus far has presented three research questions as below:

1) How can the complexities of the Dundee ADHD Treatment Pathway be efficiently communicated to a multi-disciplinary team? – As discussed in chapter 4

2) What are the risks and benefits associated with digital transformation within the Irish CAMHS service? – As discussed in chapter 5

3) How can Low-code/No-code development platforms assist in a connected health-led digital transformation of Irish CAMHS? – As discussed in chapter 6

The following three subheadings examine each of the three research questions in order to provide context for the remainder of this discussion chapter.

7.1.1 RQ 1 Conveying Complexities of the Dundee ADHD Treatment Pathway to a multi-disciplinary team

Research question one focuses on how the complexities of the Dundee ADHD Treatment Pathway can be conveyed to a multi-disciplinary team. This thesis proposes an effective way of presenting the complexities of the Dundee pathway to a team of specialists with various competencies via the utilization of integrated patient journey mapping, specifically a modified implementation of integrated patient journey mapping, as proposed in Chapter 4, mapping both the implementation of integrated patient journey mapping within the context of Irish public CAMHS environment and its use within a private case study organization, findings from both cases identified that visualizing the pathway, or using integrated patient journey mapping, was highly beneficial in conveying the complexities of the treatment pathway to a multidisciplinary team.

Connected Health Systems require a multidisciplinary team as they involve input from clinicians, policymakers, IT professionals, and consultants to effectively create an application that best suits the needs of the organization. Based on the findings of Chapter 4, it was identified that utilizing the patient journey mapping diagram to present a clinical pathway yields tangible value. This is particularly true in the context of developing a Connected Health application, as it provides non-clinical team members with context on how a clinical pathway progresses and identifies the relevant clinicians or stakeholders involved in the pathway.

In applying the integrated patient journey mapping tool to public Irish CAMHS, several key opportunities were revealed for embedding connected health systems into this pathway. Firstly, leveraging software-based screening questionnaires, aimed at reducing clinician administrative overheads. Secondly, utilizing software-based teaching materials, including digital content libraries with audio and video, can assist in non-medical interventions. Lastly, adopting remote monitoring tools such as Bluetooth blood pressure cuffs can streamline the continued care process, aiming to reduce the number of necessary follow-up appointments while maintaining high oversight and patient care standards. The insights revealed in this research provide a foundational context for research question four, which explores the key requirements of a connected health application likely targeting these specific areas for implementation within Irish CAM services.

7.1.2 RQ 2 Risks and Benefits of Digital transformation within Irish CAMHS

Research question two identifies the risks and benefits of a digital transformation within Irish CAMHS, with reference to the recommendations for connected health mobile application requirements identified from research question one. Three technology categories were discussed during interviews with clinicians, notably EHR systems, Telemedicine, and mHealth mobile applications (with functionality including remote patient monitoring, digitized screening questionnaires, and online learning material repository).

7.1.2.1 EHR Risks and Benefits

In the context of EHR systems, clinicians noted a number of risks and benefits and appeared to have a level of consensus in regard to the benefits of EHR systems in a CAMHS context, with only one of the six identified benefits receiving less than five mentioned across the seven participants. The benefits outlined include standardized structure, elimination of poor handwriting and reduction in the risk of lost records.

Risks associated with electronic health record systems within a CAMS context presented a less coherent understanding from clinicians in relation to the risks that they pose, with only three of seven identified risks receiving more than five mentions. However, the risks associated are real and tangible and must be respected when implementing any potential connected health-led digital transformation within CAMHS. Some notable mentions include the risk of data breaches through hacking, the lack of IT support present in the Irish Health Service, and also the potential difficulty in gaining user buy-in from staff or parents.

7.1.2.2 Telemedicine Risks and Benefits

In the realm of telemedicine, four benefits were identified, yet only two received five or more mentions. This suggests a lack of consensus among those interviewed and indicates that the full implications of telemedicine may not be fully realized. The highlighted benefits were accessibility and time savings, especially for stable patient monitoring. Interestingly, despite identifying four benefits, nine risks were also associated with telemedicine. However, only two of these risks received five or more mentions, reflecting some apprehension among clinicians about using telemedicine in the CAMHS context. The key risks noted include the inability to observe body language and the difficulty in forming connections through a screen compared to face-to-face meetings.

7.1.2.3 mHealth Risks and Benefits

Regarding mHealth mobile applications, eleven benefits were identified: three related to remote screening questionnaires, three to software-based teaching materials, and five to remote vital sign monitoring. Five of these benefits received five or more mentions, while only two received fewer than four mentions, indicating a higher level of consensus on the advantages of mobile health applications within the CAMHS service.

However, in terms of risks associated with mHealth, thirteen were mentioned. No risk received five or more mentions; the highest mention count was four, relating to the need to update software-based teaching materials. All other risks had three or fewer mentions, showing a clear lack of consensus among those interviewed about the potential risks of mHealth adoption within the CAMHS setting.

Based on the interviews conducted, there is a strong consensus regarding the benefits of a connected health digital transformation powered by electronic health records, telemedicine, and mobile applications. However, there is less agreement about the associated risks. Notably, telemedicine risks were frequently highlighted, particularly those related to clinician-patient interactions. Interviewees identified significant concerns such as the inability to observe body language for subtle cues, difficulties in forming connections, and challenges in fostering relationships essential for successful mental health interventions.

Additionally, a critical risk identified was the lack of direct access to patients during emergencies requiring immediate intervention, such as cases of self-harm. This risk, while not universally acknowledged by all interviewees, presents a substantial challenge.

It is this researcher's belief that electronic health records, telemedicine, and mHealth applications can add significant value to CAMHS. However, a time element certainly exists, with certain phases of treatment within a CAMHS setting presenting higher risks compared to others. For instance, during the initial phase of meeting and assessing an individual, telemedicine may not be appropriate. Face-to-face interactions may be necessary to mitigate risks such as the inability to read body language and difficulty in establishing connections.

These risks are less likely for individuals on stable treatment plans. For example, those diagnosed with ADHD and on continuous, effective medication are at lower risk of experiencing mental health issues. The existing connection with clinicians from previous engagements provides a relationship foundation, and there is a reduced impact of the lack of body language observation since the diagnosis has already been established. Ultimately, the choice of where and when to implement telemedicine, and by extension, mHealth mobile applications, should be left to the clinician to decide as their experience will guide their judgment on when and where to use these technologies. EHR systems are different in scope, as they are ideally implemented at every stage of the patient’s journey. Robust security implementation and stakeholder buy in will be critical elements of EHR system adoption within CAMHS.

7.1.3 RQ 3 Low-code/No-code development platforms assist in a connected health-led digital transformation of Irish CAMHS

In the context of a connected health-led digital transformation for Irish CAMHS, it is crucial for those developing mobile applications to understand the complexities of the treatment pathway. The responsibility for creating such an application may subsequently fall to a researcher familiar with the intricacies of ADHD treatment, thus providing an opportunity to implement no-code development platforms. These platforms allow experienced individuals without extensive system development resources to create secure applications for testing and quickly iterate through versions using an iterative software development or research approach, such as the design science research methodology highlighted by Peffers et al. (2007)

Low-code and no-code development platforms introduce the concept of the citizen developer, someone who understands the domain where an information system is applied but is not inherently a software developer. In a research-driven field like healthcare, this creates opportunities for "citizen researchers" who recognize the need for research but also possess the technical skills to develop applications, therefore able to leverage the tools provided by such platforms to deliver applications to a greater level of efficiency. Often the limiting factors for applications created in a publicly funded research environment are time and resources, with certain relevant expertise also in short supply. Low code and no code platforms enable researchers to rapidly develop and iterate applications for testing in a research environment in both an efficient and effective manner. Citizen researchers differ from Citizen developers as they are, as their name implies, researchers and therefore are ultimately responsible for producing novel findings. Therefore, they must understand the nuance of any implementation of a connected health system. Knowledge of both the systems being created or tested, and the context to which it is applied is critical for the identification of novel insights.

Based on the study presented in Chapter 6, along with the practical case study in the same chapter, clinical applications of low-code and no-code platforms are explored. The two-platform approach used in these case studies highlights significant opportunities for efficient and effective testing, evaluating, and iterating research applications, while mitigating the risk of vender lock-in. This process provides valuable insights and learnings that can be applied to future projects. Therefore, it can be inferred that using low-code and no-code development platforms is beneficial for the design and development of clinical applications in both a research and organizational setting by facilitating the “citizen researcher”.

Within the context of Irish CAMHS, and indeed other health services with limited access to robust ICT infrastructure to support connected health applications, the use of a dual-platform approach to connected health development, as discussed in chapter 6, provides researchers and IT professionals the opportunity to create a standalone application, leveraging speed and efficiency of no code application development. The combination of independent front and back-end no code platforms facilitates the creation of an application which can stand on its own, while also leveraging industry standard communication protocols in anticipation of connection into an organization’s wider ICT infrastructure once available.

The use of industry standard communication protocols is a critical component of the dual-platform approach as there is uncertainty around the types of ICT technologies that will be adopted by an organization when at the green field stage of digital transformation, as is the case with CAMHS. When proprietary protocols are employed, which is often the case with closed ecosystems, there runs the risk of potential integration issues when attempting to “on-board” a connected health application onto the organizations wider

ICT infrastructure. This results in technical debt, something which organizations generally wish to avoid. Dual platform no-code development provides a possible mitigation to the risk of technical debt within an ongoing digital transformation process.

To ensure that the use of low-code development yields positive results within a digital transformation, it is important that key requirements for a connected health application are established. In the case of this thesis, establishing key requirements for a connected health application to support ADHD diagnosis and treatment.

7.2 Key Requirements for A Connected Health System to Support ADHD

The Dundee ADHD Treatment Pathway, a preferred standard for ADHD treatment, has been visualized via the use of modified integrated patient journey mapping in chapters four and six. This process has identified several key areas where connected health can be embedded within the Dundee ADHD Pathway to support Irish CAMHS.

First, the implementation of software-based screening questionnaires can digitize the traditional manual process of scoring and interpreting screening questionnaires. This digitization has the potential to streamline clinician workflows and increase productivity by removing the manual scoring process.

Second, leveraging software-based teaching materials, including digital content libraries using text and audio-visual content, to assist in non-medical interventions of the pathway. This facilitates more effective implementation of non-pharmacological interventions in the treatment of ADHD, ensuring parents have access to the most up-to-date literature and guidance surrounding ADHD treatment. It also ensures that parents can be provided with targeted material at the clinician's discretion.

Finally, adopting smart remote monitoring tools, such as smart Bluetooth blood pressure cuffs, aims to streamline the continued care process by reducing the number of required continued care appointments while maintaining a high level of oversight and governance for patient care. This is critically important in the context of CAMHS. As noted in this thesis, staffing is a prevalent issue within CAMHS as over the course of this project, it was noted that clinicians frequently change or leave their positions. Therefore, effective use of connected health systems to streamline diagnosis and treatment of ADHD is critical to assist in delivering these services to adolescents effectively. The creation of a more efficient work environment may subsequently drive motivation for clinicians to work in the service. This possible update in staffing may drive further reductions in waiting lists due to increased overall patient visits.

Based on these findings, technologies that may be most beneficial are software-based screening questionnaires, software-based teaching materials, smart blood pressure monitoring and vital sign monitoring tools. These tools can be embedded within a connected health mobile application provided to patients to support the diagnosis and treatment of ADHD.

No-Code development platforms, as discussed in chapter 6 and section 7.1.3 of this chapter, provide an avenue for these systems to be produced in an efficient manner, while a dual-platform approach provides a hedge against vender lock-in and technical debt, as discussed in section 7.1.3. This is a key requirement of a CAMHS mHealth application, as with any application, should be an ability to leverage industry standard communication protocols between front and back-end infrastructure to ensure wide connectivity with other potential systems.

7.3 Presenting a Connected Health Framework for CAMHS Digital Transformation

This section will present a framework and section 7.4 will subsequently present a roadmap for the implementation of connected health systems within CAMHS which leverages no-code development. The framework presented is derived from Hevner et al. (2004) original conceptual model of design science, focusing on the Organization, People, Technology, Foundation, Methodology and Development approaches highlighted within. The subsequent roadmap is based on the DSRM highlighted by Peffers et al. (2007), with connected health specific objectives and relevant justification factors noted in both chapters 4 and 5, and by Tuunanen et al. (2024). A framework is presented to provide theoretical grounding for the creation of a practically applicable roadmap for designing and developing connected health systems in a CAMHS setting using low-code platforms which leverages established IS theory as its basis.

The following sections are broken down into the areas of note under Hevner et al. (2004) DS framework, notably Organization, People, Technology, Foundations, and Methodologies.

7.3.1 Organization

The first primary research chapter, chapter four, presents a modified integrated journey mapping implementation where the Dundee pathway has been visualized. This pathway is the recommended pathway for ADHD treatment as per the Maskey report. In line with Hevner et al. (2004) DS framework, the Environment also contains “Organizations”, with specific reference to the strategies and processes employed by these organizations. Based on results from interviews with clinicians, effective Dundee pathway implementation is a key goal of the CAMHS services, and therefore any connected health intervention focusing on ADHD within CAMHS should be built based on the Dundee pathway, based on current evidence.

To that end, the Dundee pathway has been mapped out using integrated patient journey mapping, with Peffers et al. (2007) design science research methodology leveraged to ensure the accuracy of the visualization. Details of the relevant information points required for a connected health application are captured within the visualization to ensure that these points are addressed within a proposed connected health application.

The lack of comprehensive ICT with CAMHS for such an extended period may present a challenge for the implantation of a connected health application. Many staff may be familiar with the incumbent, paper-based system, and there may be a culture within the service that may manifest a resistance to change. This resistance can be rooted in a number of factors, including perceived risks associated with these technologies. Ultimately, a culture change may be required to ensure adequate buy-in within the organization. A key element of this is understanding the key risks that may drive these resistances and identifying benefits that can be used to drive organizational buy-in.

7.3.2 People

The second primary research chapter of this thesis, chapter five, presents a risk benefit matrix of the views of clinicians when faced with the proposition of a digital transformation within their service. Specific reference was made to electronic health records, telemedicine and mHealth technologies, as these technologies were recommended for implementation in the Maskey report or are a logical progression of said recommendations based on existing literature.

While findings of this chapter generally align with the existing literature surrounding digital transformation within healthcare organizations, the work is critical to the research project as it ensures the nuance of the individual service is captured. The results of this research are primarily focused on identifying the view of the individual clinicians within the service, ensuring that their needs and fears are addressed when creating a connected health solution.

Reflecting back on Hevner et al. (2004) initial conception of design science research, a key element of the “Environment” is that of the people, their roles, capabilities and characteristics. Providing clinicians with an avenue to voice their opinion, both positive and negative, of digital transformation provides the opportunity to establish the feasibility and appetite for a digital transformation from the point of view of the clinicians, who are a primary cohort of users, or “people”, that will play a large part in determining the success or failure of a connected health solution.

Service users and care givers are also cohorts who have a role in the success or failure of a digital transformation of the organization as their buy-in is required to ensure a connected health application has the data clinicians need to make appropriate clinical decisions. Within the context of a CAMHS system, these service users are typically adolescents with mental health problems, and their caregivers are usually parents and teachers. While patients and service users were not participants in the research due to ethical reasons, as noted in the limitations section of this chapter, teachers and special needs assistances were included in this research project.

7.3.3 Technology

The third element of the environment within Hevner et al. (2004) DS framework is Technology. Over the course of the previous two primary research chapters, and results from the Finnerty report, it is clear that there is no evidence of a single, unified approach to technology implementation within CAMHS, and many units within CAMHS have little to no ICT implementation and is essentially a green field site. This thesis has therefore taken the approach that there is no appreciable connected health technology base within CAMHS and a “ground up” approach must be taken, where no connected health technology can be relied upon, and only basic ICT services (computer access, internet access etc) can be utilised. This presents the daunting task of creating a proof of concept, connected health application with no jumping off point. Based on existing literature, Low-code/No-code solutions offer the ability to rapidly create prototype applications for usability testing, and has been identified as an appropriate development approach, with initial results from clinical trials supporting this. However, there are noted risks associated with the use of no- code platforms, such as vender lock-in and subsequent technical debt. As discussed in chapter 6 and section 7.1.3, a dual-platform approach was leveraged to tackle this green field problem, and results of an initial observational study and design science study of artifact design, both of which are highlighted in chapter 6, leveraging this approach appear promising.

7.3.4 Foundations

As noted, both the Maskey and Finnerty report form a basis of this thesis, with their findings and recommendations forming a basis of the primary research conducted. These reports have conducted a comprehensive review of the CAMHS services, both at local and national levels, and produced findings and recommendations that are applicable to all CAMHS units within the Irish health service. The Finnerty report in particular highlights the green field nature of ICT within CAMHS, and the Irish healthcare services in general, appears to be behind the curve when it comes to advanced ICT readiness.

There are a number of connected health systems available and used by other healthcare organizations, both public and private, to great success. These include EHR’s, Telemedicine and mHealth. The general details and associated benefits and risks of these technologies are highlighted in chapter 2, with chapter 5 highlighting CAMHS specific risks and benefits. The green field nature of Irish CAMHS ICT infrastructure currently presented a challenge as there are little to no establish centralized record management systems to store readings and insights generated from the above noted technologies. When attempting to establish a foundation in the context of ICT, there was none. Section 7.2.3 has provided context as to how this was addressed during the course of this research project.

7.3.5 Methodologies

As noted, the primary methodology leveraged for chapters five and six of this thesis is the "Design Science Research Methodology" (Peffers et al., 2007), a highly cited and respected DSR approach. This approach ensures the accuracy and rigor of chapter five and chapter six (as informed by chapter four and five). It is important to note that, during the course of the final primary research of this thesis, an important publication within the DSR domain was made available, titled *"Dealing with Complexity in Design Science Research: A Methodology Using Design Echelons"* (Tuunanen et al., 2024). While this work was published after final primary research had commenced, the final overall thesis contribution is examined against the "Validation techniques" noted in this publication to ensure that this thesis remains in line with current literature.

7.3.6 Visualising this thesis

As noted in the beginning of this chapter, this discussion section attempts to frame this thesis in the context of the *"Information Systems Research Framework"* (Hevner et al., 2004). Based on this, Figure 7.1 presents a visualisation of this thesis within the context of Hevner et al. (2004) DS Framwork.

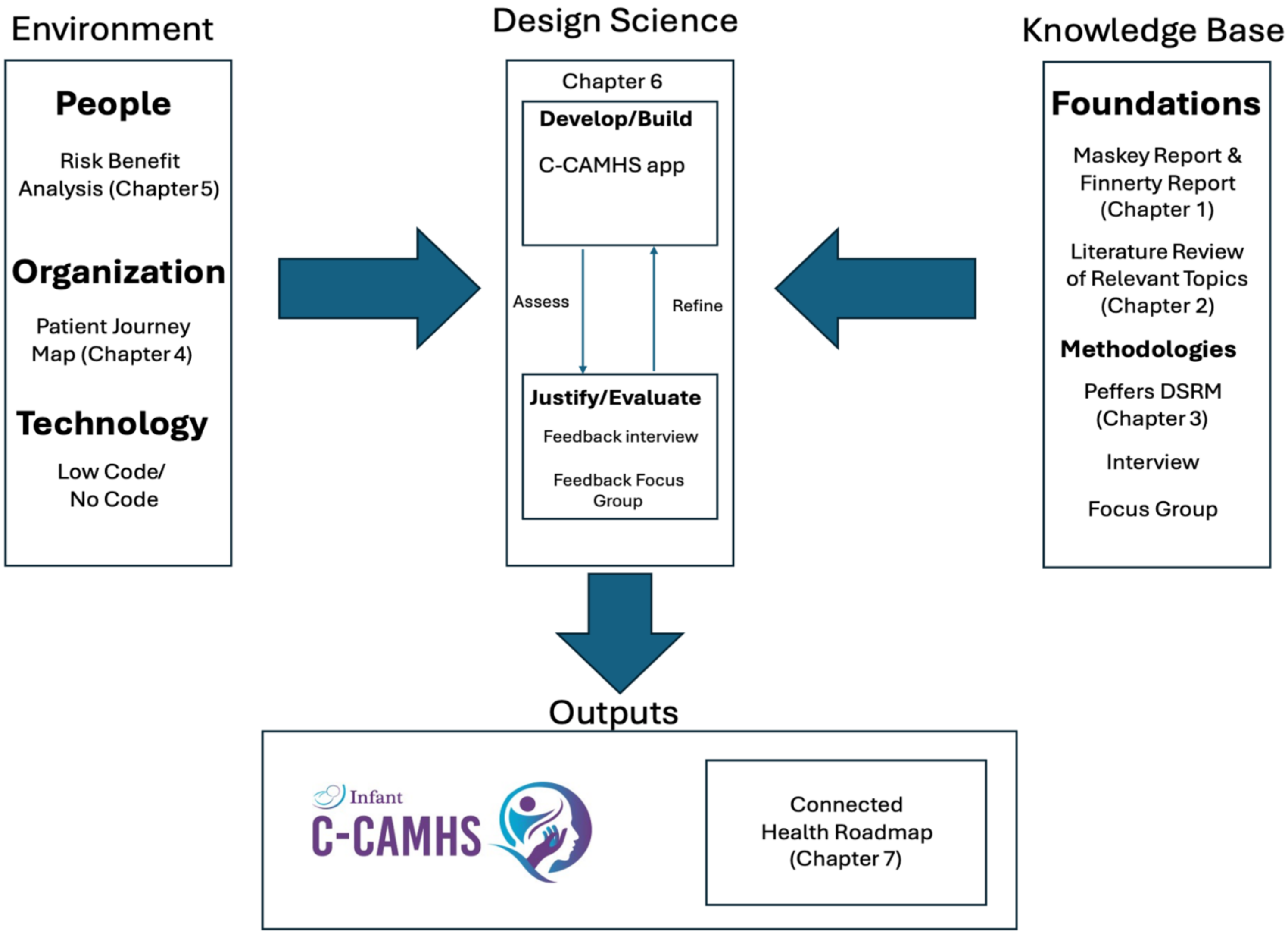


Figure 7 1 - Thesis as per Design Science Framework (Hevner et al., 2004)

7.4 Connected Health Roadmap

Based on the above work, as visualized in figure 7.1, this thesis presents a series of induvial research outputs, that may be individually placed at level one of Gregor and Hevner DSR contribution types, see figure 7.2. Chapters four and six create tangible artifacts, in the form of a patient journey map and a proof-of-concept mobile application. Chapter five, while not implementing design science specifically, it does create an artificial output in the form of two matrices of risk and benefit of connected health.

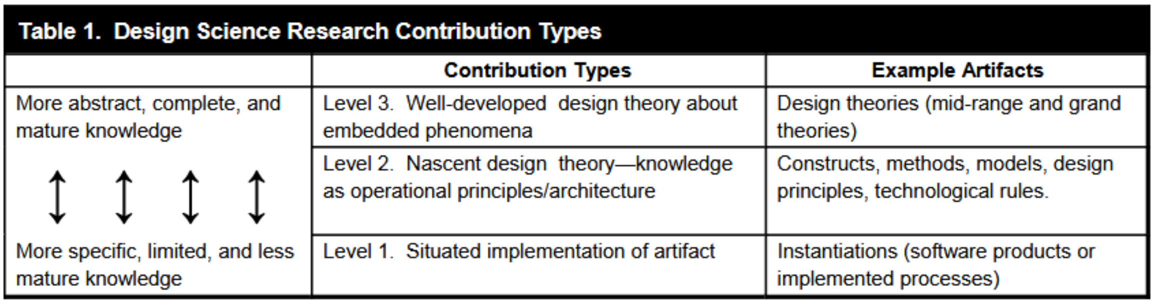


Table 1. Design Science Research Contribution Types

	Contribution Types	Example Artifacts
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
↕ ↕ ↕ ↕	Level 2. Nascent design theory—knowledge as operational principles/architecture	Constructs, methods, models, design principles, technological rules.
More specific, limited, and less mature knowledge	Level 1. Situated implementation of artifact	Instantiations (software products or implemented processes)

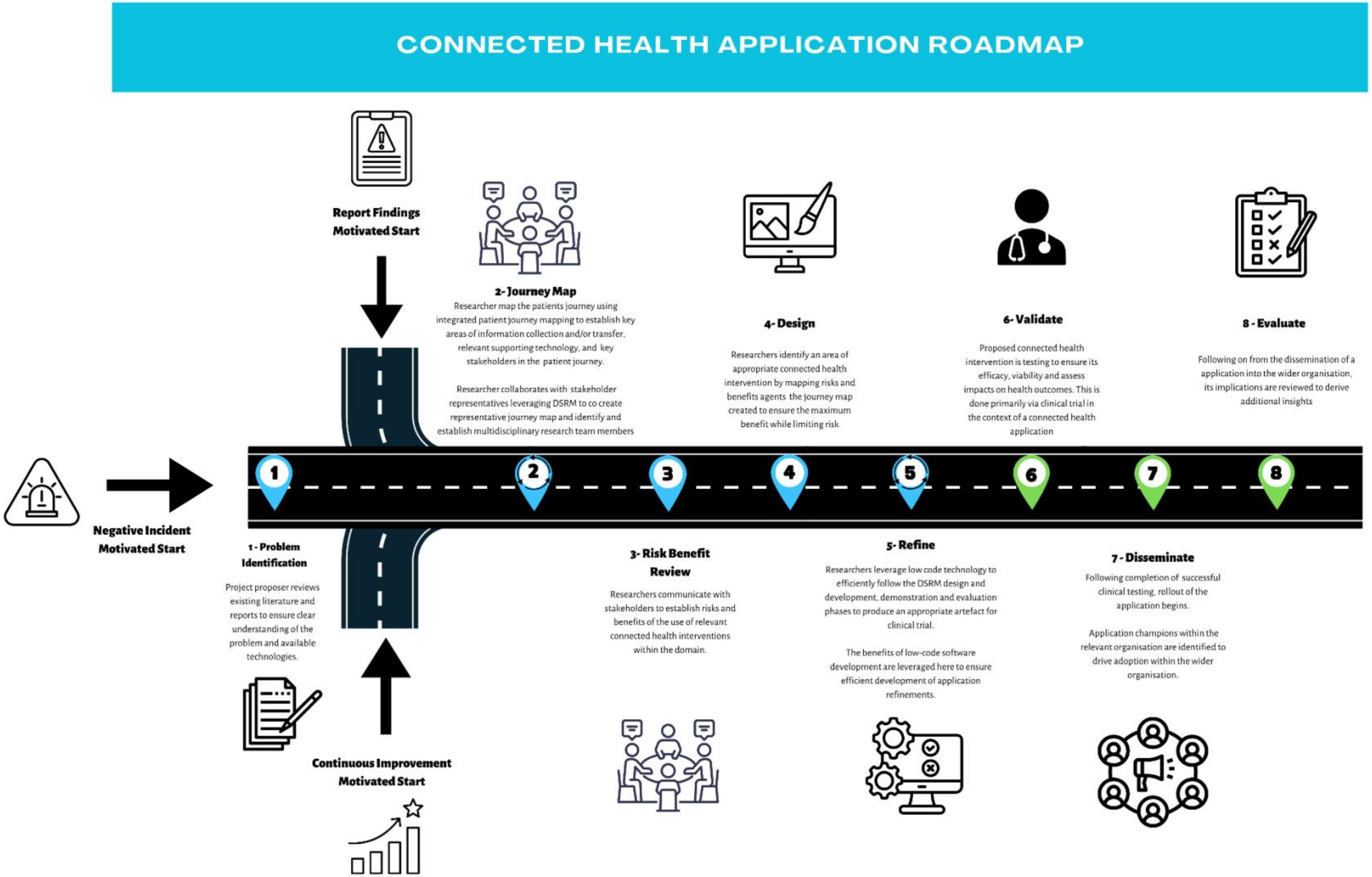
Figure 7 2 - DSR contribution as per (Gregor & Hevner, 2013b)

While figure 7.1 effectively conveys the content of this thesis, it does not necessarily convey how to produce connected health applications as it is based on a framework. In order to provide researchers with more specific guidance on how to create connected health applications, this thesis proposes the below roadmap, figure 7.3, which leverages aspects of the DSRM as per Peffers et. Al. (2007).

This roadmap provides specific guidance surrounding the creation of connected health applications. Each stage of the roadmap is informed by a number of research techniques, with heavy use of focus groups and interviews with experts. Patient journey mapping and risk benefit mapping are also a critical step when establishing the scope of a proposed application. Validation techniques can primarily be sourced from

(Tuunanen et al., 2024), including Feedback interviews, design mock-ups and focus groups.

While it is important to acknowledge the limitations of this work, particularly regarding the number of interview and focus group participants, this is primarily due to the limited number of highly experienced clinicians within the Irish Child and Adolescent Mental Health Services who can provide insights into connected health implementation. Despite these limitations, several key points remain noteworthy. Although clinical trials for C-CAMHS have not been conducted in this thesis, it is the logical next step in the process to validate the usability of C-CAMHS. Results from DMH-H, an application that employs the same two platform architecture, are very promising and provide justification for a clinical trial of C-CAMHS.



CONNECTED HEALTH APPLICATION ROADMAP

Report Findings Motivated Start

Negative Incident Motivated Start

Continuous Improvement Motivated Start

1 - Problem Identification

Project proposer reviews existing literature and reports to ensure clear understanding of the problem and available technologies.

2- Journey Map

Researcher map the patients journey using integrated patient journey mapping to establish key areas of information collection and/or transfer, relevant supporting technology, and key stakeholders in the patient journey.

Researcher collaborates with stakeholder representatives leveraging DSRM to co create representative journey map and identify and establish multidisciplinary research team members

3- Risk Benefit Review

Researchers communicate with stakeholders to establish risks and benefits of the use of relevant connected health interventions within the domain.

4- Design

Researchers identify an area of appropriate connected health intervention by mapping risks and benefits agents the journey map created to ensure the maximum benefit while limiting risk

5- Refine

Researchers leverage low code technology to efficiently follow the DSRM design and development, demonstration and evaluation phases to produce an appropriate artefact for clinical trial.

The benefits of low-code software development are leveraged here to ensure efficient development of application refinements.

6- Validate

Proposed connected health intervention is testing to ensure its efficacy, viability and assess impacts on health outcomes. This is done primarily via clinical trial in the context of a connected health application

7 - Disseminate

Following completion of successful clinical testing, rollout of the application begins.

Application champions within the relevant organisation are identified to drive adoption within the wider organisation.

8 - Evaluate

Following on from the dissemination of a application into the wider organisation, its implications are reviewed to derive additional insights

Figure 7 3 Connected Health Application Roadmap

The connected health application roadmap presented in Figure 7.3 incorporates design science research methodology proposed by Peffers et al (2007). This pathway comprises eight stages and has three presented start points. These starting points are the negative incident motivated start point, the report findings motivated start points, and the continuous improvement motivated start point.

The negative incident motivated starting point, as its name suggests, is when a connected health project is proposed or initiated based on a response to a negative incident occurring. In the context of healthcare projects, this incident may be the preventable death of, or the serious/ lifelong injury to, a patient within a health service. These incidents, often times resulting in local or national news coverage, motivates a healthcare organisation to make systematic changes to its operations to ensure similar incidents do not occur. As this is an incident response, a systems/organisation review is generally conducted by the project proposer, initiating stage 1 of the roadmap.

An example of an incident motivated start is that of the HSE case “Investigation of Incident 50278” which highlights a high-profile case of systems failure within the Irish health service resulting in the death of a pregnant individual. The report notes that, among other courses, there was *“Inadequate assessment and monitoring that would have enabled the clinical team to recognize and respond to the signs that the patient’s condition* was deteriorating*”* (Health Service Executive, 2013b, p. 13). This subsequently motivated the Irish health service to develop updated practices and guidelines to ensure this type of issue does not happen again, as seen by the publication of updated sepsis predisposition and recognition documentation for pregnant individuals (Health Service Executive, 2020b).

The report findings motivated starting point occurs when a report on an organisation’s operation identifies key deficiencies within said organisation. These reports normally are accompanied by recommendations on how to improve operations. In the context of the connected health application roadmap, this starting point initiates the roadmap at stage 2, as the problem has already been identified within the aforementioned report. An example of a report/review initiation is that of the publication of both Maskey (2022) and Finerty (2023) reports which, as discussed in this thesis, reported several deficiencies within the Irish CAMHS service. Subsequent recommendations made by these reports are used as the motivation to begin a connected health research project. Within the context of the roadmap presented, this thesis represents a report motivated project, as discussed in chapter 1.

The third and final entry point is that of a continuous improvement motivated entry point. This is in reference to opportunities that are recognised within a health service as being present but may not have a specific publication or report that speaks to the exact details of the problem/opportunity within that specific health service. In these cases, there is sufficient motivation within the health service to address the problem without the need for a formal, service specific review process prior to project initiation.

An example of this is the case of Pre-Eclampsia monitoring in the Irish Health service. The issue of pre-eclampsia is document in existing literature (Harris et al., 2022) and while there may not be a specific report highlighting the need to change or update Pre-Eclampsia monitoring in Irish health service, there is internal motivation to address the issue as a matter of continued improvement in healthcare. This may be viewed as a pre-emptive starting point, looking to address a possible deficiency prior to high-profile identification through a report or incident, as discussed in the previous two starting points.

As noted above, the roadmap has eight stages, as outlined below:

Stage one begins with the project proposer, the individual who has initially conceptualised the project. In the context of a connected health application, this stage involves a literature review or an internal review of an organization's operations to identify pain points or areas for improvement. Methods such as expert interviews, focus groups, surveys, or reviews of previous initiatives can effectively pinpoint areas where organizational efficiency can be enhanced. The ultimate goal is to identify a problem that can be addressed using connected health applications, while also building an initial understanding of the key skills required within the research team.

The next stage involves patient journey mapping, aimed at defining the appropriate area of responsibility for the connected health application in context. This stage is primarily informed by the findings of research question one, explored in chapter 4, which focused on conveying the complexities of a patient treatment pathway to a multi-disciplinary team. Patient journey mapping, as outlined in chapter 4, provides an avenue for a multi-disciplinary research teams, generally including clinicians, IS researchers, software developers and project specific experts, to engage with a problem statement and facilitates the creation of a shared understanding around the problem statement and subsequently the needs of a potential solution. This journey mapping has the potential to align the team to a single shared goal of addressing the identified problem.

Methods such as focus groups and expert interviews are useful when engaging with relevant stakeholders. Leveraging an establish design science or action design approach may be useful here in creating a representative journey map. While this thesis has leveraged the DSRM as its research methodology of choice, action design research or other established, iterative research methodology may be appropriate depending on the needs and resources available to the individual research project. This stage also involves solidifying research team members to ensure all relevant skills are available within the team based on the findings of the journey mapping exercise.

The next stage involves creating a risk benefit matrix. Here relevant stakeholders are engaged to ensure there is appropriate identification of the possible risks and benefits of implementing a connected health intervention in context. This involves engaging with stakeholders using established qualitative research methods such as interviews and focus groups. This facilitates a clear understanding of domain specific risks and benefit, which may not be readily available in literature or from previous reports. Every health service has differing risks associated with the use of connected health as each health service is a unique entity and therefor it is critical to ensure the nuance of the service is captured when discussing implementing connected health systems. This is to ensure that the relevant information is available to manage these identified risks while providing the most value to both patients and clinicians. As was the case of CAMHS, as identified in chapter 5, there may be a lack of consensus within the target service and as such, additional care should be taken as while these risks may not be identified, this does not inherently mean they do not exist. The risk benefit matrix should therefore act as a guide for researcher but not be used as a definitive identification or risks and benefits.

Stage four involves mapping the risks and benefits, established in stage three, onto the patient journey map, created in stage 2, to ensure there is an appropriate balance of risks and benefits to create an application that will operate in a clinically ethical manner and subsequently creating the first iteration of a proposed artifact for initial prototype testing, as seen in chapter 6. As mentioned in stage 3, these risk and benefits are not a definitive list but acts as a guide for where researchers can begin the process of imbedding an intervention into a treatment pathway. This stage also involves the identification of appropriate low code platforms which have the ability to leverage industry standard communication protocols to allow any created application to communicate with a third party back-end solution to ensure portability of the application, as discussed in chapter 6. This is a critical step as if the chosen platform cannot facilitate the use of industry standard protocols, the risks associated with vender lock in come into effect which, as discussed in chapter 2 and 6, pose a significant risk to the project’s success.

Stage five employs the later stages of the DSRM approach to test, evaluate and iterate prototypes as required to create an appropriate connected health application that is ready for clinical trials. Stage five is broken into three steps when iterating an artifact, in line with the DSRM.

The design and development step is where the object or artifact is iterated based on knowledge from the previous iterations. Design mock-ups, logical reasoning, testing feedback, or simulations can be used to gather information during this phase. This may be skipped in the first iteration as an initial prototype is created in stage four.

The demonstration step involves presenting the application in context to receive feedback from appropriate users. For connected health applications, this typically involves clinician feedback or patient proxies in the first instance. This is driven by ethical considerations as clinicians will need to have input into the applications design and functionality prior to clinical testing. Feedback on usability, functionality, and applicability is gathered through interviews, focus group testing, usability surveys, and demonstrations with prototypes. As discussed in section 7.2.2, service users and parents are the logical target for clinical trial, however as discussed in section 7.5, these users were not included for ethical reasons. Section 7.6 notes the next steps involved in gaining access to these participants in an ethically appropriate way, with later stages of the roadmap highlighting progression to this point on a theoretical basis.

The final step in stage 5 is evaluation. Here, feedback from the demonstration phase is assessed to determine if further iteration is necessary. Reflective analysis, statistical analysis, or case studies can be employed to make this decision. The aim is to decide whether the application is suitable for implementation or if additional testing and modifications are required. As with stage 2, the DSRM is chosen as a representative research methodology, but others, as discussed in chapter 3, may be more suitable for an individual research project depending on the resources available.

Following on is stage 6 validation, the first theoretical point on the roadmap, which takes the form of clinical testing to examine a suitably robust application in a clinical setting to establish its efficacy, viability, and impact on health outcomes. This ensures that there is sufficient data in place to promote and justify its use in a wider clinical environment. Clinical partners should be established, if not already present on the research team, to ensure any proposed research protocol has clinician input to ensure its success in ethical applications and subsequent trial implementation. The clinician with oversight of the protocol design will typically work as principal investigator on the project to ensure appropriate oversight and alignment with ethical responsibilities.

It is important to note that, in the case of an application with a screening component, appropriate follow up care is required to be available in the event of a screening yielding a result that requires further intervention. This is to ensure an individual is not left in "limbo". Reflecting on the work done over this thesis, this may be a stubbing block for future C-CAMHS clinical trials as adolescent psychiatrist resources are limited in the public sector, as noted in chapter 2, and adding additional workload to a clinicians already busy schedule may act as a barrier for adoption. This is something that must be addressed on a case-by-case basis.

Stage 7 is dissemination, which involves integrating the application into the wider organisational environment. Given the dual platform development approach highlighted in chapter 6, the integration of the connected health application should be a somewhat easier process when compared to single low code platform as the risk of vender lock in is mitigated, as discussed in chapter 6. Project champions should be identified and motivated to ensure wider cultural adoption of the application within the organisation. Risks identified as per stage 3 should be noted and managed at local level according to individual service needs, ensuring patient safety is the utmost priority. As with any healthcare intervention, a proposed connected health application it is a tool in the clinician tool kit, and the individual clinician should have the discretion on implementing such tools when treating patients while ensuring appropriate governance and record keeping.

Finaly stage eight involves Evaluation. This is where a connected health intervention is reviewed in the context of wider organisational adoption. While there are a number of key insights that should already be established during validation, there are certainly benefits to performing a look back on a connected health application adoption at scale to identify any possible learnings that may be applied to future projects. At this stage, the intervention is established within an organisations “toolkit” and is available as a proven technology for a future project.

Contrary to the original DSRM, this roadmap has no “communication” phase, as this may be viewed as an end point of a project. This thesis takes the opinion that there is no “end” of a digital transformation project within a healthcare system, due to the ever-changing landscape of healthcare. This changing landscape is driven by continued research and innovation from colleagues across many fields, and therefore an indefinite source of new technologies, methodologies, or treatment pathways. This thesis has applied this proposed roadmap in the establishment of the requirements of C-CAMHS and its subsequent development and has produced generally positive results based on feedback from research participants. As noted, stages 6 and 7 are theoretical in nature in the context of this thesis, as a clinical trial of C-CAMHS has not yet been carried out, however it is envisioned that this will take place in the near future, subject to ethical approval. Below is a breakdown of each implemented step and where is has been leveraged within this thesis.

In the context of the C-CAMHS project, problem identification was performed via the review of the Maskey report which highlighted key deficiencies within child and adolescent mental health services and provided recommendations for addressing these issues. This forms the basis for problem identification.

Subsequently, patient journey map, as seen in chapter 4, and risk-benefit matrices, as seen in chapter 5, were used to establish the scope of a potential connected health application within child and adolescent mental health services. This is a critical step as establishing appropriate scope is paramount for the success of software innovation.

The design and refine phases leveraged low-code technologies to create and iterate through various versions of a connected health application efficiently and securely. Evaluation was conducted through reflexive thematic analysis (Braun & and Clarke, 2019) of usability interviews from the demonstration phase to identify improvements for the proposed C-CAMS application. Based on feedback from these iterations, the next step would be implementing C-CAMHS in a clinical trial context.

This thesis aims to provide formative research that offers academic grounding for applying for clinical trial ethical approval, clinical testing and subsequent implementation of connected health applications within child and adolescent mental health services using a dual platform low-code development process.

It is also anticipated that the roadmap presented in Figure 7.3 may provide for implementing connected health applications in other contexts such as more acute cases within CAMHS, adult mental health services, and possibly beyond mental health services.

7.5 Practical context for this Thesis

“The Squiggle”, created by Damien Newman (2003), as shown in figure 7.4, illustrates *“The journey of researching, uncovering insights, generating creative concepts, iteration of prototypes and eventually concluding in one single designed solution”* (Newman, 2016). A goal of this thesis is to provide a roadmap to allow individuals to progress through the design and development of connected health applications in an efficient and effective way. Practically, this thesis focuses on providing guidance to future researchers and connected health application development teams with the means to move past the "Noise/Uncertainty" stages in an efficient manner by leveraging patient journey mapping as discussed in chapter 4. This initial research and synthesis phase aligns well with the first two stages of the proposed roadmap, as seen in figure 7.3. The concept/prototype phase maps well to the final stages of the roadmap, illustrating nature of prototype creation and interaction.

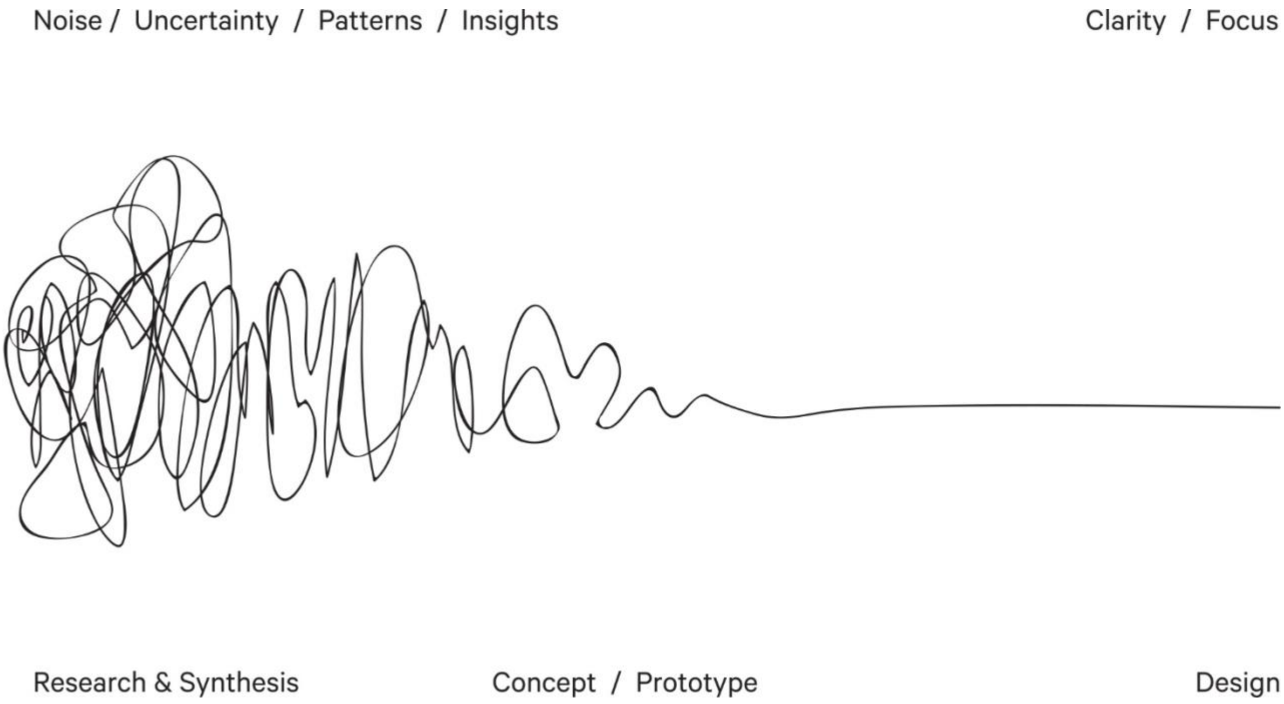


Figure 7 4 – The Process of Design Squiggle (Newman, 2003) - (CC BY-ND) 3.0 USA

In the case of connected health systems, this squiggle may be extended to form a continuing line of multiple areas of "Noise and Uncertainty", triggered by the discovery of new technologies, which must be researched in context to move towards clarity and focus on its design and application. Each time disruptive technology comes into play, the pathway as shown in figure 7.3 may be applied to assist in the embedding of said disruptive technology into the connected health system of an organization. Figure 7.5

illustrates these multiple areas of noise and uncertainty, along with the areas where the proposed roadmap, shown as black boxes, in figure 7.3 may be implemented. This is presented as an infinite process, illustrated by arrows showing a looping scenario.

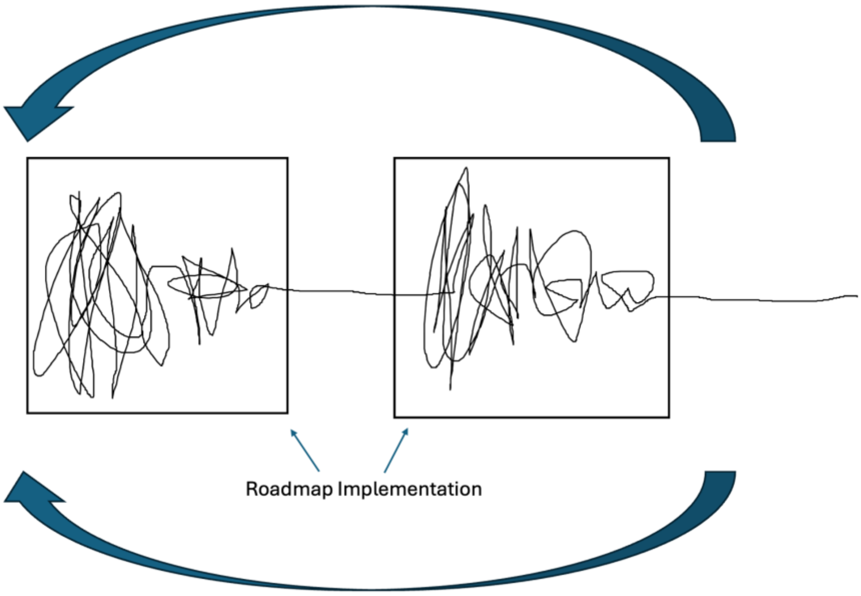


Figure 7 5 Connected Health "Squiggle" (Newman, 2003) With Roadmap Implementation Points.

7.6 Practical Contributions

This thesis offers several practical contributions to the field of child and adolescent mental health services, particularly in facilitating their digital transformation from a predominantly paper-based system to the adoption of Information and Communication Technology (ICT) for decision support, record management, and service delivery modernization.

The first contribution is the integrated clinical journey mapping presented in Chapter 4, which visualizes the Dundee ADHE treatment pathway within the context of a connected health-led digital transformation for CAMHS services. The identification and verification of recommendations in both this chapter and the Maskey report underpin the subsequent work discussed in this thesis, especially regarding the design, development, and positioning of a potential connected health artifact, C-CAMHS.

Another practical contribution is highlighted in Chapter 5 through the risk-benefit matrices. These matrices underscore that while clinicians generally agree on the risks and benefits associated with traditional e-health and connected health solutions, such as electronic health records and telemedicine, there exists some disparity concerning the risks and benefits of utilizing mobile smartphone applications in service delivery. This finding indicates a need for further testing of connected health artifacts that primarily involve smartphone application-based interventions or communication channels between patients and clinicians.

Chapter 6 further contributes by illustrating the design and development of a connected health artifact. It demonstrates how such solutions can be integrated within services through an iterative design process that involves stakeholder engagement at various stages, aimed to enhance the efficiency of patient care. The created artifact, C-CAMHS, is now in a position to progress to clinical trials which may serve as an avenue to further refine or validate its design and functionality.

7.7 Theoretical Contributions

This thesis presents several theoretical contributions to the field of information systems, with a specific focus on health information systems. Chapter Four introduces the use of integrated patient journey mapping within the context of CAMHS. It details various refinements to the integrated patient journey mapping tool, facilitating multi-persona visualization within a single journey mapping artifact. This approach is particularly beneficial for well-defined treatment pathways, such as the Dundee ADHD clinical care pathway, as it demonstrates how different personas progress through the same start and end points, albeit with variations based on individual cases.

The application of unified modelling language techniques within the journey mapping artifact enables effective visualization of these multiple personas. This allows users to comprehend how and why certain actions occur at specific points throughout the pathway, particularly in relation to decision-making regarding potential treatment options available to patients. A case study was subsequently used to validate the ability of integrated patient journey mapping to foster a shared understanding among a multidisciplinary team regarding the requirements of a connected health application, specifically focusing on the diagnosis and treatment of ADHD in adolescent mental health services. This case study illustrated that the use of IPJM can be of notable benefit to these teams during the development process.

Chapter Five predominantly offers a practical contribution through its presented matrices but also contributes theoretically by highlighting the lack of consensus among clinical experts interviewed concerning the risks and benefits associated with mobile health applications. This finding opens avenues for future research into the theoretical aspects surrounding the use of mobile applications for diagnosing and treating ADHD within adolescent populations, both in Ireland and potentially on an international scale.

Chapter Six proposes employing a dual platform, no-code development approach for designing and developing connected health artifacts in the context of ADHD diagnosis and treatment within adolescent populations. The use of no-code platforms has revealed several intriguing phenomena that, although implicitly addressed in the chapter, offer significant opportunities for future research. Utilizing no-code platforms to provide users with an emulated environment for engaging with potential applications facilitates understanding how individuals interact with the application while receiving real-time feedback from both oral responses and visual interactions. This approach can be leveraged in other context, both within and outside the mental health domain for connected health system design and development.

Moreover, employing no-code platforms to design applications presents an opportunity for a frugal innovation approach (Sarkar & Mateus, 2022) to connected health system design by the effective use of limited resources to deliver maximum benefits to patients with minimal resource expenditure.

This chapter also introduces the concept of the citizen researcher, which is an evolution of the term “citizen developer” that is commonly used to describe individuals within an organization who have specific process expertise, who can leverage no-code solutions to develop applications without the underlying technical skills required to develop applications using traditional development approaches. The citizen researcher leverages the abstracted nature of no-code platforms to develop applications for research purposes. In the context of this thesis, the area of connected health systems comes to the fore, but this approach may be applied across all software development areas where an iterative approach to designing a research mobile application may be appropriate.

7.8 Limitation

Over the course of this research project, the primary participant groups where clinicians and connected health researchers/practitioners, with special needs teachers and assistance acting as end users. While the participation of parents and/ or CAMHS service users with ADHD would have added further to this research project, it was not possible to set up a clinical trial during the course of the PhD’s funded timeline. As noted in 7.1.4, there was a considerable amount of staff turnover with CAMHS services, hindering the establishment of a relationship with clinicians who would be in a position to run a clinical trial.

The scope of this research work has been within the Republic of Ireland, with the majority of participants working in the health service within Ireland. This presents a limitation in relation to the experience of individuals interviewed, as they may differ in other settings.

Literature reviewed during this thesis was limited to the available literature licenced by University College Cork library, and open-access content available without fee.

Funding limitations prevented the use of certain relevant technologies, for example Optical character recognition (OCR) for extracting blood pressure readings from verification images, which may have benefited the functionality or effectiveness of the C-CAMHS application highlighted in chapter 6. While beneficial technologies exist, upon query or investigation, these software's required licencing or usage fees that where prohibitive given project funding scope.

7.9 Future Research

Reflecting back on Gregor and Hevner (2013a) DSR contribution types, this work may form the beginnings of a type two, nascent design theory contribution. While this approach has proven a success in producing a proof-of-concept application (C-CAMHS), further implementation of this proposed roadmap will be required to validate its effectiveness across various connected health domains. As per Jones and Gregor (2007) *"A number of instantiations in multiple case studies may need to be studied before the general principles enabling them to function can be extracted"*. It is therefore prudent to conduct multiple implementations of this roadmap to "tease out" any shortcomings and adapt it to provide a more generalized approach.

Clinical trial of the C-CAMS application, or similar, within the context of CAMHS may yield a justification for adoption within the wider Irish CAMHS network, or further afield internationally. The findings for this thesis provide key learnings which can be used as part of a clinical research protocol and subsequent clinical research ethics application. The next logical step for this research is to establish a relationship with a CAMHS service that is in a position to provide clinical oversight and running of a clinical trial.

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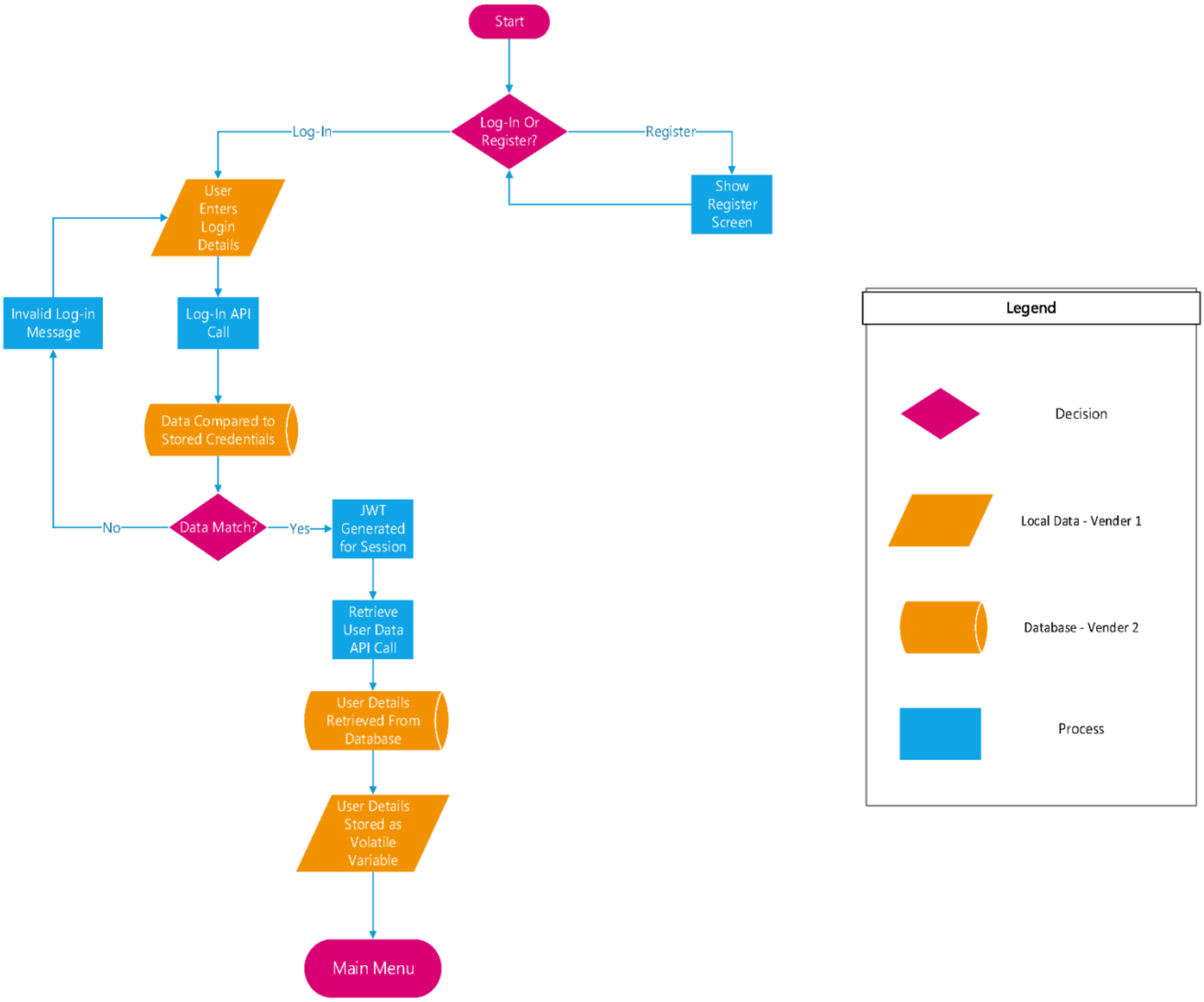
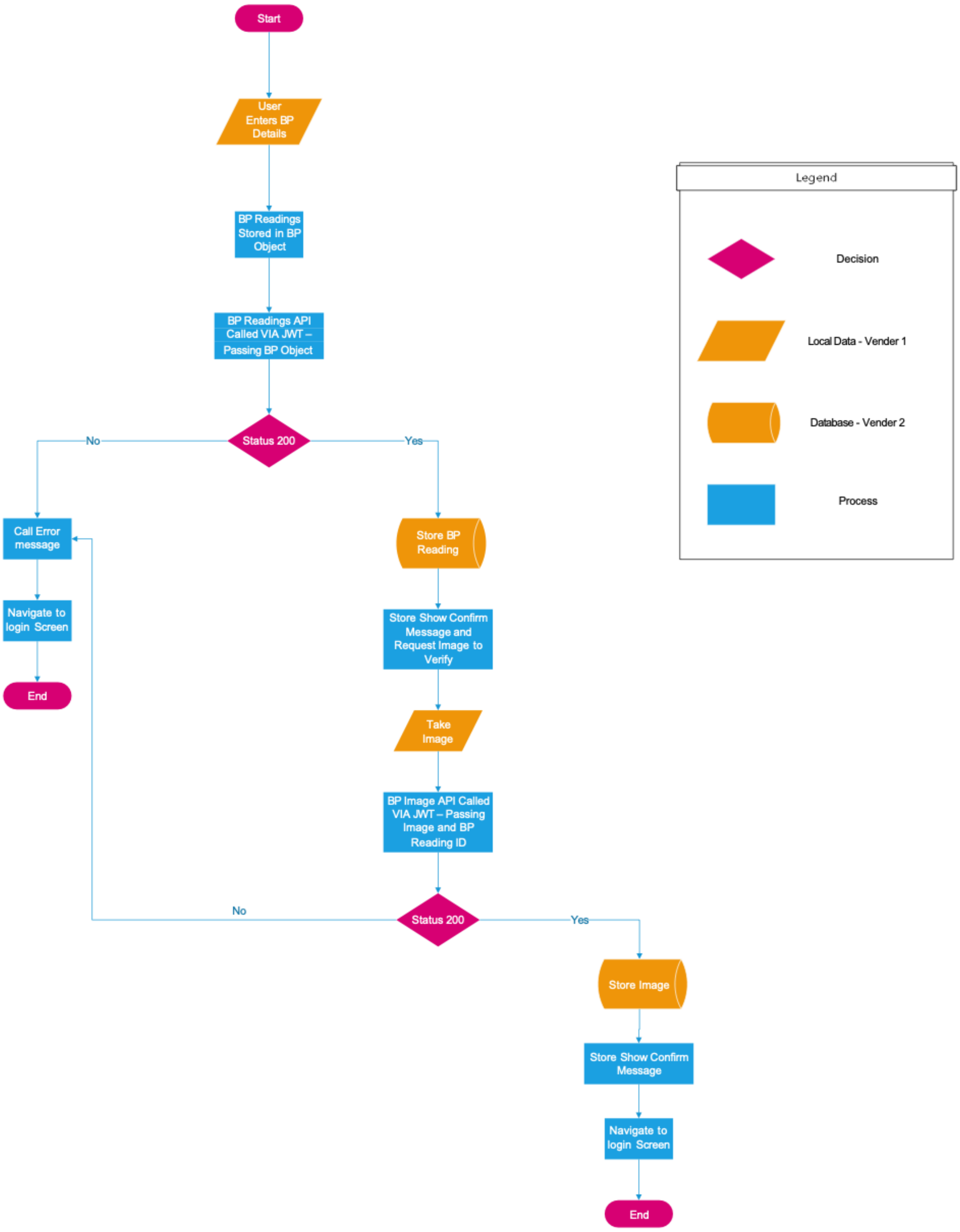
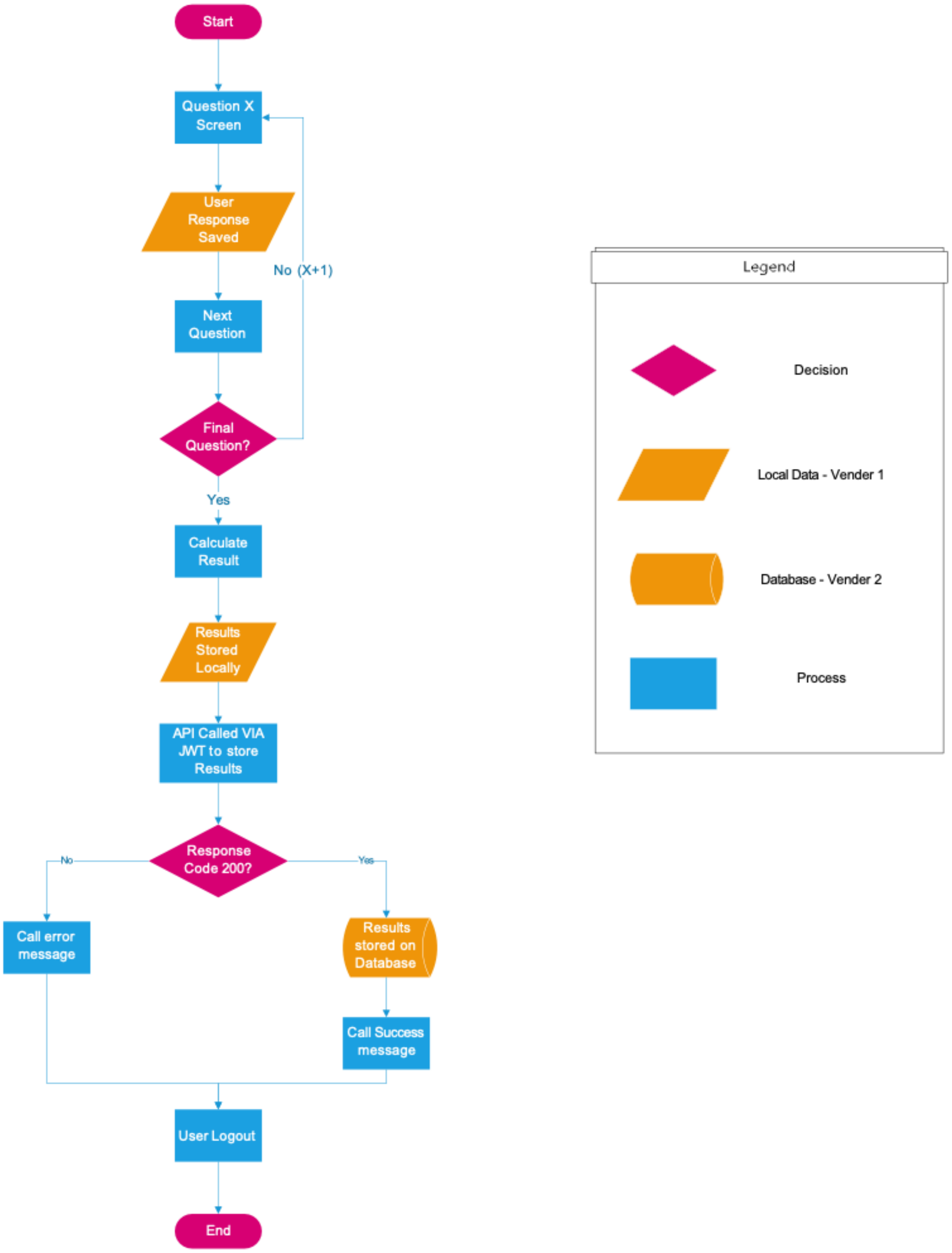
Appendix



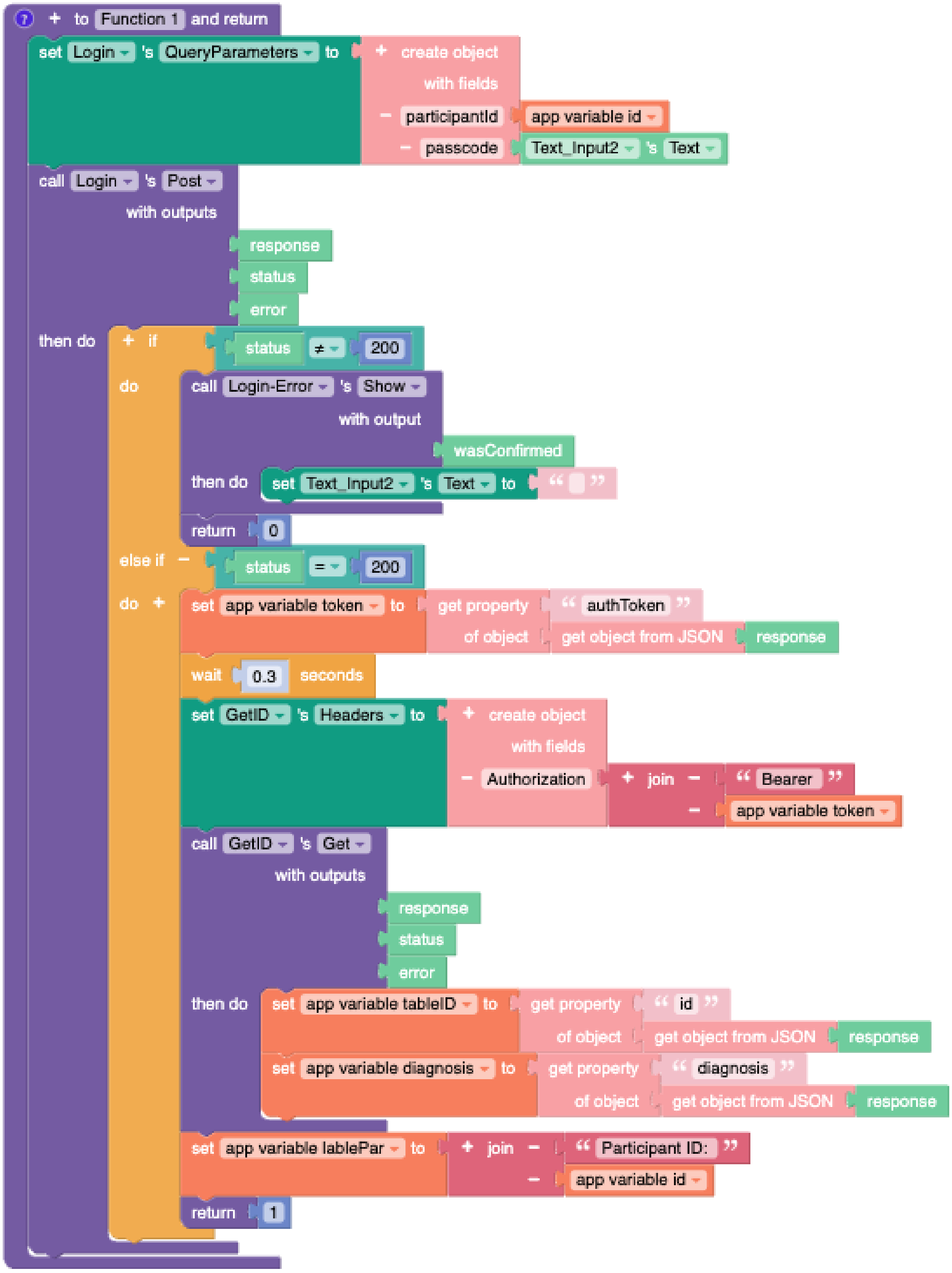
Appendix 1 – C-CAMS Login Flow Diagram



Appendix 2- Blood Pressure Measurement Flow Diagram

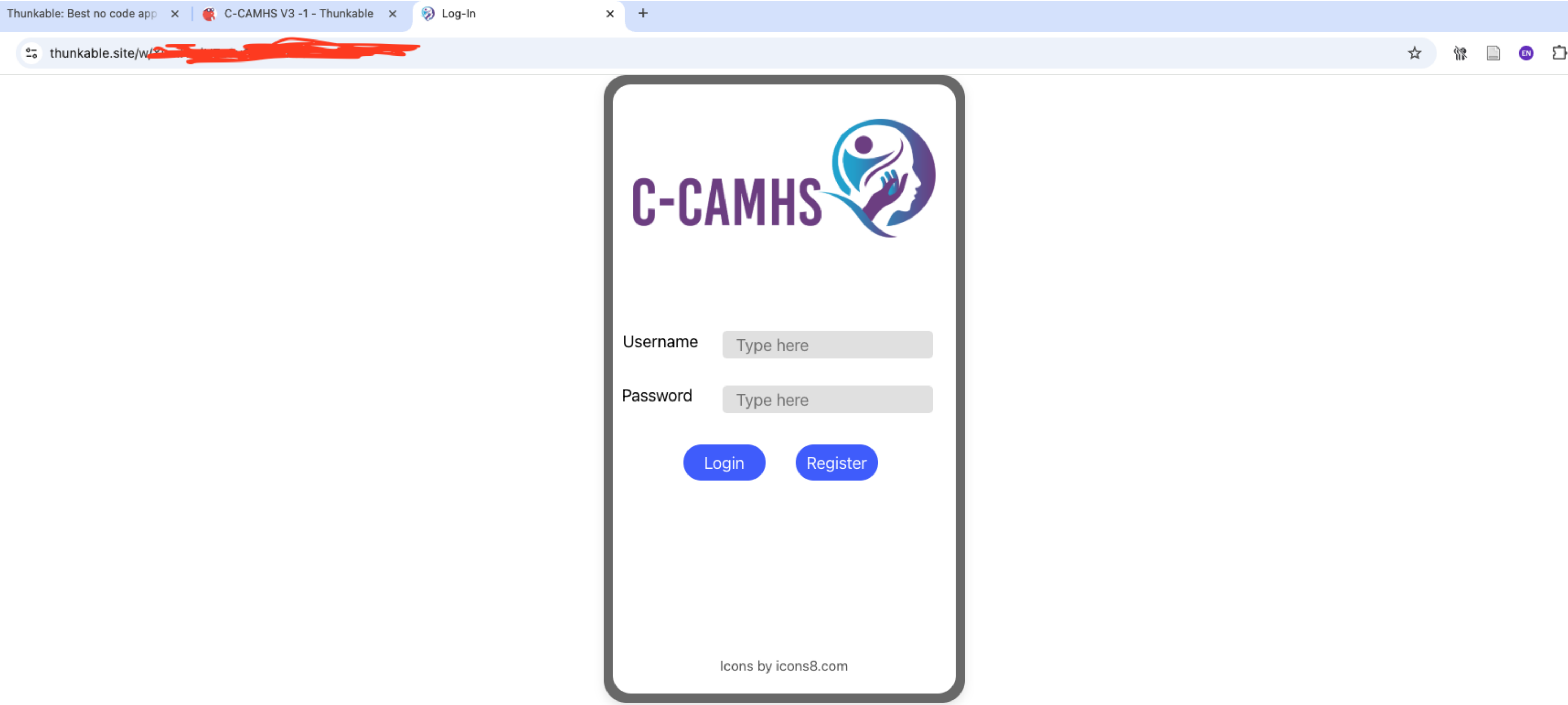


Appendix 3 - Questionnaire Response Flow Diagram

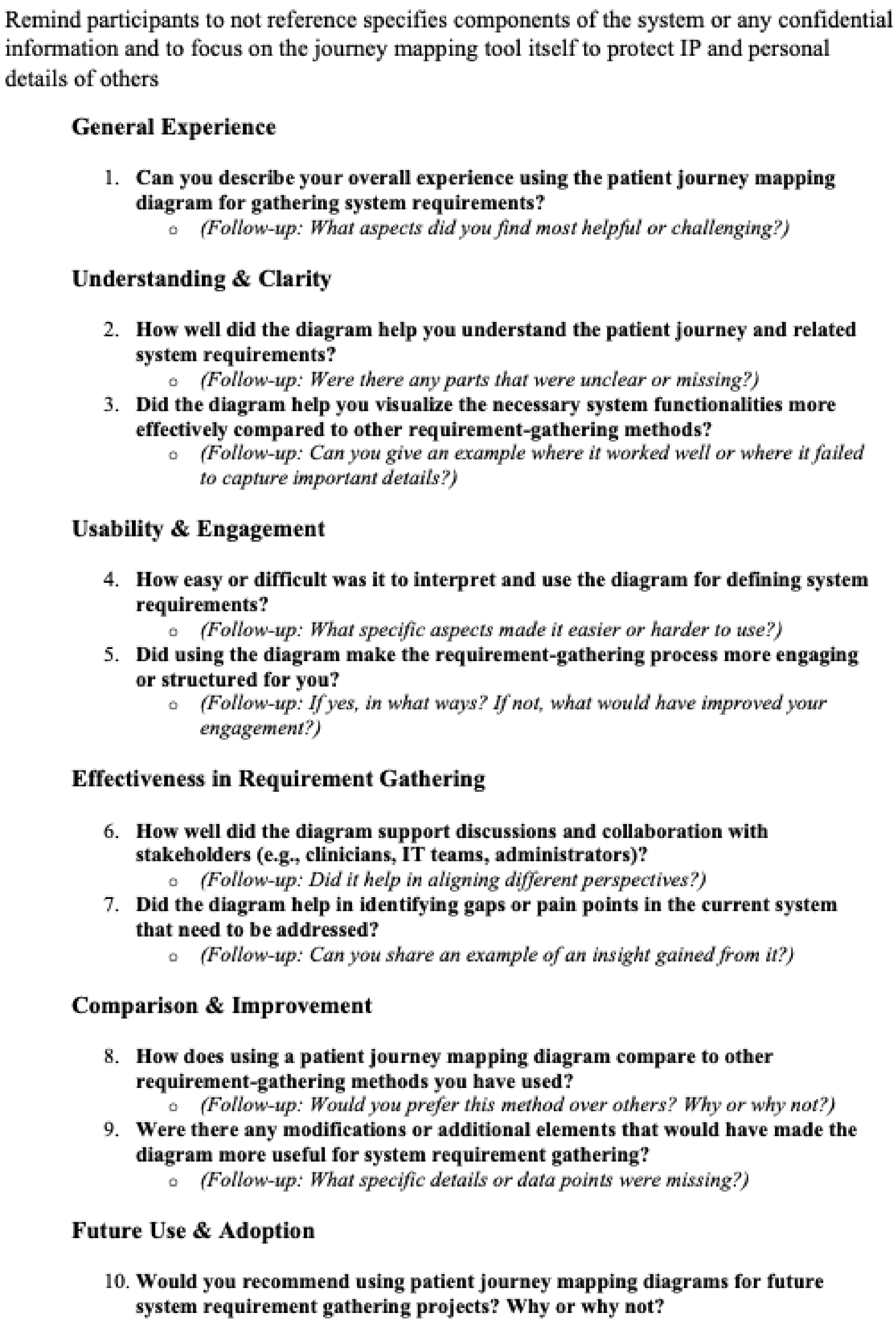


```
to Function 1 and return
  set Login 's QueryParameters to  create object
                                   with fields
                                     participantId  app variable id
                                     passcode       Text_Input2 's Text
  call Login 's Post
    with outputs
      response
      status
      error
  then do
    if  status ≠ 200
    do  call Login-Error 's Show
          with output
            wasConfirmed
          then do  set Text_Input2 's Text to " "
        return 0
    else if  status = 200
    do  set app variable token to  get property "authToken"
                                   of object  get object from JSON  response
        wait 0.3 seconds
        set GetID 's Headers to  create object
                                 with fields
                                   Authorization  join  "Bearer "
                                                        app variable token
        call GetID 's Get
          with outputs
            response
            status
            error
          then do  set app variable tableID to  get property "id"
                                                of object  get object from JSON  response
                   set app variable diagnosis to  get property "diagnosis"
                                                  of object  get object from JSON  response
        set app variable lablePar to  join  "Participant ID: "
                                            app variable id
        return 1
```

Appendix 4 - C-CAMHS Login Front End Build



Appendix 5 - Participant emulated view



Remind participants to not reference specifies components of the system or any confidential information and to focus on the journey mapping tool itself to protect IP and personal details of others

General Experience

1. **Can you describe your overall experience using the patient journey mapping diagram for gathering system requirements?**
    - *(Follow-up: What aspects did you find most helpful or challenging?)*

Understanding & Clarity

2. **How well did the diagram help you understand the patient journey and related system requirements?**
    - *(Follow-up: Were there any parts that were unclear or missing?)*
3. **Did the diagram help you visualize the necessary system functionalities more effectively compared to other requirement-gathering methods?**
    - *(Follow-up: Can you give an example where it worked well or where it failed to capture important details?)*

Usability & Engagement

4. **How easy or difficult was it to interpret and use the diagram for defining system requirements?**
    - *(Follow-up: What specific aspects made it easier or harder to use?)*
5. **Did using the diagram make the requirement-gathering process more engaging or structured for you?**
    - *(Follow-up: If yes, in what ways? If not, what would have improved your engagement?)*

Effectiveness in Requirement Gathering

6. **How well did the diagram support discussions and collaboration with stakeholders (e.g., clinicians, IT teams, administrators)?**
    - *(Follow-up: Did it help in aligning different perspectives?)*
7. **Did the diagram help in identifying gaps or pain points in the current system that need to be addressed?**
    - *(Follow-up: Can you share an example of an insight gained from it?)*

Comparison & Improvement

8. **How does using a patient journey mapping diagram compare to other requirement-gathering methods you have used?**
    - *(Follow-up: Would you prefer this method over others? Why or why not?)*
9. **Were there any modifications or additional elements that would have made the diagram more useful for system requirement gathering?**
    - *(Follow-up: What specific details or data points were missing?)*

Future Use & Adoption

10. **Would you recommend using patient journey mapping diagrams for future system requirement gathering projects? Why or why not?**

Appendix 6 - Interview Protocol IPJM Case Study

Information Sheet (Interview)

Thank you for considering participating in this research project. The purpose of this document is to explain to you what the work is about and what your participation would involve, to enable you to make an informed choice.

The purpose of this study is to identify key requirements for a connected health application to support Child and Adolescent Mental Health Service. Should you choose to participate, you will be asked to take part in a one-to-one interview with a member of the research team. This interview will be audio/video recorded and is expected to take approximately 1 hour to complete.

Participation in this study is completely voluntary. There is no obligation to participate, and should you choose to do so, you can refuse to answer specific questions, or decide to withdraw from the interview. Once the interview has been concluded, you can choose to withdraw at any time in the subsequent two weeks. Any personally identifiable provided within the two-week period will be deleted. Should you provide any data anonymously, this data can not be withdrawn once submitted.

All the information you provide will be kept confidential and anonymous and will be available only to my research supervisors (Prof Frederic Adam & Prof Deirdre Murray) and myself (Richard Harris). The only exception is where information is disclosed which indicates that there is a serious risk to you or to others. If a serious risk is disclosed, in the interest of the safety of all involved, a disclosure will be made to the relevant authorities.

Once the interview is completed, the recording will immediately be transferred to a safe UCC data storage platform and wiped from the recording device. The interview will then be transcribed by the researcher, and all identifying information will be removed. Once this is

done, the recording will also be deleted and only the anonymized transcript will remain. This will be stored on a University College Cork supported cloud storage platform, UCC's Microsoft OneDrive. The data will be stored for minimum of ten years.

The information you provide may contribute to research publications and/or conference presentations and may be included in my final PhD Thesis.

We do not anticipate any negative outcomes from participating in this study. At the end of the interview, I will discuss with you how you found the experience and how you are feeling. Should you experience distress arising from the interview, please contact your GP. Should you feel you need immediate assistance, please dial emergency services.

This study has obtained ethical approval from the UCC Social Research Ethics Committee.

If you have any queries about this research, you can contact me at rharris@ucc.ie or 120225671@umail.ucc.ie. Alternatively, you may contact my supervisor, Prof Frederic Adam, at FAdam@ucc.ie.

If you agree to take part in this study, please sign the consent form overleaf.

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Research Consent Form

I.....................................agree to participate in Richard Harris's research study.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I give permission for my interview with Richard Harris to be video / audio recorded.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that I can withdraw permission to use the data within two weeks of the interview, in which case the material will be deleted.

I understand that anonymity will be ensured in the write-up by disguising my identity.

I understand that disguised extracts from my interview (e.g. my name / location won't be used) may be quoted in presentations and publications (e.g. article, book chapter, student thesis, social media publicity of the study's findings, etc.), if I give permission below (please tick one box):

I agree to participate in this study ☐

I do not agree to participate in this study ☐

Signed: ....

PRINT NAME: .... Date: ....

Appendix 7 - Interview Consent Form Chapter 4

Information Sheet (interviews)

Thank you for considering participating in this research project. The purpose of this document is to explain to you what the work is about and what your participation would involve, to enable you to make an informed choice.

The purpose of this study is to identify the key risks and benefits involved in a digital transformation within the Child and Adolescent mental health services (CAMHS) within the Republic of Ireland. Should you choose to participate, you will be asked take part in a one-to-one interview with a member of the research team. This interview will be audio/ video recorded and is expected to take 30-40 minutes to complete.

Participation in this study is completely voluntary. There is no obligation to participate, and should you choose to do so, you can refuse to answer specific questions, or decide to withdraw from the interview. Once the interview has been concluded, you can choose to withdraw at any time in the subsequent two weeks.

All of the information you provide will be kept confidential and anonymous, and will be available only to my supervisors and myself (Richard Harris). The only exception is where information is disclosed which indicates that there is a serious risk to you or to others. In the event of disclosure of information that may pose a risk to an individual, I will discuss with my supervisor/ appropriate UCC staff and make a discloser to the relevant authority if deemed appropriate by my supervisor / relevant UCC Staff. In the event of an imminent emergency/ risk, the relevant authority may be contacted immediately by the researcher involved.

Once the interview is completed, the recording will immediately be transferred to a safe UCC data storage platform and wiped from the recording device. The interview will then be transcribed by the researcher, and all identifying information will be removed. Once this is

done, the recording will also be deleted and only the anonymized transcript will remain. This will be stored on a University College Cork supported cloud storage platform Microsoft OneDrive. The data will be stored for minimum of ten years.

The information you provide may contribute to research publications and/or conference presentations or may form part of an academic thesis.

We do not anticipate any negative outcomes from participating in this study. At the end of the interview, I will discuss with you how you found the experience and how you are feeling. Should you experience distress arising from the interview, the contact details for support services provided below may be of assistance:

Samaritans: 116 123
Emergency Services: 999

This study has obtained ethical approval from the UCC Social Research Ethics Committee.

If you have any queries about this research, you can contact me at rharris@ucc.ie or my supervisor at FAdam@ucc.ie

If you agree to take part in this study, please sign the consent form overleaf.

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Sample Research Consent Form

I.....................................agree to participate in Richard Harris's research study.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I give permission for my interview with Richard Harris to be video / audio -recorded.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that I can withdraw permission to use the data within two weeks of the interview, in which case the material will be deleted.

I understand that anonymity will be ensured in the write-up by disguising my identity.

I understand that disguised extracts from my interview (e.g. my name / location won't be used) may be quoted in presentations and publications (e.g. article, book chapter, student thesis, social media publicity of the study's findings, etc.), if I give permission below (please tick one box):

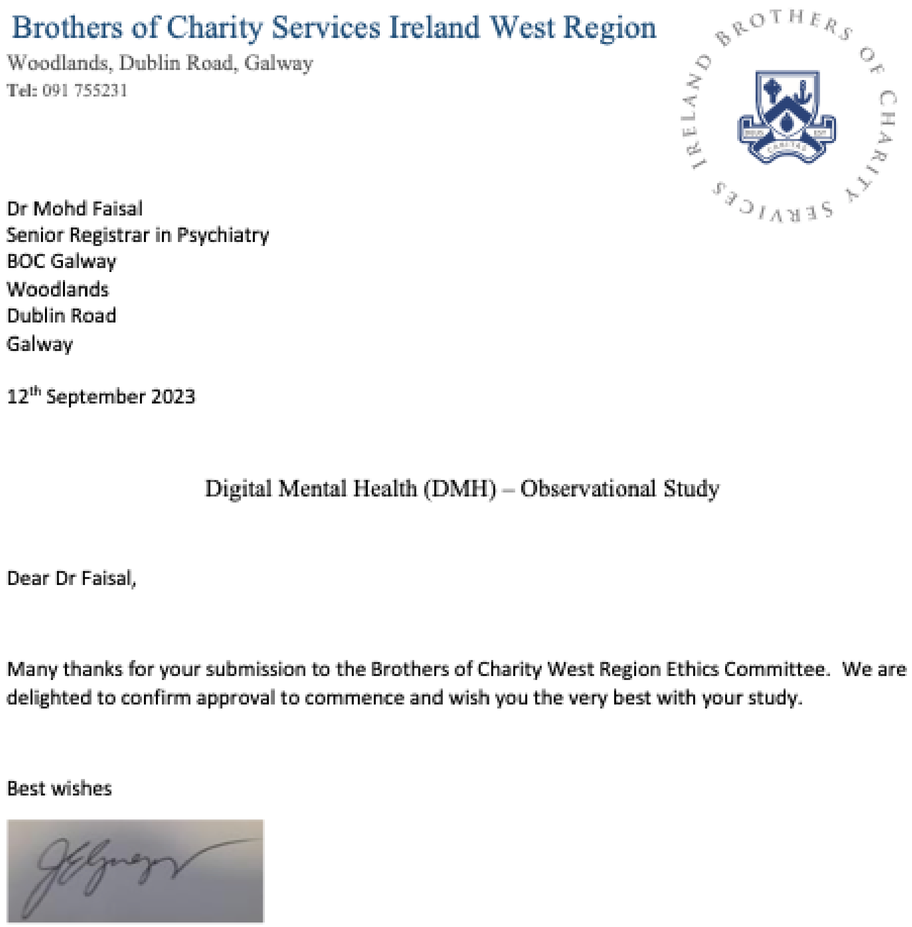
I agree to participate in this study ☐

I do not agree to participate in this study ☐

Signed: ....

PRINT NAME: .... Date: ....

Appendix 8 - Interview Consent Form Chapter 5



Brothers of Charity Services Ireland West Region
Woodlands, Dublin Road, Galway
Tel: 091 755231

Dr Mohd Faisal
Senior Registrar in Psychiatry
BOC Galway
Woodlands
Dublin Road
Galway

12th September 2023

Digital Mental Health (DMH) – Observational Study

Dear Dr Faisal,

Many thanks for your submission to the Brothers of Charity West Region Ethics Committee. We are delighted to confirm approval to commence and wish you the very best with your study.

Best wishes

Appendix 9- DMH-H Ethics Approval

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Information Sheet (Interview)

Thank you for considering participating in this research project. The purpose of this document is to explain to you what the work is about and what your participation would involve, to enable you to make an informed choice.

The purpose of this study is to identify key requirements and design elements, along with the review of requirement gathering tools, for a connected health application to support Child and Adolescent Mental Health Service. Should you choose to participate, you will be asked to take part in a one-to-one interview with a member of the research team. This interview will be audio/video recorded and is expected to take approximately 1 hour to complete.

Participation in this study is completely voluntary. There is no obligation to participate, and should you choose to do so, you can refuse to answer specific questions, or decide to withdraw from the interview. Once the interview has been concluded, you can choose to withdraw at any time in the subsequent two weeks. Any personally identifiable provided within the two-week period will be deleted. Should you provide any data anonymously, this data can not be withdrawn once submitted.

All the information you provide will be kept confidential and anonymous and will be available only to my research supervisors (Prof Frederic Adam & Prof Deirdre Murray) and myself (Richard Harris). The only exception is where information is disclosed which indicates that there is a serious risk to you or to others. If a serious risk is disclosed, in the interest of the safety of all involved, a disclosure will be made to the relevant authorities.

Once the interview is completed, the recording will immediately be transferred to a safe UCC data storage platform and wiped from the recording device. The interview will then be transcribed by the researcher, and all identifying information will be removed. Once this is

done, the recording will also be deleted and only the anonymized transcript will remain. This will be stored on a University College Cork supported cloud storage platform, UCC's Microsoft OneDrive. The data will be stored for minimum of ten years.

The information you provide may contribute to research publications and/or conference presentations and may be included in my final PhD Thesis.

We do not anticipate any negative outcomes from participating in this study. At the end of the interview, I will discuss with you how you found the experience and how you are feeling. Should you experience distress arising from the interview, please contact your GP. Should you feel you need immediate assistance, please dial emergency services.

This study has obtained ethical approval from the UCC Social Research Ethics Committee.

If you have any queries about this research, you can contact me at rharris@ucc.ie or 120225671@umail.ucc.ie. Alternatively, you may contact my supervisor, Prof Frederic Adam, at FAdam@ucc.ie.

If you agree to take part in this study, please sign the consent form overleaf.

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Research Consent Form

I.....................................agree to participate in Richard Harris's research study.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I give permission for my interview with Richard Harris to be video / audio recorded.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that I can withdraw permission to use the data within two weeks of the interview, in which case the material will be deleted.

I understand that anonymity will be ensured in the write-up by disguising my identity.

I understand that disguised extracts from my interview (e.g. my name / location won't be used) may be quoted in presentations and publications (e.g. article, book chapter, student thesis, social media publicity of the study's findings, etc.), if I give permission below (please tick one box):

I agree to participate in this study ☐

I do not agree to participate in this study ☐

Signed: ....

PRINT NAME: .... Date: ....

Appendix 10- Interview Consent Form Chapter 6

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Information Sheet (Focus Group)

Thank you for considering participating in this research project. The purpose of this document is to explain to you what the work is about and what your participation would involve, to enable you to make an informed choice.

The purpose of this study is to identify key requirements and design elements for a connected health application to support Child and Adolescent Mental Health Service. Should you choose to participate, you will be asked to take part in a focous group with a member of the research team. This focus group will be audio/video recorded and is expected to take approximately 1 hour to complete.

Participation in this study is completely voluntary. There is no obligation to participate, and should you choose to do so, you can refuse to answer specific questions, or decide to withdraw from the focus group. Once the focus group has been concluded, you can choose to withdraw at any time in the subsequent two weeks. Any personally identifiable provided within the two-week period will be deleted. Should you provide any data anonymously, this data can not be withdrawn once submitted.

All the information you provide will be kept confidential and anonymous and will be available only to my research supervisors (Prof Frederic Adam & Prof Deirdre Murray) and myself (Richard Harris). The only exception is where information is disclosed which indicates that there is a serious risk to you or to others. If a serious risk is disclosed, in the interest of the safety of all involved, a disclosure will be made to the relevant authorities.

Once the focus group is completed, the recording will immediately be transferred to a safe UCC data storage platform and wiped from the recording device. The focus group will then be transcribed by the researcher, and all identifying information will be removed.

Once this is done, the recording will also be deleted and only the anonymized transcript will remain. This will be stored on a University College Cork supported cloud storage platform, UCC's Microsoft OneDrive. The data will be stored for minimum of ten years.

The information you provide may contribute to research publications and/or conference presentations and may be included in my final PhD Thesis.

We do not anticipate any negative outcomes from participating in this study. At the end of the focus group, I will discuss with you how you found the experience and how you are feeling. Should you experience distress arising from the interview, please contact your GP. Should you feel you need immediate assistance, please dial emergency services.

This study has obtained ethical approval from the UCC Social Research Ethics Committee.

If you have any queries about this research, you can contact me at rharris@ucc.ie or 120225671@umail.ucc.ie. Alternatively, you may contact my supervisor, Prof Frederic Adam, at FAdam@ucc.ie.

If you agree to take part in this study, please sign the consent form overleaf.

Research Consent Form

I.......................................agree to participate in Richard Harris's research study.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I give permission for my focus group with Richard Harris to be video / audio recorded.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that I can withdraw permission to use the data within two weeks of the interview, in which case the material will be deleted.

I understand that anonymity will be ensured in the write-up by disguising my identity.

I understand that disguised extracts from the focus group (e.g. my name / location won't be used) may be quoted in presentations and publications (e.g. article, book chapter, student thesis, social media publicity of the study's findings, etc.), if I give permission below (please tick one box):

I agree to participate in this study ☐

I do not agree to participate in this study ☐

Signed: ....

PRINT NAME: ....

Date: ....

Appendix 11- Focus Group Consent Form Chapter 6