MSc Digital Transformation

for the Health and Care Professions

BMDS7005

Evaluation of the Usability and Fit Between Individual, Task, Technology and Environment of an Electronic Prescribing and Administration System (ePMA)

Dissertation submitted in partial fulfilment of the award of

Master of Science in Digital Transformation for the Health and Care Professions

James Goddard

2111623

24th May 2024

Acknowledgements

I am profoundly grateful to all those who have helped me with this project, the members of Swansea Bay University Health Board who took the time to help with distributing or completing my questionnaire and the ePMA project team for their help and support. I would particularly like to thank my supervisor, Mr Paul Curley, CCIO, Mid Yorkshire Teaching NHS Trust, who guided me so positively with constructive and useful feedback, providing a sounding board and support throughout the project.

Declaration

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed ... James Goddard…

Date ... 24.05.2024……..

CONTENTS

1. Introduction

This project evaluates and examines the usability and fit between people, tasks and technology of the electronic prescribing and medicines administration (ePMA) system implemented in Swansea Bay University Health Board. ePMA systems have been evidenced as reducing medication related errors, improving patient safety and offering opportunities for optimising and improving prescribing, medicines review and administration processes (Cattell *et al.*, 2023; Williams *et al.*, 2022; Slight *et al.*, 2019). Whilst these more recent studies have considered system optimisation and configuration there is limited research around the relationship between usability and safety of ePMA systems specifically. However, there is clear evidence that usability in health information technology systems (HIT) can affect clinical safety (Adams *et al.*, 2021; Ratwani *et al.*, 2018; Sujan *et al.*, 2017; Carayon *et al.*, 2017; Brown *et al.*, 2016; Ratwani *et al.*, 2015). The usability of technology, defined by its efficiency, effectiveness, and satisfaction in use, remains a contributing factor to healthcare provider burnout and introduces risks to patient safety (Melnick *et al.*, 2020; Howe *et al.*, 2018; Middleton *et al.*, 2013a; Gomes and Ratwani, 2019). Examples of medication related usability issues, amongst others, can include an overwhelming number of medications listed within a menu or visual display challenges, which can result in the inadvertent selection of the wrong medication. This may lead to patients receiving medications not intended for them or receiving incorrect doses, posing potential harm to both adults and children (Howe *et al.*, 2018; Ratwani *et al.*, 2018). Thus, it is important that usability is considered in any evaluation of HIT implementation, which goes hand in hand with how well the technology "fits" into the intended processes it should support. Fit has been described as the degree to which technology assists and "fits" the requirements of a task (Goodhue and Thompson, 1995).

The most frequent and common interventions made in healthcare today relate to the use of medicines (NICE, 2022). Maintaining optimised and accurate medical treatment in hospital settings and between transitions of care is highly important in terms of the patient receiving safe and effective care (World Health Organization, 2019) (Elliott *et al.*, 2021). Figure 1.1 demonstrates the stages in the medicines management process that a patient goes through during the transitions from primary to secondary care.

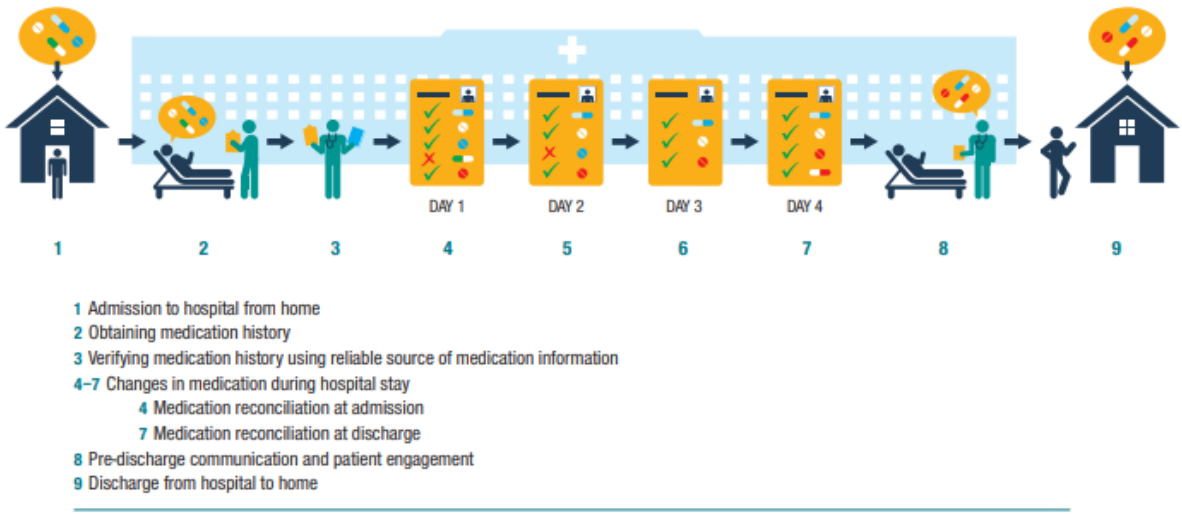

Figure 1.1 Stages in medication management during transitions of care between home and hospital (WHO, 2019)

The development and implementation of electronic Prescribing and Medicines Administration (ePMA) systems across secondary care healthcare providers is increasing and becoming the new normal for the way that medicines are prescribed and administered to patients within NHS hospitals. These systems can increase patient safety (Gates *et al.*, 2021) and can offer advantages within the prescription review, prescribing, medicines ordering and administration processes. Nevertheless, there is a scarcity of usability data concerning ePMA systems, particularly in the UK, and it is evident that usability is closely associated with clinical safety (Iqbal *et al.*, 2021). The association between inadequate system usability and poor patient outcomes and consequences is acknowledged within literature and ineffectual medicines management system usability can lead to inefficient care delivery, extended task durations, diminished user satisfaction and erroneous system usage (such as workarounds), with the potential for patient harm (ISO, 2009; Ratwani *et al.*, 2018; Nohr *et al.*, 2016; Carayon *et al.*, 2017; Brown *et al.*, 2016; Ratwani *et al.*, 2015; Sujan *et al.*, 2017; Iqbal *et al.*, 2021). In addition, effective usability has been recognised as a significant aspect of good practice when developing digital applications (Zapata et al., 2015). Adams et al. (2021) demonstrated that 97.3% of medication errors reported were linked with poor usability and workflow within HIT as contributing factors. As well as an effect on possible increased risks of errors occurring, poor design of health information technology (HIT) systems such as ePMA, can also lead to increased workload and burden on the clinician and burnout (Fong et al., 2018; Ellsworth et al., 2017; Middleton et al., 2013b; Avansino and Leu, 2012). Thus, it is important to understand where systems such as ePMA sit in terms of their usability and how well the fit is between the individual, the associated tasks and the technology within the healthcare setting involved.

The importance of looking at how well the system fits and its usability can support evaluation of some key aspects of human centred design and human factors such as

designing around the person not attempting to make the person fit the design, and creating systems that make it hard to do something wrong (Dul *et al.*, 2012).

1.1 Project Aims and Research Objectives

Context

To assess and examine the usability and technological alignment of an implemented ePMA solution within Swansea Bay University Health Board (SBUHB). Swansea Bay is recognised as a pathfinder site for ePMA implementation, having introduced the system at Neath Port Talbot Hospital and Singleton Hospital, with ongoing implementation at Morriston Hospital. So far, SBUHB's evaluations have primarily focused on measuring benefits in relation to the project's business case (ABMUHB, 2017) and gathering user opinions and feedback, providing valuable insights for understanding and improvement. Additionally, a comprehensive evaluation was published in December 2021 (SBUHB 2021).

While there are numerous aspects and advantages that can be extracted and examined through the introduction of ePMA, there is limited published research or evaluation specifically addressing usability, although many electronic health records (EHR) and HIT studies have been undertaken. In a clinical setting, the usability of electronic health record systems can be linked to clinical safety (Sujan, Huang, and Braithwaite, 2017; Lichtner et al., 2017). Hence, this underscores the importance of concentrating on ePMA usability, as an area that has received comparatively less substantiated study.

Scope

The boundaries, context and scope of ePMA systems relative to other aspects and benefits associated with ePMA can be seen in Figure 1.2. This boundary identifies the focus of this evaluation.

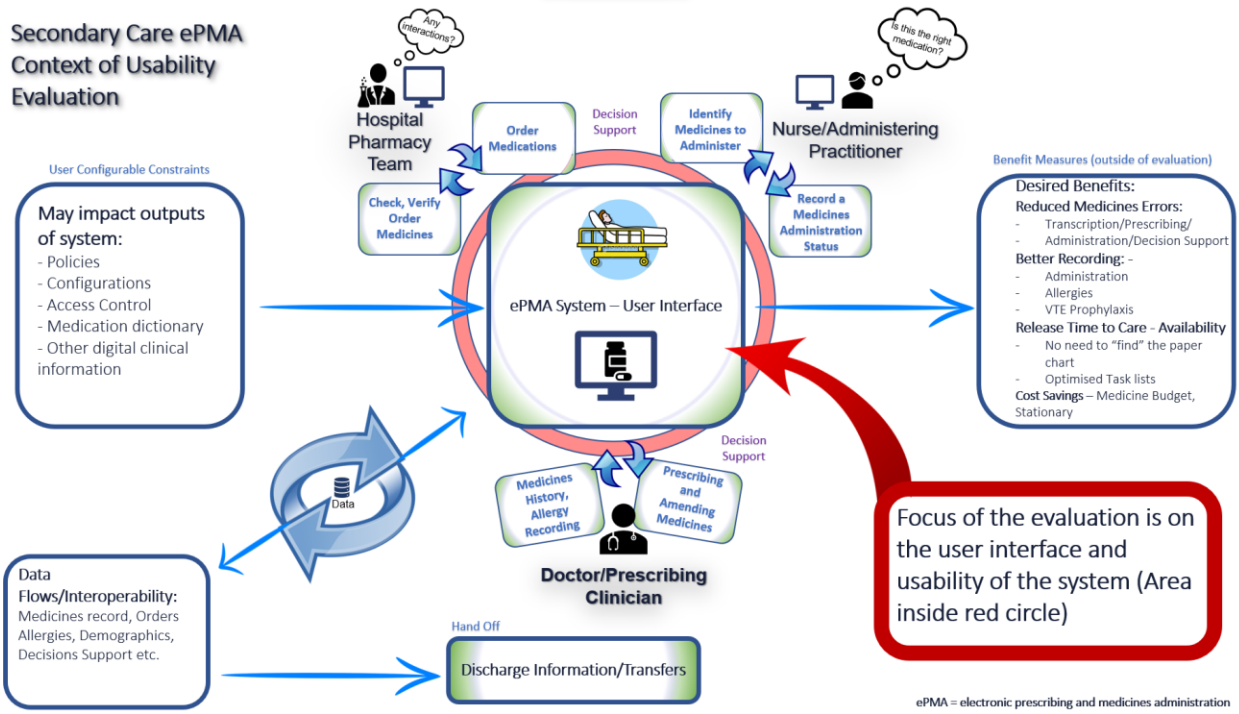

Figure 1.2 Scope of EPMA and Context of Usability Evaluation (Goddard, 2023)

The evaluation focuses on the interaction with the system itself, depicted in Figure 1.3, which illustrates how various user types relate to the functions within the system. Not all users or disciplines will engage with the same functionalities, leading to potential differences in workflows and perceived usability. Consequently, capturing the perspectives of diverse users is valuable for gaining a more profound and relatable understanding.

The main areas of focus will be around the tasks related to certain roles such as those listed in Table 1.1.

Table 1.1 Description of Main Tasks/Roles to be evaluated.

Task/Role/Function (No. 4. In Figure 1.3)	Description
Prescribing	The task of prescribing medication for a patient either to treat or prevent a condition.
Medicines Administration	This refers to task of checking what medicines a patient has been prescribed, preparing them and then administering them to the correct patient at the correct time, via the correct route, following the prescribed instructions.
Medicines Reconciliation	This is the task of ensuring medicines history and the medicines the patient is intended to take are correct and accurate. It also checks to understand whether any changes are deliberate and records any reasons for changes.
Medicines Ordering	The task of requesting medication supply whether for inpatient or for discharge supply.
Medicines Review	This is the task of reviewing current medication and whether it is still appropriate or not.

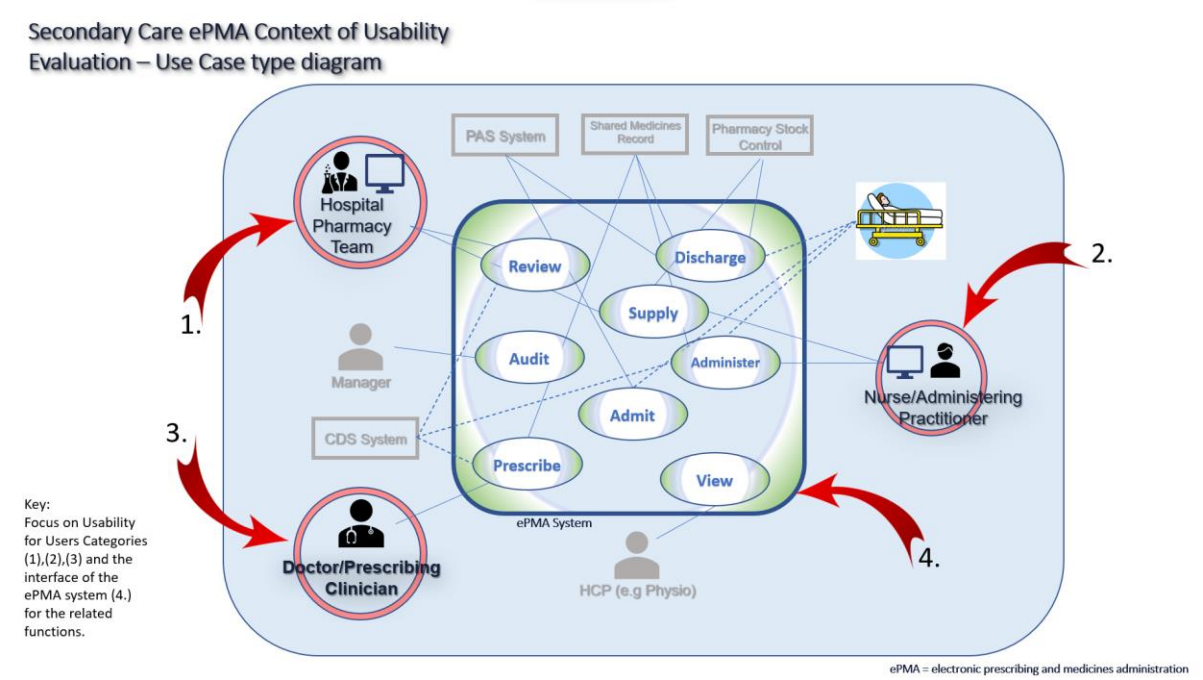

Figure 1.3 Secondary Care ePMA Use Case Type Diagram concept adapted from Cornford et al. (2009)

Project Aims and Objectives

The objective of the project was to assess the usability of the ePMA solution using the System Usability Scale (SUS) (Brooke, 1996; Bloom et al., 2021). In addition, it aimed to evaluate and compare the system's alignment with the "Fit between Individuals, Task, and Technology" (FITT) framework, based on Ammenwerth *et al.* (2006) model, later enhanced by Prgomet *et al.* (2019). The goal was to gain a comprehensive understanding of successes or perceived shortcomings within the intricate sociotechnical environment of the ePMA rollout.

Objectives (Goddard, 2023):

1. Produce SUS score.
2. Understand the current fit between technology, user and task of the ePMA solution.
3. Explore relationships and themes between individual SUS scores and responses to questionnaires and interviews surrounding fit between technology, user and task. For example, between task complexity and the usability of the interface and whether cognitive load might be influenced.
4. Identify areas for improvement or further research.

Table 1.2 Summary of Research Approaches adapted from Goddard (2023)

Research Question	Method	Data to be Collected	Analysis Technique
What is ePMA system's usability score?	Quantitative/Qualitative	SUS Score Questionnaire	Defined SUS Score calculation.
Are there any correlations between the usability score and other factors such as previous user experience?	Quantitative/Qualitative	Site details Profession Previous experience of ePMA Age	Correlation analysis between SUS Score
How well does the system fit in terms of individuals, tasks and technology?	Interviews/Questionnaire (FITT Evaluation) Qualitative	Based on FITTE Semi-structured Interviews.	Thematic Analysis

1.2 Justification and Usability

Electronic Prescribing and Medicines Administration systems (ePMA) must be devised to improve the medicines management process throughout the patient journey in secondary care (Figure 1.1). This should include facilitation of managing the patients' medication information during care transitions, such as medication reconciliation both in and out of the hospital. The system should also provide support for medication prescribing, medication review and verification, medication administration, ordering medicines and discharge, without introducing additional load or complexities.

Thus, usability should be considered. Usability is defined as the degree to which a product can be effectively, efficiently, and satisfactorily used by designated users to achieve specific goals within a specified context of use (ISO, 2009), although the precise definition of usability has been debated (Lewis, 2014). Brooke (1996) characterises usability as a measure of how effectively a solution performs its intended function. In a broader sense, usability pertains to how easy a user can interact with an application to achieve their anticipated objectives. This involves creating user-friendly interfaces, intuitive design, and efficient workflows that facilitate quick and accurate task completion, factors that play a vital role in ensuring the safe prescribing and administration of medicines.

Usability encompasses not only the attributes of the graphical user interface, such as feature arrangement, font, and colour schemes but also how well the technology, workflow model, and embedded knowledge align with users' needs and actual work processes. Usability can impact user adoption and satisfaction, as well as patient outcomes (Kutney-Lee *et al.*, 2021). Ultimately, good usability will result in increased user satisfaction, enhanced interaction, and is a pivotal factor in the success of a product (Thomas and Macredie, 2002). Zhang and Walji (2011) portrays usability in terms of how satisfying, usable, and useful a solution is for those using it to complete their tasks.

In healthcare, the potential impact on patient safety and outcomes means that usability holds a heightened level of significance. Research on usability within healthcare has concentrated on diverse areas, including electronic health records (EHRs), medical devices, and health information technology (HIT) systems (Ratwani *et al.*, 2015; Zhang and Walji, 2011; Sujan *et al.*, 2017; Kutney-Lee *et al.*, 2021). These investigations reveal that suboptimal usability of EHRs may result in errors, disruptions in workflow, and user dissatisfaction, ultimately affecting patient safety and the quality of care provided. Consequently, it becomes crucial to actively enhance the usability of EHRs and HIT systems, including ePMA systems, through approaches such as user-centred design, usability testing, and evaluation.

Overall, studies on HIT usability underscore the significance of prioritising user-centred design and evaluation with the aim of enhancing the usability of health related applications, products and systems, contributing to improved patient outcomes and care

quality. Therefore, it is still crucially important to comprehend the usability of existing systems that may have already demonstrated tangible benefits.

2. Literature Review

2.1 Introduction

Electronic prescribing and medicines administration (ePMA) systems have the potential to improve medicines safety and to reduce medicines related errors, when optimised or configured appropriately (Slight *et al.*, 2019). Without this optimisation the range of potential error reduction is limited (Cattell *et al.*, 2023). Whilst ePMA systems can bring about a reduction in errors, they can conversely introduce new types of errors that are linked to the way the system is designed and used (Slight *et al.*, 2019). Therefore, Implementation of digital systems should go beyond replacing paper processes (Sheridan *et al.*, 2021). Thus, it is important to understand usability and effectiveness characteristics as well as system performance.

The literature review will seek to explore the existing literature on usability, task, technology and fit from the point of view of ePMA systems, supporting the aims of the project.

2.2 Study Selection

To ascertain and determine the relevance of study search results and subsequent papers found from references, exclusion and inclusion criteria were adopted. This considered the type of system, the context and the related outcomes and a search strategy was developed using PubMed, Ovid Journals Database, Embase, Medline and NHS Wales Full Text Journals, using the search terms identified in Table 2.1.

Table 2.1 Keywords, Search and Mesh Terms used in search methodology.

Keywords and MeSH terms used in search methodology:		
Design and Core Subject:	**System Types:**	**Filters:**
Usability	CPOE – (Computerised Physician Order Entry system - a well-known term in US that describes equivalent systems to UK)	Last 5 years, Medicines Related, Hospital
Usability	ePMA – (Electronic Prescribing and Medicines Administration – the well-known term used in the UK)	Last 5 years, Medicines Related, Hospital
Usability	Medicines/Medication	Last 5 years, Medicines Related, Hospital
Usability	Prescribing/Prescription	Last 5 years, Medicines Related, Hospital
Usability	Medicines Administration	Last 5 years, Medicines Related, Hospital
User Centered Design	ePMA – (Electronic Prescribing and Medicines Administration – the well-known term used in the UK)	Last 5 years, Medicines Related, Hospital
User Centered Design	CPOE – (Computerised Physician Order Entry system - a well-known term in US that describes equivalent systems to UK)	Last 5 years, Medicines Related, Hospital
User Experience	Medicines	Last 5 years, Medicines Related, Hospital
Task, Technology, Fit	Health	Hospital - Health Information Systems
Task, Technology, Fit	Medicines	Hospital - Health Information Systems
Note *The term electronic or digital was not used but neither was it excluded. This was primarily to ensure that search results were not limited if they did not include the words digital or electronic, despite this being a key feature and basis for health information systems.*		
Focus of Evaluation *There are many usability and user centred design guidelines and papers that the search criteria initially identified, however the focus of this project and subsequent literature review is specifically around the context of secondary care (hospital based) electronic prescribing and medicines administration. Therefore, the screening of papers specifically sought to focus on hospital based health information systems that may include medicines management such as prescribing medicines, medication review and administering medicines to patients.*		

Results were in the context of hospital based medicines management related electronic health systems, or the interface between primary and secondary care and included core elements related to usability, or design in relation to function. Peer reviewed papers, available in the English language that specifically evaluated electronic prescribing or

computerised physician order entry (CPOE) systems were included. Whilst papers not in the hospital setting may offer valuable and general viewpoints the nuanced environment of the hospital setting (secondary care) meant that studies not applicable to hospitals or workflows related to hospitals were excluded.

A limitation of the last 5 years was adopted ensuring that the studies retrieved were current. This is important in fields where new research is constantly being published. In addition, it may help to reduce the amount of irrelevant information retrieved, considering that several papers will have already consumed research from previous years, especially in papers undertaking systematic literature reviews. Using date parameters to limit a search can help improve precision without unduly affecting sensitivity (NICE, 2012).

Quality Assessment

To assess the qualitative, quantitative and mixed methods studies the Mixed Methods Appraisal tool (MMAT) was used (Hong *et al.*, 2018). The MMAT is a tool used to evaluate the methodological quality of studies that are part of systematic mixed studies reviews. These reviews include qualitative, quantitative, and mixed methods studies. The instrument evaluates the calibre of research in five areas: mixed methods studies, non-randomised studies, randomised controlled trials, qualitative research, and quantitative descriptive studies. MMAT can only be used to assess certain types of research, empirical studies that are based on simulation, observation or experiment. Thus, an MMAT analysis was carried out on the applicable papers (Table 2.2). Based on the results all the relevant papers were found suitable for comparing findings and approaches and methods.

2.3 Results of Literature Review

The results from the search criteria identified 2176 references, summarised in the PRISMA diagram (Figure 2.1). After screening and duplication checking, 20 met the inclusion criteria, summarised in Table 2.3.

Out of the studies 16 were specific to CPOE or ePMA, 16 related specifically to usability type evaluations within secondary care, and 4 to FITT evaluations. There was one exception noted that was a FITT but not secondary care or health related. The main emphasis was on the broader aspects of the CPOE systems, while the remaining attention was directed toward other components of electronic medicines management systems, including the medication transition interface, nursing e-chart, and the electronic Medication Administration Record (eMAR).

PRISMA Diagram

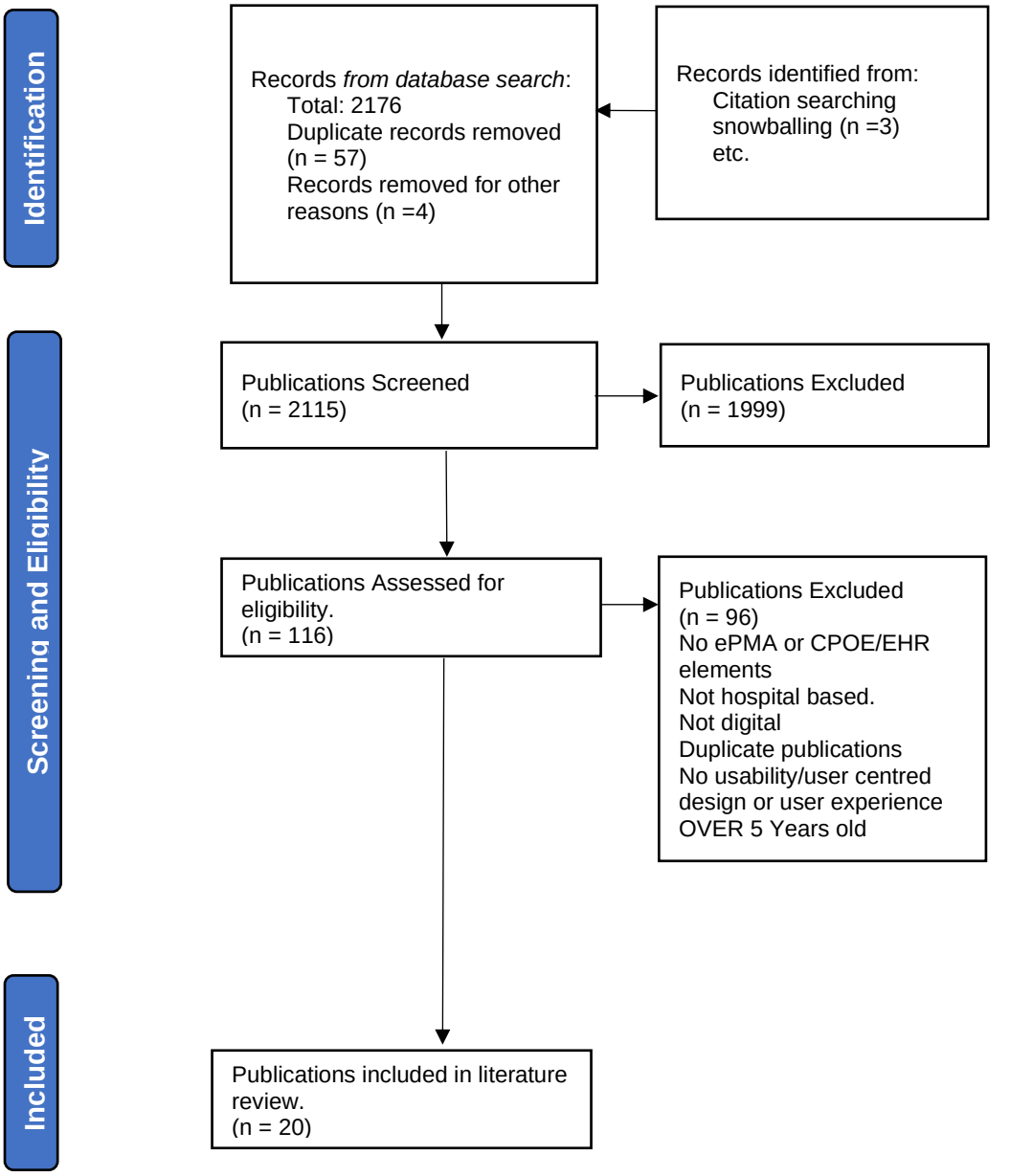

Figure 2.1 PRISMA Diagram

Table 2.2 MMAT Quality Appraisal Results

First author	Year	SCREENING QUESTIONS		1. QUALITATIVE STUDIES					4. QUANTITATIVE DESCRIPTIVE STUDIES					5. MIXED METHODS STUDIES					%SCORE
		S1.	S2.	1.1.	1.2.	1.3.	1.4.	1.5.	4.1.	4.2.	4.3.	4.4.	4.5.	5.1.	5.2.	5.3.	5.4.	5.5.	
Marcilly	*2023*	Yes	Yes	Yes	Yes	Yes	Yes	Yes						Yes	Yes	Yes	Can't tell	Yes	92%
Schmidtchen	*2023*	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Can't tell	Can't tell	71%
Pruitt	*2022*	Yes	Yes	Yes	Yes	Yes	Yes	Yes											100%
Iqbal	*2021*	Yes	Yes	Yes	No	Yes	Yes	Yes											86%
Adams	*2021*	Yes	Yes	Yes	No	Yes	Yes	Yes											86%
Akhloufi	*2019*	Yes	Yes	Yes	Yes	Yes	Yes	Yes											100%
Marien	*2019*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Can't tell	94%
Baysari	*2018*	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes											86%
Marcilly	*2018*	Yes	Yes	Yes	Yes	Yes	Yes	Yes											100%
Russ	*2018*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%
Staggers	*2018*	Yes	Yes	Can't tell	Yes	Yes	Yes	Yes											86%
Zhai	*2022*	Yes	Yes	Yes	Yes	Yes	Yes	Yes											100%
Ali	*2018*	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes											86%
Cresswell,	*2020*	Yes	Yes	Yes	Yes	Yes	Yes	Yes											100%
Prgomet	*2019*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Can't tell	94%

SCREENING QUESTIONS
S1. Are there clear research questions?
S2. Do the collected data allow to address the research questions?

1. QUALITATIVE STUDIES
1.1. Is the qualitative approach appropriate to answer the research question?
1.2. Are the qualitative data collection methods adequate to address the research question?
1.3. Are the findings adequately derived from the data?
1.4. Is the interpretation of results sufficiently substantiated by data?
1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?

4. QUANTITATIVE DESCRIPTIVE STUDIES
4.1. Is the sampling strategy relevant to address the research question?
4.2. Is the sample representative of the target population?
4.3. Are the measurements appropriate?
4.4. Is the risk of nonresponse bias low?
4.5. Is the statistical analysis appropriate to answer the research question?

5. MIXED METHODS STUDIES
5.1. Is there an adequate rationale for using a mixed methods design to address the research question?
5.2. Are the different components of the study effectively integrated to answer the research question?
5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?
5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?
5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?

Table 2.3 Summary of Reviewed Studies

Usability and User Acceptance					
Paper	**Country**	**Context**	**Aim and scope**	**Methods and data sources**	**Main findings and implications**
Awad *et al.* (2023)	Australia	Secondary Care	To review the human factors and safety analysis methods used in the design and redesign of electronic medication management systems (EMMS)	Systematic review of 21 studies that applied human factors and safety analysis methods to EMMS. Conducted from January 2011 to May 2022, and examined 21 relevant papers.	Found that most studies used qualitative methods, such as interviews and observations, and focused on usability and workflow issues. Studies in review frequently utilised human factors and safety analysis methods for evaluating system designs, with prototyping, usability testing, surveys, questionnaires, and interviews being the most common. Recommended more use of quantitative methods, such as simulation and eye-tracking, and more attention to safety and error prevention.
Marcilly *et al.* (2023)	France	Secondary Care	To improve the usability and usefulness of computerised decision support systems (CDSS) for medication review by clinical pharmacists	Convergent, parallel evaluation of a CDSS for medication review with clinical pharmacists using the CDSS and providing feedback	47 usability and usefulness issues identified, such as lack of clarity, lack of relevance, lack of reliability, and lack of flexibility. Guidelines were produced to enhance the design and acceptability of CDSSs to better support clinical pharmacists in medication reviews. Several design improvements suggested, such as providing more explanation, more customisation, more feedback, and more integration with other systems.
Schmidtchen *et al.* (2023)	Germany	Primary and Secondary Care	To analyse the usability of a medication visualisation tool for decision support	Usability analysis with physicians using the tool in a real clinical setting and providing feedback	Found that the tool was useful and intuitive. Some usability issues identified, e.g., data quality, data integration, data visualisation, and data interaction. The tool improved the efficiency and accuracy of medication management, but also increased the workload and responsibility of medics.

Pruitt *et al.* (2022)	US	Secondary Care	To develop and evaluate an electronic health record (EHR) usability and safety self-assessment tool	Literature review, expert consultation, and pilot evaluation with 5 physicians in two different hospitals using two different HIT EHR tools and providing feedback	Developed and evaluated an EHR usability and safety self-assessment tool that consists of questions and a scoring system. Found that the tool was easy to use, useful, and reliable, and that it helped to identify and prioritise EHR usability and safety issues – more work needed to reduce variable responses.
Iqbal *et al.* (2021)	US	Primary and Secondary Care	To identify the electronic medicines administration record (eMAR) usability issues from patient safety event reports	Retrospective analysis of 849 patient safety event reports related to eMAR from a large health system	Found several usability challenges, such as confusing interface, inaccurate information, and system errors. Classified the usability issues into 8 categories and mapped them to the medication process stages. Suggested potential solutions for each category of usability issues
Adams *et al.* (2021)	US	Primary and Secondary Care	To identify HIT usability issues that contributed to medication errors across medication process stages	Retrospective analysis of 2700 patient safety event reports from a large database of 595 healthcare facilities in the US.	Found that 55.9% of the reports mentioned medication error related to HIT use and usability issues, and that these issues occurred across all medication process stages, with the highest frequency in the administration stage. Identified the most common types of HIT usability issues and mapped them to the medication process stages
Lee *et al.* (2021)	South Korea	Secondary Care	To develop a safety and usability guideline for clinical information systems (CIS) based on international standards and best practices	Literature review of 32 articles and safety and usability guidelines best practices related to CIS safety and usability, and expert consultation with experts from various fields	Developed a guideline consisting of principles and sub-principles for CIS safety and usability, covering aspects such as user needs, user interface, user feedback, error prevention, error recovery, and evaluation
Akhloufi *et al.* (2019)	Netherlands	Secondary Care	To improve a clinical decision support system (CDSS) for antibiotic prescription in a hospital setting	Usability study with 8 medical residents and 3 evaluators using CDSS designed for empirical antibiotic treatment in hospitalised adult patients, in a simulated environment and providing feedback	Identified 51 usability issues and suggested design improvements for the CDSS

Maramba *et al.* (2019)	UK	Primary and Secondary Care	To review the methods of usability testing in the development of eHealth applications	A literature scoping review was conducted using sources available from April 2014 to October 2017, which searched four databases, and included 133 articles that met their inclusion criteria, which reported usability testing methods for eHealth applications. The study extracted and then synthesised the data using descriptive and thematic analysis.	Found that most studies used qualitative methods, such as interviews and observations, and applied usability testing in the later stages of development. Recommended more use of mixed methods, such as surveys and analytics, and more involvement of end-users in the early stages of development. The paper underscores the critical importance of a high-quality database to ensure accurate ADE visualisation and suggests the integration of additional patient data for improved ADE identification. Integration into existing IT systems is proposed to further enhance the tool's acceptance and utility. The key take-home messages, derived from the methods used highlighted the HIT tool's potential to reduce medication errors and the importance of addressing user feedback and database quality to optimise its functionality. Both of which the evaluation approaches helped to successfully determine.
Marcilly *et al.* (2019)	US	Primary and Secondary Care	To identify HIT usability issues from incident reports in a hospital setting	Qualitative content analysis of 359 incident reports from a French hospital	Found that 69.3% of the reports mentioned HIT usability issues, and that these issues affected various HIT systems. Identified the most frequent types of HIT usability issues and mapped them to the HIT systems

Marien *et al.* (2019)	Belgium	Secondary Care	To design and test a web-based medication reconciliation application integrated in an eHealth network	User-centred design and usability testing with 48 healthcare professionals using the application in a simulated environment and providing feedback	Designed and tested a web-based medication reconciliation application that allows healthcare professionals to access and update medication lists from different sources. Identified several usability issues and user needs, such as data quality, data integration, data visualisation, and data validation
Randhawa *et al.* (2019)	Canada	Primary and Secondary Care	To provide evidence-based usability principles for safe computerised provider order entry (CPOE) interface design	Literature review of 30 studies that evaluated the usability and safety of CPOE interfaces.	Provided 11 usability principles for safe CPOE interface design, covering aspects such as data entry, data display, data validation, data integration, and data feedback. Rated the level of evidence for each principle
Baysari *et al.* (2018)	Australia	Secondary Care	To examine the user experiences of a computerised provider order entry (CPOE) system in a paediatric hospital over time	Longitudinal study with nurses and doctors who completed semi-structured interviews before, during and after the implementation of the CPOE system	Found that the user satisfaction and perceived usefulness of the CPOE system increased over time, but the perceived ease of use and efficiency decreased. Identified several factors that influenced the user experiences, such as training, support, feedback, and system performance
Marcilly *et al.* (2018)	Australia	Primary and Secondary Care	To provide evidence-based usability design principles for medication alerting systems (MAS)	Systematic review of identified 9 publications on design principles that evaluated the usability of MAS.	Provided 20 usability design principles for MAS, covering aspects such as content, format, timing, frequency, and interaction of alerts. Rated the level of evidence and the level of agreement for each principle
Russ *et al.* (2018)	US	Primary and Secondary Care	To evaluate the usability of a medication reconciliation tool that embeds safety probes	Usability evaluation with 20 healthcare professionals and 10 patients, using the tool in a simulated scenario and providing feedback. The evaluation integrated artificial safety probes, such as missing medications, extra medications, and inaccurate doses, to measure	Found that the tool was well received but identified several usability issues. The results indicated that the detection of medication discrepancies was low, with less than 50% of HCPs identifying safety probes. Patients had slightly better detection rates. Found that the safety probes were effective in measuring performance and revealing cognitive processes, but raised some ethical and practical challenges

				users' ability to detect medication discrepancies.	
Staggers *et al.* (2018)	US	Secondary Care	To discuss the importance of solving nurses' usability problems with health information technology (HIT)	Literature review and expert opinion on the current state and future directions of HIT usability for nurses	Found that nurses face many usability problems with HIT, such as poor interface design, workflow disruption, information overload, and error induction. Recommended more involvement of nurses in the design and evaluation of HIT, more adoption of usability standards and guidelines, and more research on the impact of HIT usability on nurses and patients
Task, Technology Fit based					
Paper	**Country**	**Context**	**Aim and scope**	**Methods and data sources**	**Main findings and implications**
Zhai *et al.* (2022)	China	Secondary Care	To explore the barriers and facilitators to implementing a nursing clinical decision support system (CDSS) in a tertiary hospital setting	Qualitative study involving interviews and observations with nurses using the CDSS in a real clinical setting and providing feedback. Used FITT framework to interpret results.	Found that the CDSS had a moderate fit with the nursing work, and identified several barriers and facilitators to the implementation, such as data quality, data integration, data visualisation, data interaction, user training, user feedback, and user involvement
Ali *et al.* (2018)	US	Secondary Care	To adapt a patient portal for patient work using a task-technology fit model	3 Phase, Mixed methods study with 23 (11 phase 2, 12 phase 3) patients with chronic conditions using the patient portal for four weeks and providing feedback	Found that the patient portal had a low fit with the patient work, and suggested design recommendations to help improve the fit to patient needs

Cresswell *et al.* (2020)	UK	Secondary Care	To develop and apply a formative evaluation framework for health information technology (HIT) implementations	Literature review and qualitative study from 3 national formative evaluations of HIT implementations primarily in a hospital setting. Combined data set of 703 interviews, 663 hours of observations and 864 documents from different NHS care settings	Developed a formative evaluation framework (TPOM) that consists of four dimensions: Technological Factors, People Factors, Organisational context, Macro-environmental factors. Applied the framework to evaluate the HIT implementation project and identified the barriers and facilitators to the project.
Prgomet *et al.* (2019)	Australia	Secondary Care	To propose an extension of the fit between individuals, tasks, technology, and environment (FITT) framework to evaluate and optimise HIT use	Mixed method approach with 38 clinicians, involving interviews, observations and field notes and use FITT principles to assess the links between tasks, technology and users.	Proposed an extension of the FITT framework that includes additional dimension: Environmental factors. Discussed the implications of the extended framework for HIT evaluation and optimisation

2.4 Usability Literature Review

Usability and the relationship between human factors are crucial in the design of digital medicines management systems. Awad *et al.* (2023) recognise that not just configuration but poorly designed systems can lead to usability issues and patient safety risks. While the review aimed to describe methods to enhance safe and friendly design, the included studies focused more on usability than safety-orientated methods. Awad *et al.* (2023) conclude that the potential risks in medication management warrant a comprehensive application of safety-oriented human factors and safety analysis methods to ensure both usability and safety. They also focus on general findings relating to HIT systems, usability and safety relationships previously identified by Adams *et al.* (2021), Ratwani *et al.* (2018), Sujan *et al* (2017) and Carayon *et al.* (2017). Awad *et al.* (2023) also substantiate the use of the system usability scale (SUS) being used in conjunction with surveys, among other qualitative methods for evaluation and design assessment. Thus, usability is a key aspect of system safety as well as a measure of how well the system is used.

Maramba *et al.* (2019) conducted a scoping review to explore usability testing of eHealth applications. Descriptive and thematic analysis showed wide variation in type, purpose, setting, participants, data collection, data analysis, and reporting of usability testing methodology. Functionality, complexity, and maturity of the eHealth applications also influenced usability testing methods. The authors concluded there was no one-size-fits-all approach to usability testing, and that methods should be tailored to the specific context and user needs. Maramba *et al. (2019)* identified that the system usability scale (SUS) was a common technique, also used by Schmidtchen *et al.* (2023) to study a medication safety system. SUS is known for its reliability in assessing application intuitiveness and user-friendliness (Bloom *et al.*, 2021). Schmidtchen *et al.* (2023) undertook SUS usability analysis - supplemented with additional questions - to explore user-friendliness, intuitive design, and efficient search capabilities among healthcare professionals. The study helps establish the use of mixed methods combining SUS and other qualitative methods as an effective approach. This study also captured the number of years' experience of each participant.

In contrast the study by Marcilly *et al.* (2023) aimed to evaluate the usability and perceived usefulness of a clinical decision support system (CDSS) and to create guidelines for enhancing usability, using a convergent, parallel approach method. This included a heuristic evaluation, a USE (Usefulness, Satisfaction, and Ease of Use) questionnaire completed by pharmacist users, and semi-structured interviews, analysed using the Unified Theory of Acceptance and Use of Technology (UTAUT) and a task-technology fit model. They formulated 23 guidelines to address usability challenges by comparing results from these methods. The combined methods not only pinpointed usability issues within the CDSS but also gauged user satisfaction of usability. This provides a useful perspective and complements both the approach by Schmidtchen *et al.* (2023) and Awad *et al.* (2023) whilst differing in the exact methods used.

Interestingly, there were some negative issues discovered in the follow-up interviews in this study that reinforce why analysing fit between task, individual and technology is so important, reinforcing a benefit of a mixed methods approach to assessing usability. The paper proposes that there is not a “one size fits all” approach and highlights the importance of properly analysing future system context and tasks before system selection and delivery, ensuring that the necessary gaps are addressed. Therefore, it is likely the use of a FITT type framework (Ammenwerth *et al.*, 2006) to help assess the responses to their research would have provided further insight.

Marien *et al.* (2019) developed and tested a medicines reconciliation solution, using a three-phase user-centred usability evaluation, incorporating observations, questionnaires, discussions and the System Usability Scale (SUS). They highlighted the need for improvements related to workflow integration, usefulness, and interoperability. The SUS was felt an important tool because it has been validated for digital user interfaces and effectively used in the health care setting (Maramba *et al.*, 2019; Marien *et al.*, 2019; Schmidtchen *et al.*, 2023). It was also considered easy to understand and simple to complete. Amongst other qualitative and thematic findings there was consensus that making improvements around workflow integration, alongside interoperability and usefulness was a key factor in reaching user acceptability. These are important factors when it comes to considering how well a system “fits” in terms of the tasks an individual uses the technology for, providing a sound basis for applying a FITT lens (Fit between Individual, Task and Technology) on this type of evaluation (Ammenwerth *et al.*, 2006).

Considering the application of principles to apply to usability testing, Pruitt *et al.* (2022) created and evaluated a self-administered assessment tool for EHR usability and safety, focussing on CPOE, medicines, radiology and lab ordering. The tool consisted of 104 questions (with branching), with an average of 46 needing answers. The authors suggest it can be used by any healthcare facility to pinpoint concerns and offer actionable suggestions for enhancement, highlighting the importance of defining usability terminology. Their evaluation tool was designed around well-known and researched usability issues (Table 2.4). The questions in the study focussed on specific areas of usability, based on the American ISMP safety guidance (ISMP, 2019) and therefore may not be as applicable in the UK.

Table 2.4 Key EHR Usability Issues (adapted from Pruitt et al. (2022)

Usability Issue	Detail
Visual display	The EHR's display of information is cluttered, confusing, or inaccurate, making it difficult for clinicians to interpret the information presented.
Availability of information	Clinically relevant information is not easily accessible due to incorrect storage or entry of information in the EHR.
System automation and defaults	The EHR automates or defaults information that is unexpected, unpredictable, or not transparent to the clinician, leading to confusion and errors.
Alerting	EHR alerts or other feedback are inadequate because they are absent, incorrect, or ambiguous, leading to missed or delayed diagnoses.
Data entry	EHR data entry is difficult or not possible given the clinicians' work process, preventing the clinician from appropriately entering the desired information.

While Pruitt *et al.* (2022) developed an analysis tool with recommendations based on evidenced guidelines, Lee *et al.* (2021) created a comprehensive safety and usability guideline for Clinical Information Systems (CISs) to prevent harm from poor system design. The guideline focussed on user interface (UI) and to task-related usability and was validated by experts in medical informatics, patient safety, and human engineering. Positive results indicated the guideline could be used to enhance CISs usability and safety and provide useful feedback for system improvement. However, limitations specific to South Korea, such as regulatory and policy constraints, should be noted, including the prohibition of electronic prescribing.

In the paper by Adams *et al.* (2021) they aimed to categorise medication errors linked to the use of HIT, their impact on patients and pinpointing when these errors occurred within the medication process. They used thematic analysis to extract data on HIT usability issues, medication errors and patient outcomes, identifying common themes. The authors concluded that HIT usability is critical for medication safety, with most errors involving usability factors. Recommendations for improving HIT usability and medication safety include improving data entry, support for workflows and alerts. Despite differences in the study design, size and approach, the findings are supported by Iqbal *et al.* (2021) and Howe *et al.* (2018).

The analysis by Iqbal *et al.* (2021) demonstrates poor usability can contribute to medication errors and found several usability challenges, such as confusing interface, inaccurate information, and system errors. These were classified into 7 usability categories (Table 2.5) using the same categories identified by Adams *et al.* (2021),

mapping them to the medication process stages. It suggested potential solutions for each category of usability issue.

Table 2.5 Usability Challenges Identified and adapted from Adams et al. (2021) and Iqbal et al. *(2021) (512 words)*

Usability Challenge	Detail	Usability Theme	Sub theme/Example
Alerting	The health IT component does not provide adequate alerts or other feedback mechanisms because they are missing, wrong, or unclear.	Duplicate order and/or alerting problem	Duplication order and no alert appearing. Leading to Improper administration.
		Failure to stop original order.	Both orders being active with no alert.
		Lack of allergy alert	No alert related to a patient allergy
Availability of Information	The clinician cannot access clinically relevant information because it is stored or entered in the wrong place, or it is not available.	N/A	N/A
Data Entry	Data Entry - The clinician cannot enter data easily or at all because the clinical workflow does not allow the clinician to enter the information they want.	Wrong Chart	Prescribed on wrong patient chart
		Wrong Field	Instructions in wrong place – e.g. number of tables to be given in comment field instead of a dose field.
		Wrong Input	Wrong dosage entered and confirmed.
Display/Visual Clutter	The information displayed is confusing, messy, or inaccurate, making it hard to understand the information.	Misinterpreted data	Misinterpreted dose
			Misinterpreted schedule
			Misinterpreted medication name
			Misinterpreted patient name
			Misinterpreted route of administration
			Missed amendment to prescription
			Missed the prescription altogether not administered as not properly visualised.
			Missed special instructions
Interoperability	The health IT component does not communicate well with other parts of the same health IT component or with different health IT components, preventing the exchange of information.	Transfer of data between care settings – from one department to another.	Emergency department medicines prescribed and administered details did not transfer to eMAR system in intensive care.

System automation and defaults	The health IT component automatically fills in or defaults to information that the clinician does not expect, predict, or see.	Automatic dosing schedule	Prescribed for nighttime but available for administration at a default time in the morning.
		Electronic removal of a prescription without any user input	Prescription dropped off the administration task screen without any user input.
Workflow Support	The health IT component does not support the workflow because it does not match the clinical goal of the end user.	Delayed Time of action	Nursing – workflow did not facilitate timely action.
			Pharmacy - workflow did not facilitate timely action.
		Schedule cannot be adjusted to match intended action	Nurse unable to amend the "actual" administration time in eMAR after giving at a time that was not available in the eMAR schedule.
		Prescription not received or approved by pharmacy.	Workflow did not facilitate seamless receipt of a prescription or pharmacy approval.
		Health IT not supporting user needs.	Unable to record details about an administration that was given in error.
		Machine Malfunction	System down – paper used and not transcribed back into digital system.
		No input	Administration not documented.
		User completed an action digitally that was not done physically.	An administration was recorded on the system when not actually given.
		User did not use Health IT when available.	Reliance on an out of date printout despite eMAR availability.

Pruitt *et al.* (2022), Iqbal *et al.* (2021) and Adams *et al.* (2021) refer to usability issues that are prominent in literature, such as consistently identifying the state of the screen and the way that information is displayed. These are also principles that are highlighted in terms of design checklists by Randhawa *et al.* (2019). Iqbal *et al.* (2021) and Adams *et al.* (2021) also include interoperability and consider workflow support. Workflow support is an important aspect when it comes to considering how well the adopted HIT fits into the clinical work process. Iqbal *et al.* (2021) goes on to undertake thematic analysis and attribute themes and subthemes to each usability issue.

The literature review by Randhawa *et al.* (2019) produced an evidenced based list of eleven usability principles for safe CPOE interface design; covering data entry, data

display, data validation, data integration, and data feedback. Whilst there were some similarities with aspects of usability highlighted in studies by Pruitt *et al.* (2022), Iqbal *et al.* (2021) and Adams *et al.* (2021), which included screen design and layout, the principles by Randhawa *et al.* (2019) were categorised differently and were mainly focused on the physical design of the user interface and alert visibility. Randhawa *et al.* (2019) rated the level of evidence for each principle, thus providing an evidence base which has been demonstrated in the other usability studies.

Focussing on specific functionality related to EHR, CPOE and ePMA, Akhloufi *et al.* (2019) involved 8 medical residents who evaluated four patient cases modelled on actual clinical scenarios using the "think-aloud" method. A total of 51 usability problems were identified with the majority being cosmetic or minor issues. Some of these issues had the potential to result in ordering errors. The severity rating and the impact of these problems on task outcomes were used to prioritise system redesign efforts. The study highlights the value of usability studies in enhancing the layout and functionality of HIT systems, even after they have used a multidisciplinary team to develop them. This supports Randhawa *et al.* (2019) design principles and is not contradictory to subsequent usability recommendations already cited.

Similarly, Marcilly *et al.* (2018) aimed to create an exhaustive and organised list of evidence-based design principles for medication alerting systems' usability, analysing nine collections of principles and matching them to known usability flaws. They summarised 60 principles into meta-principles, principles, and sub-principles, covering areas such as signal-to-noise ratio, workflow integration, data display, transparency, and actionable tools within alerts. The study concludes that their list improves upon existing literature by associating each principle with evidence of its violation, offering valuable insights to enhance usability, improve on flaws and mitigate their harmful consequences in medication alerting systems.

Staggers *et al.* (2018) studied the usability challenges nurses encounter with HIT and evaluated their significance and consequences, then proposed potential solutions to enhance user experience. User interface (UX) pain points and the consequent "fit to workflow" are among the themes and categories identified by the study, which emphasised the need to address usability issues. Therefore, when conducting usability evaluations, it demonstrates that it is essential to consider the user experience and the impact of usability issues on the users and the organisation and how well the system fits in terms of different workflows, the information required for different workflows, and the differences for these within each specialisation. Whilst the study centred on using semi-structured interview questions, the outcomes of the study highlight why it is important to consider combined methods, that allow further exploration of user experience when undertaking usability evaluations.

Baysari *et al.* (2018) investigated the experiences of nurses and doctors during the early stages of implementing a CPOE system and tracked changes in their perceptions and behaviours as they progressed to routine use. The research involved semi-structured

interviews, using 8 questions, asked at multiple time points, including one week, three weeks, six weeks, and six months after CPOE implementation, with a total of 122 users participating. Initially, user perceptions were influenced by unfamiliarity with the system, but as they gained proficiency, they recognised additional safety benefits. However, usability issues and new error types emerged as use increased (Table 2.6). Interestingly workarounds, introduced to mitigate perceived negative consequences of CPOE, were observed at six-months. The study provides valuable insights into the evolving perceptions and challenges associated with CPOE adoption, suggesting the importance of adaptive implementation and support programs to address changing concerns during the initial six months of use. It also highlights the importance of understanding the relationship and purpose of the technology and how well it sits in terms of the workflows and tasks individuals need to accomplish as part of their role within an organisation.

Table 2.6 Usability and Error Themes summarised from Baysari et al. (2018)

Issue Type	Sub Type	Description
Usability	Confusing Interfaces	Difficulty Telling if a medication had been administered.
Usability	Navigation	Excessing Navigation/Clicks/More steps in the prescribing process.
Usability	Data Entry	Excessive Data Entry
Usability	Data Entry	Long Lists of Options
Usability	Addition of Tasks	Longer processes as more steps involved
Usability	Interface	Slow Loading Times
Error	Dosing Related Error	Wrong doses prescribed
Error	Selection Error	Incorrect Weights being used for dosing
Error	Selection Error	Wrong drug/route selected - Choice
Error	Selection Error	Out of Date Order Sentences due to policy change
Error	Patient Selection Error	Prescribing under the wrong patient
Error	Delayed Medication	Missed doses or delay in prescribing.

The interview questions used by Baysari *et al.* (2018) were based on The Extended Technology Acceptance Model (e-TAM) (Mathieson *et al.*, 2001) (Figure 2.2) and were used as a guide during short 8.5 minute interviews (Table 2.7).

Table 2.7 Semi-structured interview questions used by Baysari et al. (2018)

No.	Question
1.	What is your overall impression of how the CPOE system is going?
2.	How has the CPOE system changed your prescribing (or administration) of medications?
3.	Do you think the CPOE system is safer or less safe than the paper system? Why?
4.	How is the CPOE system helping and/or hindering your work?
5.	Have any new problems or issues emerged?
6.	Can you think of any ways the CPOE system can be improved?
7.	Overall, do you think implementation of the CPOE system has been positive or negative for you as a health professional? For patients? For the organisation as a whole?

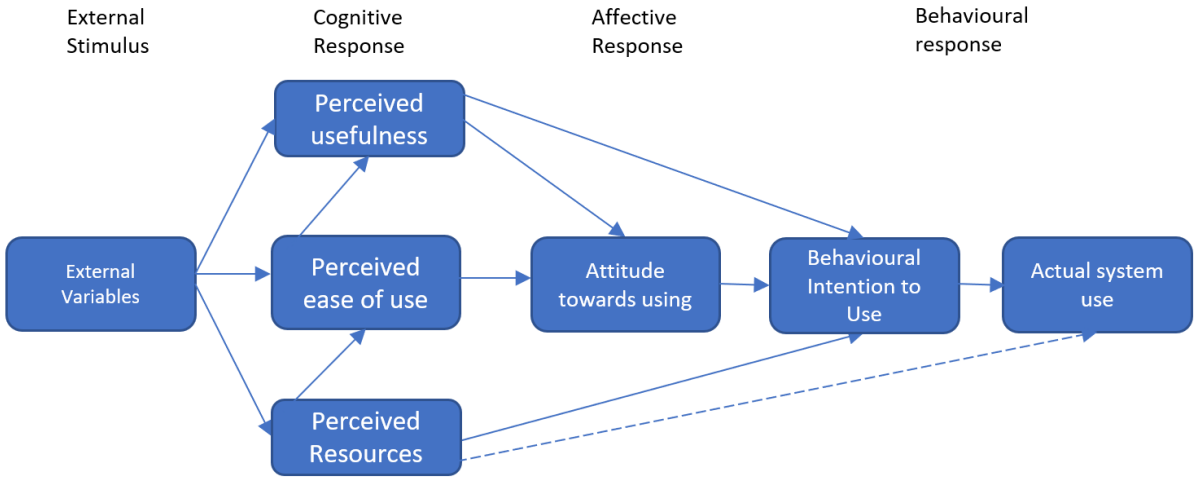

Figure 2.2 Extended Technology Acceptance Model (eTAM) adapted from Mathieson, Peacock and Chin (2001)

Undertaking studies is a vital aspect to support the advancement of technology to help improve safety and address workflow issues. However, they may not reveal how the healthcare workers operate technology in the real-world clinical context or offer insight on how the HIT connects with other components of the healthcare ecosystem, such as other work processes, organisational controls and/or other systems (Sittig *et al.*, 2020; Sittig and Singh, 2015). Although several usability themes are picked up in this usability literature review, there is a clear indication that many different approaches are needed. Thus, it is important to look at evaluation methods that can help to assess this relationship whilst considering that there is no "one size fits all" approach.

2.5 Fit Between Task and Technology Literature Review

Usability studies have demonstrated the importance of looking beyond the actual usability and user acceptance of technology. It is important to consider factors around the environment (Rabiei *et al.*, 2018), individuals and workflows using HIT technology.

When examining literature around evaluating technology by focussing on how well it fits into work process, Zhai *et al.* (2022) study explored the barriers and facilitators to the implementation of a clinical decision support system (CDSS) among nurses in a hospital in China. The study used the FITT framework, which evaluates the fit between the technology, the individual, and the task attributes (Ammenwerth *et al.*, 2006). This idea considers the Technology Acceptance Model (TAM) and Task Technology Fit (TTF) models, two theoretical frameworks for investigating the properties and fit between tasks, technology, and people (Figure 2.3)(Davis, 1993; Goodhue and Thompson, 1995).

Zhai *et al.* (2022) collected data from participatory observation and semi-structured interviews with nurses in four medical-surgical wards and identified twelve categories of barriers and facilitators (Table 2.8), which were related to the system, the user, and the organisation.

Table 2.8 Barriers and Facilitators to system implementation mapped to FITT framework. Adapted from Zhai et al. (2022) (Goddard 2023)

Theme	Category	Fit between attributes within the FITT framework
Barriers	Interface design issues	*Task and Technology*
	Information linkage issues	*Task and Technology*
	Acceptance of the system	*Individual and Technology*
	Inter-professional barriers	*Not matched*
	Standards of practice (lacking)	*Individual and Task*
	Increase workload	*Individual and Task*
Facilitators	Value added – clinical decision support	*Task and Technology*
	Value added – documentation templates (structured)	*Task and Technology*
	Technical staff support	*Individual and Technology*
	Management support	*Individual and Technology*
	Adapting to the system	*Individual and Technology*

The study suggested that management intervention was crucial to improve the fit between the attributes and to promote the system implementation. They also proposed to extend the FITT framework to include the inter-disciplinary collaboration between nurses and technical staff and concluded that the FITT framework could help understand and improve the CDSS implementation in health care settings.

Figure 2.3 Goodhue's Task-Technology-Fit (TTF) model diagram adapted from Ammenwerth et al. 2006.

Cresswell *et al.* (2020) explored the development and application of a formative assessment framework that emphasises the connections between the identified dimensions and provides HIT implementers with guidance, in a similar manner to Marcilly *et al.* (2018), which was centred around usability design principles. The study used a qualitative approach and collected information from three national formative evaluations of various HIT interventions (electronic health record, electronic prescribing, and clinical decision support functionality) in 19 case studies of primarily hospital settings in England and Scotland. The paper analysed the data using a prototype framework based on the existing literature and refined it into the Technology, People, Organizations, and Macroenvironmental factors (TPOM) framework (Figure 2.4), which expounds the interrelationships between these four dimensions and offers guidance for implementers. Cresswell *et al. (*2020) found that the TPOM dimensions were closely related and influenced the HIT implementation outcomes. The study also found that the environmental factors, such as policy and market changes, had a significant impact on the HIT use. The study concluded that the TPOM framework could support formative evaluations of HIT implementation and digital transformation efforts.

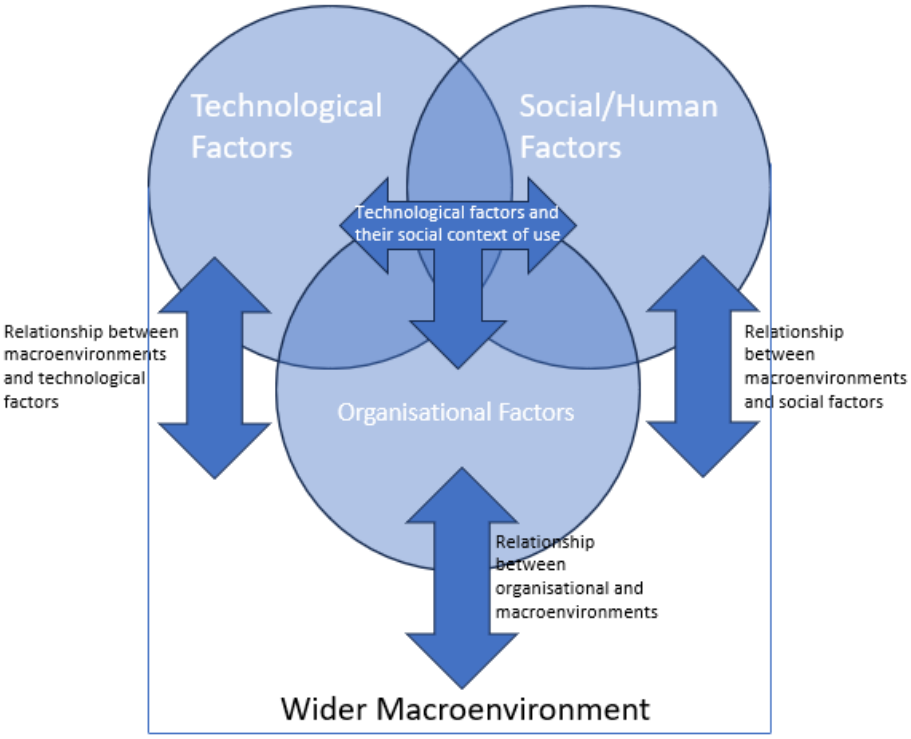

Figure 2.4 Illustration of TPOM evaluation framework adapted from Cresswell, Williams and Sheikh (2020)

There are several similarities between the approaches taken by the studies reviewed. Both Cresswell *et al.* (2020), Prgomet *et al.* (2019) and Zhai *et al.* (2022) have some similarities in their aims, methods, and frameworks. Each of the studies are concerned with creating and utilising a formative assessment framework for the use of HIT, which means they seek to assess and improve the fit between technology and clinical work. Each uses a mixed method approach, combining qualitative data from interviews, observations, and documents, to explore the factors that influence the success of HIT interventions, and they draw on existing literature and evidence to inform their frameworks.

However, there are some differences in the scope, context, and findings of these studies. The paper by Cresswell *et al.* (2020) focuses on the UK context, evaluating three HIT interventions in secondary care. Whereas, Prgomet *et al.* (2019) focuses on the Australian context, where they collected data from a sample of 38 clinicians on two wards at an Australian hospital, using a range of HIT interventions (electronic discharge summaries, test ordering and results viewing, and an electronic medicines management system). However, in a similar way to Zhai *et al.* (2022), Prgomet *et al.* (2019) proposed to analyse data using a task fit framework, the FITT framework (Ammenwerth *et al.*, 2006), which assesses the fit between users, tasks, and technology and proposed

an extension of it. The subsequent “FITTE framework”, adds the dimension of environment to account for the factors that affect technology use beyond the user-task-technology triad (Figure 2.5). Prgomet *et al.* (2019) found that the environment, such as the ward rhythms, infection control rooms, and space limitations, also affected the HIT use, even when the fit between users, tasks, and technology was adequate and therefore, proposed environmental considerations as an extension to the framework. Thus, the study suggested that the FITTE framework could better capture the complex and dynamic nature of HIT use and help improve the design and implementation of HIT systems. Therefore, both studies have some commonalities in their objectives, methods, and frameworks, but also some distinctions in their settings, interventions, and outcomes. They both contribute to the field of formative evaluation of HIT implementations, critical in ensuring the intended benefits of technology are achieved.

The study undertaken by Prgomet et al. (2019) has some similarities with Cresswell et al. (2020) research. The similarities can be seen in methods and approaches they used. Both took a qualitative approach and collected data from multiple case studies from hospital settings in Australia and the UK. Each also used a formative evaluation framework to analyse their data and assess the fit between the technology, the users, and the tasks. Both studies proposed an extension to evaluating more than just the fit between the task the individual and the technology, but also to include the environmental factors that affect the use of HIT. However, there were also some differences between the studies in terms of the data collection methods, the types of HIT interventions, and how they named their extended frameworks; Prgomet et al. (2019) used structured observation, interviews, and field notes, while Cresswell et al. (2020) also examined documents used in the work processes. The other key difference was that Prgomet et al. (2019) focused on a single HIT intervention, an electronic medication management system while Cresswell et al. (2020) focused on three different HIT interventions, these were an electronic health record system, electronic prescribing, and clinical decision support functionality.

In the paper by Zhai *et al.* (2022), management intervention was vital to address user resistance, improve system usability, set standards on practice, and build connectivity between nurses and the technical staff and suggested extending the FITT framework to include organisational dimensions. A similar approach to both Cresswell *et al.* (2020) and Prgomet *et al.* (2019), in that they recognised additional dimensions to the technological fit that looked at the organisation or environment beyond the person, technology and immediate process itself. The paper concluded that the FITT framework could be used to interpret the complex interactions between multiple attributes that affect the Nu-CDSS implementation in China but recognised the need to extend the framework to include wider factors such as managerial and organisational interactions. This viewpoint oscillates slightly with that of Prgomet *et al.* (2019) in suggesting extensions related to wider organisational environment.

FITT was also a theme seen when assessing HIT usability in Ali *et al.* (2018) paper which reports on a usability evaluation of a patient portal that was designed to deliver inpatient data, including secondary care medicines information, to patients upon hospital discharge. The study used a task-technology fit model to assess how well the portal matched the needs and preferences of patients with chronic disease or managing the care of family members with chronic disease. The paper conducted 23 user testing sessions with patients and applied heuristic usability evaluation and qualitative analysis. It found that the portal improved throughout iterative development, but some challenges remained, such as understanding the tasks that the portal could support.

There are some similarities in the approaches and methods by Ali et al. (2018) to the papers by (Ali *et al.*, 2018; Cresswell *et al.*, 2020; Prgomet *et al.*, 2019; Zhai *et al.*, 2022). However, when comparing to Progmet *et al* (2019), both papers used a qualitative approach and collected data from multiple case studies of hospital settings. Both papers used the FITT framework to analyse the data and assess the fit between the technology, the users, and the tasks. However, the papers also differed in the type of HIT interventions, the data collection methods, and the extension of the FITT framework. Ali *et al*. (2018) focused on an electronic patient portal for patients with chronic disease or managing the care of family members with chronic disease in the United States rather than medicines management seen in the Progmet *et al* (2019). The paper by Prgomet *et al.* (2019) used structured observation, interviews, and field notes to collect data whereas Ali et al. (2018) used heuristic usability evaluation and individual user testing sessions to collect data. Unlike the papers by Zhai *et al.* (2022), Cresswell *et al.* (2020), Prgomet *et al.* (2019) the evaluation by Ali et al. (2018) did not propose any extension of the FITT framework, but suggested providing narratives about hypothetical patients to educate about the types of work that the portal could support.

Thus, examining the fit and links between task, technology and individuals has been a theme and backbone to several recent secondary care related formative evaluations and studies (Ali *et al.*, 2018; Cresswell *et al.*, 2020; Prgomet *et al.*, 2019; Zhai *et al.*, 2022).

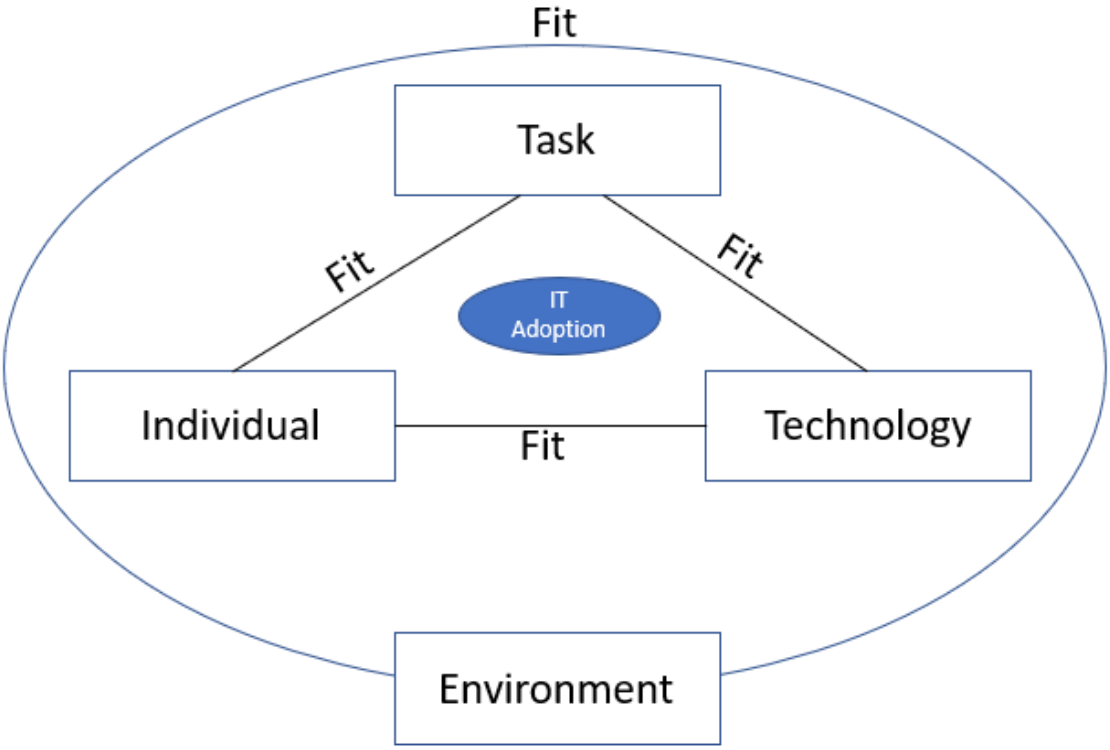

Figure 2.5 Illustration of FITTE Framework adapted from Ammenwerth, Iller and Mahler (2006)

2.6 Conclusion

Combining Usability with FITT.

Maramba *et al*. (2019) systematic review helps to identify that there is not a one size fits all approach to evaluating usability of systems and provides a sound logic and basis to justify tailoring approaches, whilst, at the same time considering that it is important to be able to repeat and compare similar studies against each other. This supports using a validated and comparable usability scoring system (SUS) whilst incorporating aspects and perspective from fit between individual task and technology based evaluations.

Usability is intrinsically linked with user experience and user interaction, the way that users interact with the technology, the interplay between individual characteristics, and the tasks and the features of the implemented HIT. The FITT framework with the added environmental aspect (FITTE) (Ammenwerth *et al.*, 2006; Prgomet *et al.*, 2019), is specifically designed for healthcare and unlike other theoretical frameworks aims to understand HIT use by focussing in on the impact of the "user-task" interaction.

Ali *et al*. (2018) demonstrates the successful use of undertaking a multiphase combined methods approach, ultimately followed by a comprehensive FITT analysis evaluation to help evaluate system usability.

Interestingly, there were no HIT related studies within the last five years that combined both a task-technology fit type evaluation with a system usability scale. During the search, an exception was found that related to a learning management system (LMS) used during the COVID19 pandemic (Chuenyindee *et al.*, 2022). This study aimed to explore the factors that influenced the perceived usability of the learning management system (LMS) among students and instructors during the COVID-19 pandemic. The study used an integrated model of system usability scale (SUS), technology acceptance model (TAM), and task-technology fit (TTF) to measure the LMS usability. The team found that gender, age, and experience moderated the relationships among the variables. Chuenyindee *et al.* (2022) concluded that the LMS usability was influenced by both technological and human factors, and that the integrated model could provide a comprehensive and reliable measure of LMS usability. Thus, although this study is not specific to HIT, it demonstrated meaningful insights between individual SUS category scores and the perceptions of the participants in relation to task-technology fit, allowing for more exploration on the underlying factors of the evaluation.

Therefore, combining the use of various techniques and tools has been substantiated within the literature review (Maramba *et al.*, 2019). Whilst there were no immediate examples of the system usability scale (SUS) and FITT type frameworks being combined for ePMA type applications, it is clear from literature that it would be meaningful to do so, allowing more knowledgeable insights to be gained then from using any one technique alone. It is possible that attitudes and thoughts from one technique might be able to be exposed or correlated to the effect on another. Whilst

not specifically identified as a usability study, mixed methods approaches have also been demonstrated in Bell *et al.* (2019) study exploring the effects of medication related decision support alerts in a UK hospital, combining both a quantitative and qualitative approach which helped to gain insights on user experience and suggestions to improve. The use of both quantitative and qualitative techniques can be considered a crucial element for producing a more thorough study that allows for deeper insights and comprehension that may not otherwise be collected from one approach alone (Scott, 2016; Venkatesh *et al.*, 2013; Scott and Briggs, 2009).

3. Methods

3.1 Introduction

The literature review highlights that there is no one size fits all approach to the evaluation or study of health information technology (HIT). Thus, the assessment of the ePMA system employed a combination of quantitative and qualitative methodologies. These included an evaluation using a "fit" framework as a lens, usability scoring, a qualitative questionnaire and semi-structured interviews.

There are differing views on mixed methods (Hesse-Biber, 2015; Blackwood *et al.*, 2010), but these can be rebutted (Scott, 2016). Incorporating both qualitative and quantitative methods is deemed essential for a comprehensive study that enables deeper insights not attainable through a singular method alone (Venkatesh *et al.*, 2013; Scott, 2016; Scott and Briggs, 2009). Moreover, the use of mixed methods has been effectively applied to investigate usability in ePMA systems and decision support (Marcilly *et al.*, 2023; Marien *et al.*, 2019; Zhai *et al.*, 2022; Bell *et al.*, 2019). Therefore, a predominantly convergent mixed methods design was implemented, integrating and analysing data from both qualitative and quantitative techniques (Creswell *et al.*, 2011).

Recruitment

Participants in this project were selected through invitation, and recruitment through the clinical reference group of the ePMA system at Swansea Bay University Health Board and through email bulletins (Pruitt, *et al 2022)*. The recruited individuals represented nursing, medical, and pharmacy staff, all of whom actively use the ePMA system.

Questionnaire

A questionnaire was designed (Appendix 8), incorporating the system usability scale (SUS) for usability scoring (Bloom *et al.*, 2021) and contained questions that reflect aspects of the FITTE framework (Prgomet *et al.*, 2019) using Microsoft Forms©.

Follow up semi-structured interviews were conducted probing themes from the questionnaire and using questions adapted from Baysari *et al.* (2018) (Table 2.7). This helped to identify any further themes and helped towards ensuring a saturation of themes.

3.2 Acceptance and Fit Type Frameworks

Fit between Individuals Tasks and Technology (Ammenwerth *et al.*, 2006) was used to analyse the "socio-organisational-technical factors" influencing the implementation of technology in healthcare settings. This framework incorporates concepts from two theoretical models, the Technology Acceptance Model (TAM) and Task Technology Fit (TTF) models (Davis, 1993; Goodhue and Thompson, 1995) (Table 3.1) (Figure 2.2 and Figure 2.3) to explore the characteristics and alignment between tasks, technology, and individuals.

Table 3.1 Description of Technology Fit Models

Model	Detail
TAM Model	The TAM Model assesses the perceived ease of use, usefulness, and the end user's reactions, behaviours, and attitudes toward technology, along with how it is ultimately utilised. Holden and Karsh (2010) conducted a review of TAM's application in Health Information System (HIS) evaluations, affirming its suitability as a predictive model. They acknowledged that the model could be enhanced with modifications and additions, highlighting a deficiency in specific reviews related to tasks (Dishaw and Strong, 1999).
TTF Model	In contrast, the TTF model explicitly incorporates a task-technology concept. It evaluates the characteristics of tasks and technology, focusing on their alignment and how this alignment influences technology adoption (Goodhue and Thompson, 1995). The assumption here is that if the technology effectively supports task requirements, it will be adopted. However, a crucial aspect overlooked in the TTF model is the characteristics of the users (Lepanto *et al.*, 2011).
FITT Model	Ammenwerth *et al.* (2006) FITT model, specifically tailored for the healthcare domain, posits that the effective adoption and utilisation of technology hinges on the interplay among the attributes of individuals, the nature of tasks, and the features of the technology. When there is a noticeable disconnect, a "loose fit," or no alignment among the characteristics and attributes of users, tasks, and technology, it is likely to result in challenges and issues during the adoption and implementation of the technology.

In the FITT framework, individuals are examined either in isolation, as individual users, or as part of a broader user group. The user characteristics or "attributes" encompass those outlined in Table 3.2.

Table 3.2 FITT characteristics or Attributes of Individual, Task and Technology (Adapted from Ammenwerth et al. 2006 and Goddard (2023))

Individual Attributes (User or User group)	**Task Attributes** (Complete tasks or working processes e.g., completing documentation or entering orders).	**Technology Attributes** (Tool required to complete a task)
Knowledge of the digital solution and IT.	Organisation of the tasks to be completed	Stability and usability of a software of hardware tool
Motivation and interest in the task to be completed	Activities and their interdependence	Costs of a tool
Flexibility and openness to new ways of working	Complexity of tasks	Functionality
Team Culture		Available Technical Infrastructure
Organisational Context		Integration of tools
Cooperation within a team		Availability of tools in a certain clinical situation.
Politics within an organisation		

FITTE – Environment Extension

When examining the FITT model, the context in which the HIT sits is important. Systems are positioned within a physical infrastructure and may be subject to architectural constraints or limitations, such as room size, layout, and the location of plug sockets. The tasks enhanced by the technology are integral to a broader system of processes and components, encompassing ward activities, busyness, time of day, and may be influenced by overarching policies.

Ammenwerth et al. (2006) identified that variables related to the environment were found to impact technology utilisation and adoption indirectly or directly, even with a satisfactory alignment between the characteristics of users, tasks, and technology (Table 3.2). These environmental facets can be contemplated as an additional element or extension to the FITT model, thus FITTE (Environment). Prgomet et al. (2019) emphasised the significance of environmental factors and recommended this extension to assess contextual elements influencing the relationships between users, tasks, and technology (Figure 3.1).

FITTE – Approach to evaluation

Thus, the evaluation approach that was undertaken reflects on the elements of the FITTE (Figure 3.1) and incorporated the steps described in Table 3.3:

Table 3.3 Steps involved in approach to FITTE evaluation adapted from Goddard (2023).

Step	Description
1.	Assess individual needs and characteristics: Evaluate the needs and characteristics of individuals who use the ePMA system, considering factors such as age, education level (inferred from minimal professional requirements), computer literacy, and experience with similar technologies. Data on these characteristics was gathered through the survey and interviews.
2.	Examining task requirements: Identify the specific tasks that ePMA is intended to support and evaluate the associated requirements. This involved considering factors such as task complexity, collaboration level, and the need for decision support tools. Ideally, data on task requirements would be collected through workflow analysis, time-motion studies, or task observation. However, due to time constraints and study limitations, this analysis was restricted to existing knowledge, anything specific learnt from participant responses and literature reviews.
3.	Evaluate technology usability: Assess the usability of the ePMA system, including factors like ease of use, navigation, and user interface design. Data on technology usability was collected through a standardised usability test, the SUS.
4.	Consideration of environmental factors: Evaluation of the environmental factors that may influence ePMA use, including the physical layout of the workspace, availability of support resources, and organisational culture. Data on environmental factors was collected through the survey, interviews and any existing knowledge. Recognising limitations in gathering certain data, such as physical layouts, generalisations, experiences, and observations of the evaluator were also used to complement this aspect.
5.	Utilisation of a mix of quantitative and qualitative data: The FITTE Framework underscores the importance of employing both quantitative and qualitative data to assess technology use in the clinical environment. Therefore, the approach supported the use of surveys, interviews, usability testing, and other data collection methods. Combining these diverse approaches provided a more comprehensive understanding of the alignment between individuals, tasks, technology, and the environment, identifying areas for optimisation.

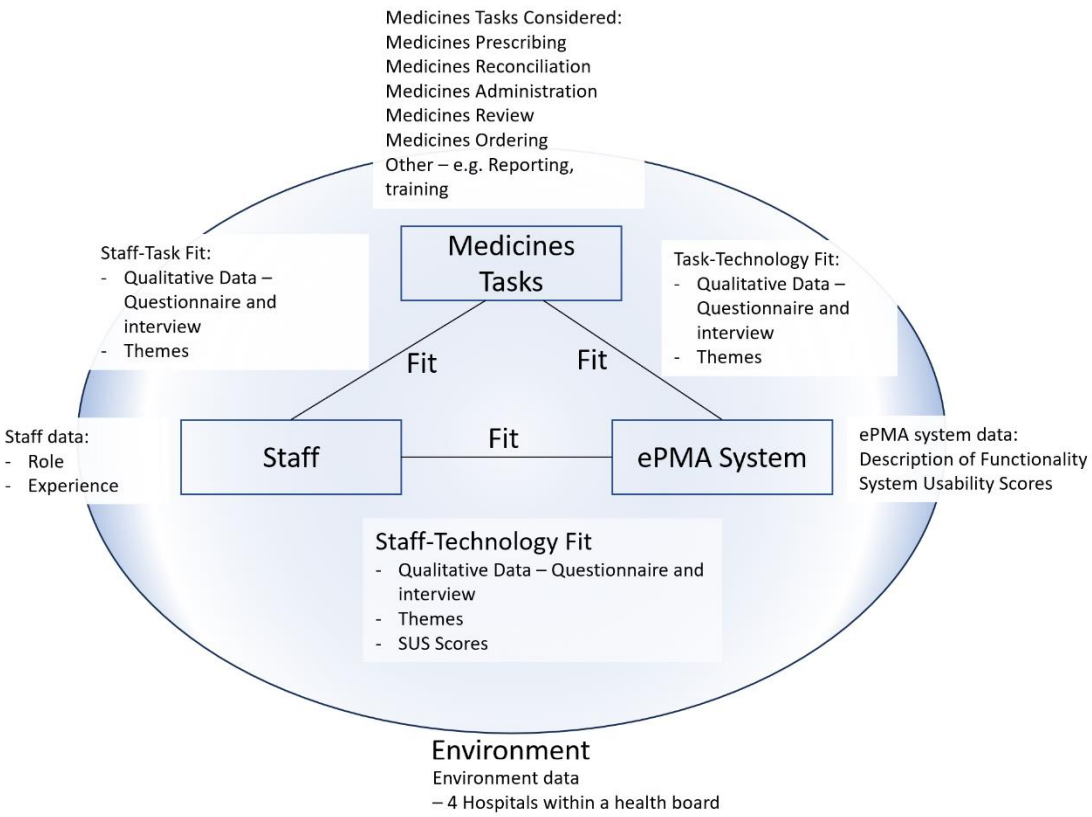

Figure 3.1 Task, Technology, Fit and environment model that portrays the conceptual links between the ePMA system, medicines management related tasks, staff and the portal. Adapted from Ali et al (2018), original concept from Ammenwerth et al (2006)

3.3 Assessment of Usability

Why SUS and not USE?

The literature review highlighted a number of usability, user acceptance evaluation tools, with the two key tools being USE (Usefulness, Satisfaction and Ease of Use) (Marcilly *et al.* 2023) and SUS (System Usability Scale) (Maramba *et al.*, 2019; Marien *et al.*, 2019; Schmidtchen *et al.*, 2023). Both are widely used, but with differences, SUS focuses on overall usability, whereas USE focuses on perceptions around three factors, usefulness, satisfaction and ease of use.

The methodology of this dissertation project sought to understand nuances through the lens of FITTE and combined this with usability assessment based on single usability scoring, helping to provide similar insights to USE. Applying a robust and standardised usability assessment was key and, within the time constraints and resources available for this project it was decided that SUS was an acceptable model. Whilst SUS alone may not be specific to healthcare, it does allow for a validated comparison of results and indeed was identified by Maramba *et al.* (2019) as one of the most frequent tools used in their systematic literature review. Therefore, it is a proven, acceptable and validated tool (Maramba *et al.*, 2019; Marien *et al.*, 2019; Schmidtchen *et al.*, 2023).

The System Usability Scale (SUS)

Since the 1980s, the System Usability Scale (SUS), has been widely utilised in over 1500 studies and 2300 surveys across various sectors and technologies (Brooke, 2013; Bangor *et al.*, 2008). It is an established industry standard for usability measurement with a track record in healthcare analysis, recently used by Bloom *et al.* (2021) in a survey involving 25 distinct EHR providers, predominantly from the NHS. As such, it was considered a suitable, comparable, consistent, and standardised method for ePMA scoring in this project. Additionally, it was a cost-effective choice, being freely available, when cited. The agnostic nature of the tool renders it suitable for future study and comparisons of iterated or alternative ePMA systems (Bangor *et al.*, 2008).

The steps involved in calculating the SUS score and the questions are described in Table 3.4 and Table 3.5.

Table 3.4 Steps involved in SUS score calculation adapted from Goddard 2023.

Steps Involved in SUS Scoring Mechanism	Detail
Step 1. Each of the 10 questions scored by participant.	Ten questions, each with a minimum score of 1 and a maximum score of 5. The odd-numbered questions (1, 3, 5, 7, 9) are positively framed, such as "I thought the system was easy to use," while the even-numbered questions (2, 4, 6, 8, 10) are negatively framed, for instance, "I found the system unnecessarily complex."
Step 2. Scores for odd-numbered calculated and scores for even numbered calculated differently.	When assigning scores to each question, the contribution to the overall score ranges from 0 to 4. For odd-numbered questions, this is the given scale response minus 1. For example, if a respondent scores a 5 for question 1, the result for that question is 5 – 1 = 4. For even-numbered questions, the score is determined by subtracting the scale response given from 5. For instance, if a respondent scores a 4 for question 2, the result for that question is 5 – 4 = 1.
Step 3. Scores summarised.	The individual scores are then summed up and multiplied by 2.5 to yield the final value. The overall scale used in the SUS measure ranges from 0 (indicating the worst usability) to 100 (indicating the best usability). The industry average is 68, and this has been adopted as the lower limit for acceptable usability (Sauro, 2011).
Table 3.5 *and Figure 3.2 present the SUS questions and an example scale.*	

Table 3.5 SUS Questions and scoring method (Adapted from Bloom, et al. 2021)

SUS Questions and scoring method (Adapted from Bloom, *et al.* 2021)			
No.	**Question**	**Strongly Disagree to Strongly Agree**	**Scoring Method**
1.	I like using the system	1 2 3 4 5	Respondent Answer - 1
2.	I find the system unnecessarily complex	1 2 3 4 5	5 – Respondent Answer
3.	I think the system is easy to use	1 2 3 4 5	Respondent Answer - 1
4.	I need the support of a technical person to use the system	1 2 3 4 5	5 – Respondent Answer
5.	I find the various functions in the system are well integrated	1 2 3 4 5	Respondent Answer - 1
6.	I think there is too much inconsistency in the system	1 2 3 4 5	5 – Respondent Answer
7.	I learnt to use the system very quickly	1 2 3 4 5	Respondent Answer - 1
8.	I find the system very cumbersome/awkward to use	1 2 3 4 5	5 – Respondent Answer
9.	I feel very confident using the system	1 2 3 4 5	Respondent Answer - 1
10.	I needed to learn a lot of things before I could get going with this system	1 2 3 4 5	5 – Respondent Answer

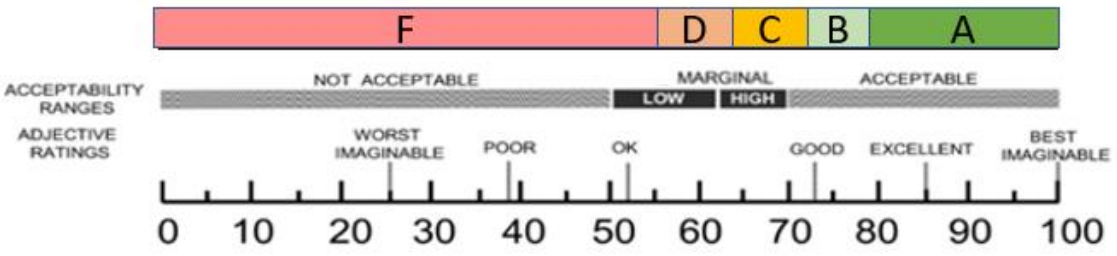

Figure 3.2 SUS Scores shown against acceptability ranges (adapted from Sauro and Lewis (2016) and Brooke (1996) (See Table 16 for key)

Brooke (1996) highlights that results of individual questions within the scoring system lack meaningful interpretation on their own. Thus, Bangor *et al.*, 2008 recommend examining individual answers in the context of the survey-taker to gain further insight into specific aspects of the system that these scores may help identify.

Thus, it is essential to take this into account when comparing individual SUS answers with any responses related to determining FITTE evaluation. Beyond the SUS score, additional insights and contrasts are obtained by including extra questions around concepts like user-friendliness and about user satisfaction, as proposed by Bangor *et al.*, 2008, such as in Figure 3.3.

11. Overall, I would rate the user-friendliness of this product as:

☐ Worst Imaginable	☐ Awful	☐ Poor	☐ OK	☐ Good	☐ Excellent	☐ Best Imaginable

Figure 3.3 Appended Adjective rating statement (Adapted from Bangor, et. al. 2008)

3.4 Semi-structured Interviews

The questionnaire allowed candidates to enter their details if they were happy to be contacted and to receive a follow-up interview. Baysari *et al* (2018) utilised a simple and effective set of questions to ascertain levels of user satisfaction and perceived ease of use, identifying factors that influenced user experiences (Table 2.7). These questions were adapted and formed the basis for the interviews in this study (Table 3.6).

Reflecting on questionnaire questions – to expand further e.g. on questions related to function and whether users felt the system had changed the way they work, interview question 2 – asks the interviewee to describe how they feel the ePMA has changed their practice.

Table 3.6 Interview Questions adapted from Baysari et al (2018)

No.	FITTE Attribute	Question
1.	Technology	What is your overall impression of how the ePMA system is going?
2.	Task Individual	How has the ePMA system changed your prescribing/administration/review/ordering of medications?
3.	Technology	Do you think the ePMA system is safer or less safe than the paper system? Why?
4.	Individual	How is the ePMA system helping and/or hindering your work?
5.	Task	Have any new problems or issues emerged?
6.	Technology	Can you think of any ways the ePMA system can be improved?
7.	Environment	Overall, do you think implementation of the ePMA system has been positive or negative for you as a health professional? For patients? For the organisation as a whole?

3.5 Analysis and Significance of Data

Quantitative Data

It is suggested by Sauro (2011) that a minimum of 20 participants is necessary to produce a valid and comparable SUS score. However, this does not consider comparing results across a range of factors such as hospital sites, professions, and age groups. Obtaining a minimum of 20 participants from each profession or within each category group would enable effective comparisons.

To enhance understanding and ensure significance, descriptive statistics and parametric tests were undertaken on the results presenting the SUS score along with a standard confidence interval (CI) using z or t statistics (Orfanou *et al.*, 2015). In addition, comparing any differences in SUS scoring between professional groups and validating with p-values for significance. This can be achieved using either a paired t-test or analysis of variance. To establish a significant difference between groups, a p-value of <0.05 was required.

Confidence intervals demonstrate, with 95% confidence, the span of values likely to hold the true value of the percentage of the SUS score. In other words, if the sampling process were replicated numerous times, 95% of the resulting intervals should hold the true population mean. Closer range CIs are preferable as they provide a more precise interpretation of scores (Clark *et al.*, 2021).

Qualitative Data

Data pertaining to the fit between individuals, technology, and tasks in the evaluation was collected through questions added to the SUS questionnaire and through interviews. These additional questions inquired about tasks and perceptions of the technology in accomplishing these tasks, covering the attributes outlined in Table 3.2. Themes arising from the responses to these questions were identified and quantified. Subsequently, they may guide a select number of semi-structured interviews and further thematic analysis.

In terms of qualitative data's themes and significance, the evaluation aimed to achieve thematic saturation, indicating the point where no new themes emerge (Maramba *et al.*, 2019). This qualitative approach will contribute to the development of grounded theory, offering deeper insights into how the ePMA system influences workflow and communication in the hospital setting.

Furthermore, demographic information such as experience, and profession was gathered to facilitate an exploration of correlations between subsets of data and SUS scores. This approach aligns with the methodology endorsed by Bangor *et al.* (2008). Correlations between themes, categories, and responses to SUS-related questions were explored, supported by descriptive statistics, and subjected to significance testing.

3.6 Ethics

Prior to data collection, ethical and information governance issues required consideration, and ethical approval was obtained (Appendix 1,2,3,4,5). Ethics plays a pivotal role in any assessment of digital services, encompassing personal behaviour, conduct, and guiding principles (Séroussi *et al.*, 2020). It was imperative to deliberate on the human subjects involved in the evaluation, with a focus on protections such as privacy, risks, and inequities, while comprehending biases and influences.

Whether a study constitutes an evaluation or research can influence the level of scrutiny. Use of the NHS Health Research Authority Decision tool (Health Research Authority, 2020) classed the project as an service evaluation. Nonetheless, it essential to consider ethical subtleties and factors such as confidentiality, inclusivity, information provided to participants, and potential impacts or sensitivities resulting from the evaluation, including its implications for the involved organisation.

It is important that usability studies take into account diversity and inclusion, particularly with the potential for systems to become more intricate and feature-rich (Thomas and Campbell, 2020). It was not possible to actively seek out cultural backgrounds but parameters such as staff group and age banding aided in capturing a limited amount of these diverse elements. While broader research studies oriented toward patients may require additional consideration for literacy and language, it is noteworthy that NHS staff in Wales must be literate in English or Welsh, minimising literacy as a primary inclusivity concern for this evaluation.

However, attention needs to be given to the accessibility of data capture methods. Therefore, paper or alternative forms of questionnaire were available. Distribution among users being evaluated is acknowledged as a potential limitation when reporting results.

The nature of collecting additional demographic details underscores the importance of confidentiality and sensitivity in data collection and governance. In this regard, no patients participated, and staff were anonymised, ensuring that data cannot be reconstructed to identify individuals. To mitigate the risk of accidental disclosure of personally identifiable information, any transcriptions or quotes were anonymised, and subject details not retained. Once transcriptions were obtained from recordings, the recordings were deleted. Responses from questionnaires also underwent anonymisation.

It was crucial that all participants had a clear understanding of the evaluation, their involvement, and the implications of the results. Consequently, a participant information sheet was provided to all subjects, and verbal information given before any interviews (Appendix 6). This approach aimed to alleviate any potential unease respondents may have regarding confidentiality.

3.7 Bias

It is acknowledged that the evaluator, as an advocate for digital solutions, may possess bias. However, limitations prevented the engagement of a broader team or the use of independent agents. Consequently, it was imperative to exercise reflexivity. This involved enhancing the awareness of bias and helped control unwanted bias throughout the evaluation. Reflexivity entailed the researcher identifying personal biases and ethical considerations prior to and through the evaluation, comprehending one's position, and reflecting on thoughts and beliefs (Friedman *et al.*, 2022).

Being reflexive aids in mitigating prejudices that may exist for individuals with vested interests in the solutions under study, such as product designers or advocates (Adler-Milstein, 2019). The evaluator, being a digital champion and a pharmacist with extensive experience in the paper process, could have received anecdotal feedback from system users. Considering this, exercising reflexivity was essential, making sure to understand and then reflect. After reflecting on these biases and when deciding what was evaluated, the use of the SUS usability scoring tool (Brooke, 2013) and FITTE type lens (Prgomet *et al.*, 2019) helped contribute to limiting biases in the qualitative process, especially since the SUS questions were confined.

In addition, it was crucial to contemplate influences that could potentially impact participants' responses and, consequently, the way data is collected. These are considerations particularly relevant to interviews and questionnaires (Reid *et al.*, 2018). Caution was exercised regarding the potential for compulsion, especially in interview situations, to prevent biasing participant answers. Considering this, questions remained consistent, and were structured based on validated tools, and neither interviews nor questionnaires involved financial incentives.

In contemplation of participant selection, all were users of the system, at different stages of familiarity. Thus, thoughtful reflection and consideration were essential to ensure that responses encompassed "regular" users and champions, as well as those who may not have a favourable opinion of the system. Therefore, incorporating questions to gauge a user's "feelings" about the system was considered pivotal for interpreting and analysing potential participant bias.

Bias is a factor to consider when interpreting results, emphasising the importance of preventing the evaluator's personal interpretations from influencing the results. Consequently, both results and interpretations underwent validation and discussion with the evaluator's MSc supervisor.

4. Results

4.1 Introduction

There were 19 replies from ePMA users within Swansea Bay University Health Board (SBUHB), NHS Wales and a total of 3 follow-up interviews took place. There were responses from 7 nurses, 2 doctors, 7 pharmacists, 2 pharmacy technicians and 1 facilitator (Table 4.1), who either worked in one or more hospital site, with ages ranging between 21-59 years old and experience in their role ranging from 1 to more than 10 years.

A profession may have multiple roles and purposes to use the system therefore there were more purposes (roles) reported then overall respondents (Figure 4.1).

Table 4.1 Professions That Responded

Profession	Count
Nurse	7
Doctor	2
Pharmacist	7
Pharmacy Technician	2
Facilitator	1
Total	19

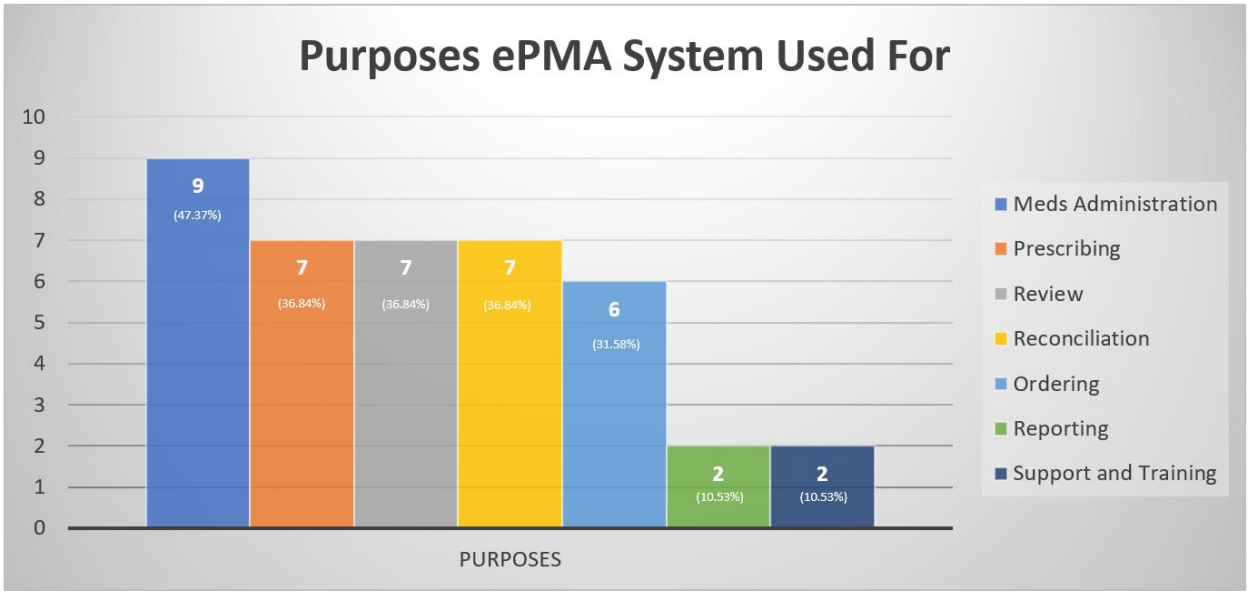

Figure 4.1 Main Purposes of ePMA system.

The breakdown of profession and the tasks that were completed per professional group is shown in Figure 4.2.

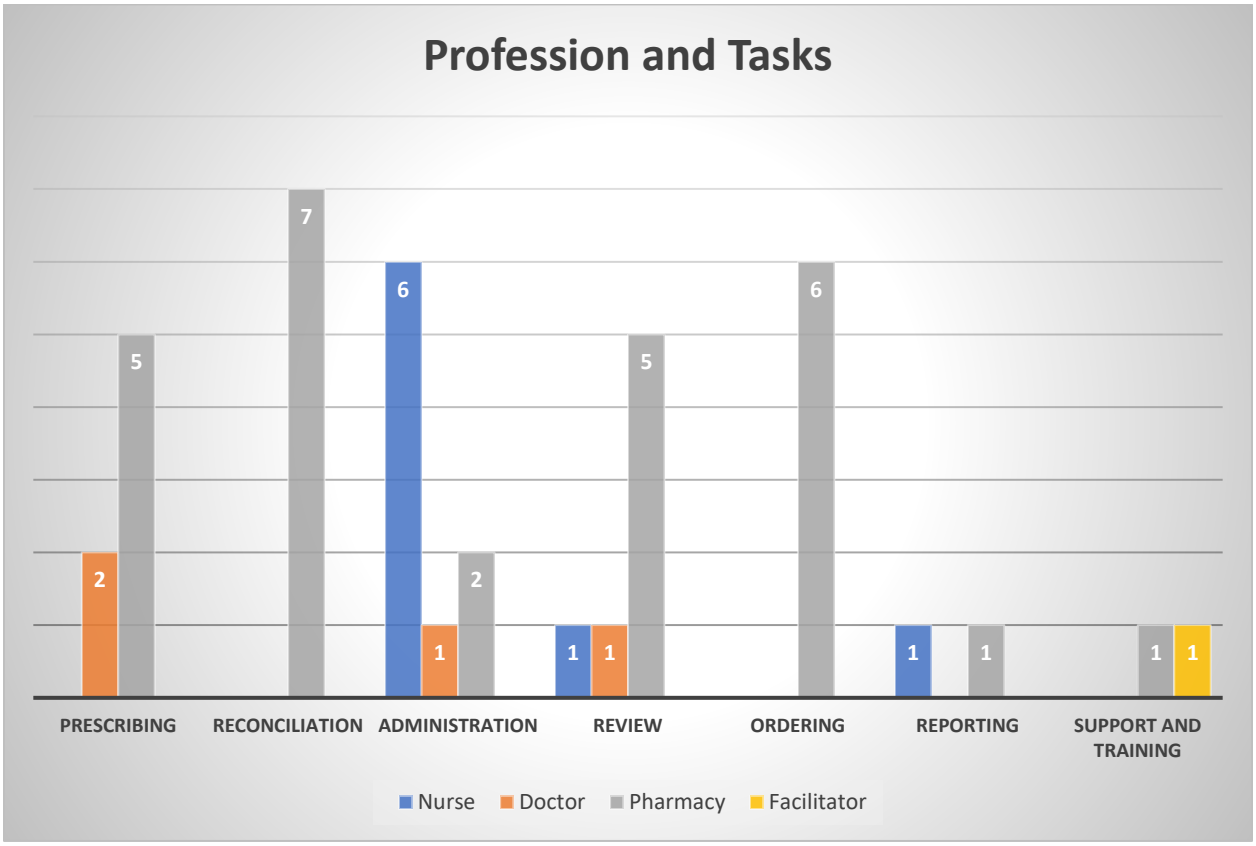

Figure 4.2 Breakdown of Profession and tasks each profession uses the system for (note: pharmacy – includes both pharmacists and pharmacy technicians)

4.2 Previous experience with ePMA

Responses relating to experience with ePMA systems showed that 12 (63%) of respondents had previous ePMA experience and 7 (37%) had none.

Previous experience was compared with one of the SUS questions around needing to learn before using the system (Table 4.2). This was also compared with how quickly they needed to learn (Table 4.3).

Table 4.2 Previous Experience (Yes or No) - with Likert Scale against SUS question statement "I needed to learn a lot of things before I could get going with this system."

Groups	**Count**	% Overall Frequency	% of Agreement in separate Yes/No
No – to Previous Experience and "I needed to learn a lot of things before I could get going with this system"	**12**	**63.16%**	
Strongly Agree	3	**15.79%**	25.00%
Agree	5	26.32%	41.67%
Neutral	2	10.53%	16.67%
Disagree	2	10.53%	16.67%
Strongly Disagree	0	0.00%	0.00%
Yes – to Previous Experience Previous Experience and "I needed to learn a lot of things before I could get going with this system"	**7**	**36.84%**	
Strongly Agree	3	15.79%	42.86%
Agree	1	5.26%	14.29%
Neutral	2	10.53%	28.57%
Disagree	1	5.26%	14.29%
Strongly Disagree	0	0.00%	0.00%

Table 4.3 Previous Experience (Yes or No) - with Likert Scale against SUS question statement "I learned to use the system very quickly".

Groups	**Count**	% Overall Frequency	% of Agreement in separate Yes/No
No - to Previous Experience and "I learned to use the system very quickly"	**12**	**63.16%**	
Strongly Agree	4	21.05%	33.33%
Agree	7	36.84%	**58.33%**
Neutral	1	5.26%	8.33%
Disagree	0	0.00%	0.00%
Strongly Disagree	0	0.00%	0.00%
Yes - to Previous Experience and "I learned to use the system very quickly"	**7**	**36.84%**	
Strongly Agree	2	10.53%	28.57%
Agree	4	21.05%	**57.14%**
Neutral	0	0.00%	0.00%
Disagree	1	5.26%	14.29%
Strongly Disagree	0	0.00%	0.00%

A comparison was also made between those with previous ePMA experience and the answer to the SUS question “I feel very confident using the system”, Table 4.4.

Table 4.4 Those with previous experience (Yes/No) and the answer given for SUS question 9, “I feel very confident using the system". Key - 1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. Strongly Agree

Groups	Count	% Overall Frequency	% of Agreement in separate Yes/No
No - to Previous Experience and “I feel very confident using the system”	**12**	**63.16%**	
Strongly Agree	4	21.05%	33.33%
Agree	5	26.32%	**41.67%**
Neutral	3	15.79%	25.00%
Disagree	0	0.00%	0.00%
Strongly Disagree	0	0.00%	0.00%
Yes - to Previous Experience and “I feel very confident using the system”	**7**	**36.84%**	
Strongly Agree	1	5.26%	14.29%
Agree	4	21.05%	**57.14%**
Neutral	1	5.26%	14.29%
Disagree	1	5.26%	14.29%
Strongly Disagree	0	0.00%	0.00%

4.3 System Usability Scale Results

The SUS ratings were computed, the average overall score was 67.5 with a lower 95% confidence interval of 57.96 and an upper 95% confidence interval of 77.04 and the median rating was 63.75 (IQR 58-81, the range of the middle half of the ratings). According to the classifications in Table 4.7 this can be interpreted as “Marginal” acceptability. The span of the 95% confidence interval straddles a few categories (see Figure 4.3). However, when considering Bangor *et al.* (2008) interpretation the range sits more in the “marginal” than within “acceptable”.

Table 4.5 shows the average and median results of each question and Figure 4.3 illustrates t-distribution, the mean and the position of the SUS rating on the acceptability scale.

Table 4.5 Individual Usability Scale Responses

No.	Question	Median (IQR)	Mean (SD)
1	I like using the system	4 (3.5-4)	3.79 (0.85)
2	I find the system unnecessarily complex	3 (2-3)	2.53 (1.02)
3	I think the system is easy to use	4 (3-4)	3.53 (1.17)
4	I need the support of a technical person to use the system	1 (1-2)	1.58 (0.69)
5	I find the various functions in the system are well integrated	3 (2-4)	3.21 (1.08)
6	I think there is too much inconsistency in the system	3 (1.5-3.5)	2.68 (1.16)
7	I learned to use the system very quickly	4 (4-5)	4.16 (0.76)
8	I find the system very cumbersome to use	3 (2-3.5)	2.63 (1.21)
9	I feel very confident using the system	4 (3.5-4.5)	3.95 (0.85)
10	I needed to learn a lot of things before I could get going with this system	2 (1-3)	2.21 (1.08)

first and third quartiles are shown in brackets next to the median for each question type and the mean is displayed with the standard deviation

The overall mean SUS score is displayed in Table 4.6, alongside the standard deviation, standard error and the consequent upper and lower confidence intervals. For both the individual and overall results the standard deviation indicates the level of variation. Thus, the smaller the standard deviation, the less variation in how far apart

the overall results are from one another, and similarly a larger value is indicative of increased variation in results. Therefore, it is important to look at the level of confidence in the results. Using a significance level (α) value of α=0.05 (for a confidence level of 95% (0.95) α=1-Confidence level) a confidence interval is used, which has been done for each SUS question but also for the overall result. Together with the degrees of freedom (df) = sample size (n)-1, the critical value of t = 2.11 was chosen from the table in Turney (2022). The confidence interval is calculated from the mean of the relevant question or overall result and from the relevant standard error (SE), i.e. Mean +- t value x SE.

Table 4.6 SUS Results with Confidence Intervals

Population	Mean (SD)	Standard Error	95% CI Lower*	95% CI Upper*
Overall SUS Score	67.50 (19.70)	4.52	57.96	77.04
I like using the system	3.79 (0.85)	0.20	3.38	4.20
I find the system unnecessarily complex	2.53 (1.02)	0.23	2.03	3.02
I think the system is easy to use	3.53 (1.17)	0.27	2.96	4.09
I need the support of a technical person to use the system	1.58 (0.69)	0.16	1.24	1.91
I find the various functions in the system are well integrated	3.21 (1.08)	0.25	2.69	3.74
I think there is too much inconsistency in the system	2.68 (1.16)	0.27	2.12	3.24
I learned to use the system very quickly	4.16 (0.76)	0.18	3.79	4.53
I find the system very cumbersome to use	2.63 (1.21)	0.28	2.05	3.22
I feel very confident using the system	3.95 (0.85)	0.19	3.54	4.36
I needed to learn a lot of things before I could get going with this system	2.21 (1.08)	0.30	1.58	2.84
*using a t value of (2.11) – chosen value in respect to sample size. Sample Size 19.				

The confidence intervals are a representation of the range that is likely to be a true representation of the score given, where there is a 95% confidence that this is true. Thus, in this case if the same scoring system were to be repeated, in the same circumstances, with no other changes to the system, 95% of the results would contain true representation of the wider population.

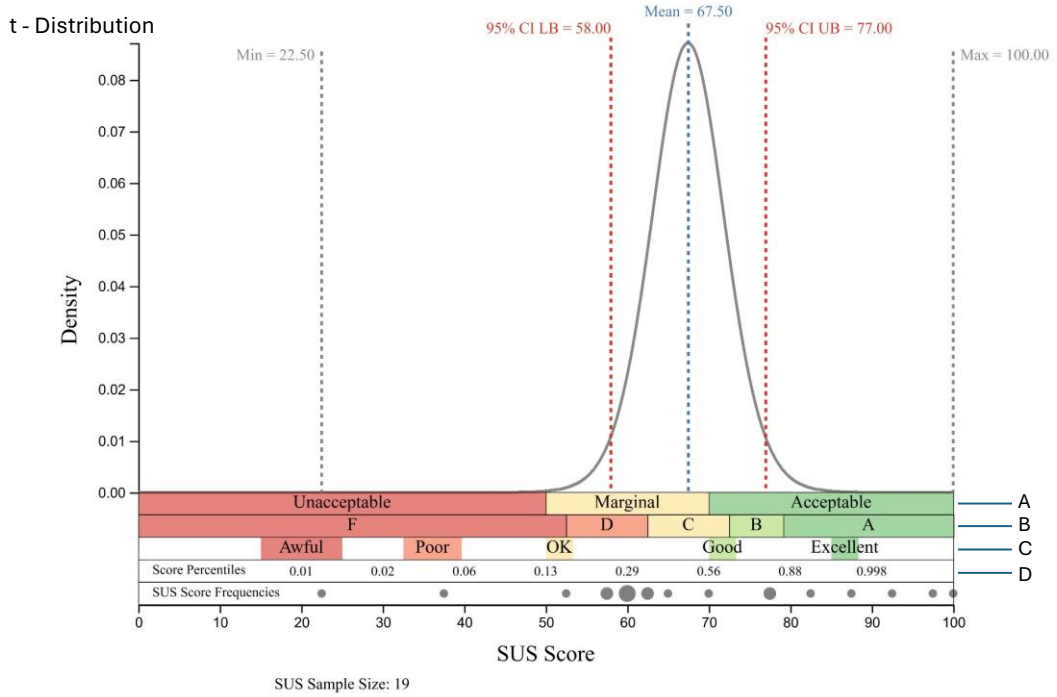

Figure 4.3 t – Distribution CI and Mean ePMA SUS Score. (key table 4.7)

Clark *et al.* (2021) suggested a statistical analysis approach and tool for SUS responses of less the 20 users. The tool was used to produce the frequency related t-distribution curve seen in Figure 4.3, which illustrates the sample mean and 95% confidence interval for the population mean SUS score. The confidence interval was estimated from the t distribution. The min and max bars show the range of the single-user SUS scores, and the circles in the bottom bar display the frequencies of the single-user SUS scores, larger circles denote a larger number of scores. Although the SUS score reports that the system would be considered "Marginal", it can be seen from Figure 4.3, that confidence interval crosses over Bangor *et al* (2008) classification of the scoring to the system being "Marginal" to "Acceptable", therefore it can't be concluded with 95% confidence that the system is either one or the other, but is clearly not deemed as "Unacceptable" and better then "OK" when using Bangor *et al* (2009) classification.

Table 4.7 SUS Score classifications key

Key – For Figure 10	**Description** (*from categories used in Clark et al. (2021)'s tool*)
A	This row shows the categories identified by Bangor *et al.* (2008): Unacceptable Marginal Acceptable
B	Grading letters that are suggested by Sauro and Lewis (2016)(p204): A B C D F
C	These are the ratings assigned by Bangor *et al.* (2009): Awful Poor OK Good Excellent
D	These are the percentile scores indicated by Sauro and Lewis (2016) (p203)

Analysis undertaken by Clark *et al.* (2021), suggested that t-distribution and width of the confidence interval band for smaller SUS sample sizes (e.g. n < 11), is at risk of being skewed or overlapping descriptive parameters labels and proposed a Bayesian analysis, using population data from previously published SUS studies. Although the projects sample size is >11 it is <20, so for further clarity the results of this project are presented, using the proposed differing probability analysis, in Figure 4.4. It clearly identifies a similar confidence interval that encroaches less on the acceptable side than the t-distribution. Although the band is tighter, it is not possible to classify with a confidence of 95% that the results truly represent one classification over another, but that they clearly sit above "unacceptable".

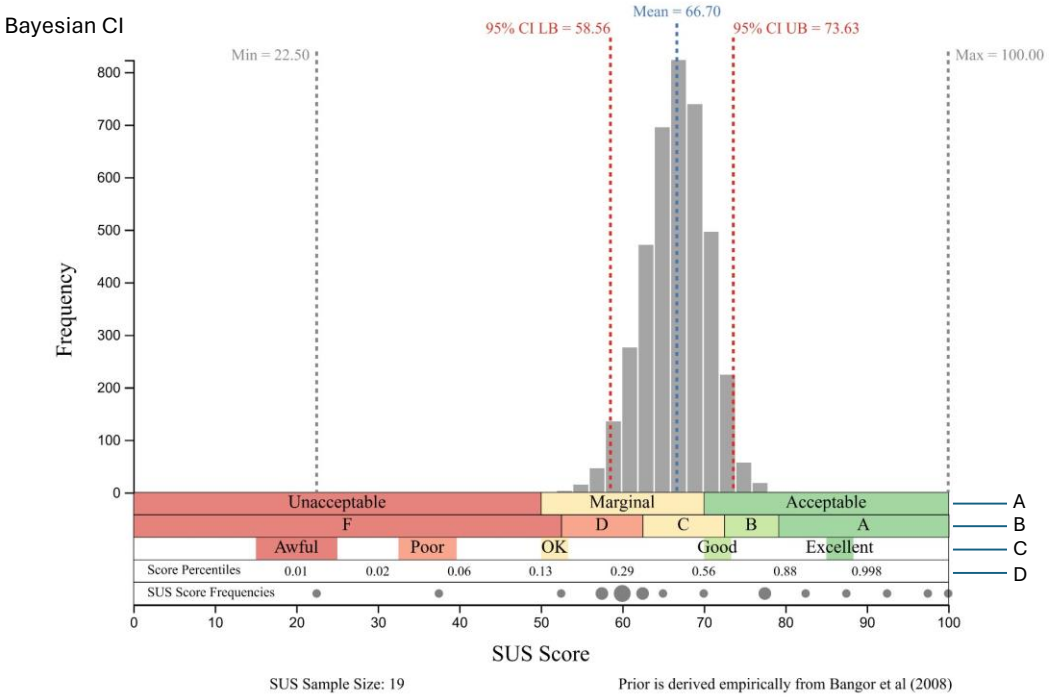

Figure 4.4 Bayesian CI and Mean ePMA SUS Score

Examining the SUS Scores further between those who had previous ePMA experience and those who had not had previous ePMA experience, using a two sample t-test revealed that there was no statistically significant difference between the scores from these two groups, however this is inconclusive due to the numbers in the groups being underpowered.

Table 4.8,Table 4.9). The observed difference between the two groups was -8.53, with a standard deviation difference of 10.22, and a 95% confidence interval for the difference of lower -32.08 and upper of 15.03, the test statistic of *t* =-0.83 and a p value of 0.43, means that this comparison is may not be significant, however it was not powered enough to be conclusive.

Table 4.8 Individual SUS Scores from those with previous ePMA experience compared to those without.

Individual SUS Scores - Previous Experience	
Yes (n=6)	No (n=13)
65	60
87.5	57.5
62.5	92.5
22.5	52.5
70	82.5
62.5	77.5
	60
	97.5
	60
	57.5
	37.5
	100
	77.5

Table 4.9 Descriptive Statistics for comparing the SUS scores of those with previous experience vs those without

Group	N	Mean	StDev	SE Mean
Yes – Previous Experience	6	61.667	21.37	8.7243
No – Previous Experience	13	70.192	19.161	5.3143

When comparing the SUS results between the professions and undertaking a one way ANOVA analysis it was evident that statistically meaningful results could not be drawn and the null hypothesis that all the groups are equal could not be rejected (Table 4.10). The F=1.33, with a p-value of 0.2939, using α of 0.05 significance level means that there is not enough evidence to say that the populations can be treated as not equal (the alternative hypothesis) and therefore the usability results cannot be meaningfully and significantly used to make comparisons between the professions. In summary the results would not be able to confidently say that doctors found the system less usable than nurses or pharmacists. Likewise, the results could not determine whether nurses found the system more usable than pharmacists and doctors. However, the overall score from all users does have confidence.

Table 4.10 Descriptive Statistics comparing professions SUS scores.

Individual SUS Scores - Profession			
	Doctor (n=2)	Nurse (n=7)	Pharmacy (n=9)
	37.5	60	65
	62.5	52.5	57.5
		97.5	82.5
		60	77.5
		57.5	60
		87.5	77.5
		100	62.5
			22.5
			70
Mean	50	73.571	63.889
$\sum_i X_{ij}^2$	5312.5	40425	39262.5
St. Dev.	17.678	20.558	17.771
Sum of Squares	312.5	2535.714	2526.389

Note: a lower score indicating a user believes the system to be less easy to use and a higher score very easy

4.4 Questions related to Fit between Individual, Task and Technology

Responses related to purpose and individual roles.

These responses are shown in Table 4.11.

Table 4.11 Responses for medicines related tasks related to individual roles.

	I feel that the ePMA system allows me to do the medicines related tasks required for my role for the purpose of:							Proportion of Scale Response for Tasks	
Response:	Prescribing	Med's Administration	Reconciliation	Ordering	Review	Other Categories	Total	%	%
Strongly Agree	2	4	0	1	1	1	9	19.15%	57.45%
Agree	4	2	3	1	6	2	18	38.30%	
Neutral	1	2	3	5	3	3	17	36.17%	36.17%
Disagree	0	1	0	1	0	0	2	4.26%	6.38%
Strongly Disagree	0	0	1	0	0	0	1	2.13%	

Individual tasks are reported in further detail below.

Prescribing Role

Responses related to prescribing roles are show in Table 4.12 and Table 4.13

Table 4.12 PRESCRIBING – "I feel that the ePMA system allows me to do the medicines related tasks required for my role as a prescriber".

	PRESCRIBING - I feel that the ePMA system allows me to do the medicines related tasks required for my role as a prescriber (response from 37% of users/n=7)
Strongly Agree	2
Agree	4
Neutral	1
Disagree	0
Strongly Disagree	0

Table 4.13 PRESCRIBING - Describe why ePMA system allows you to do prescribing tasks required for your role.

PRESCRIBING - I feel that the ePMA system allows me to do the medicines related tasks required for my role as a prescriber. Please describe why you feel the ePMA system allows you to do the prescribing tasks required for your role.	
Strongly agree	*The system has templates of protocols that when chosen calculate the bespoke doses for the patient, rounds and bands doses as needed, choose correct infusion fluid & volume, includes all supportive care as well as SACT.*
Strongly agree	*It allows me to prescribe medications. While there are some disadvantages, chiefly in terms of **time and flexibility**, there are some other advantages in terms of **legibility, safety etc**.*
Agree	*Able to add the medications but I have not put strongly agree as I believe there could be improved functionality such as with doses ranges and antibiotic prescribing*
Agree	*It's straightforward. Has handy protocols for complex prescriptions (e.g. clozapine titration)*
Agree	*Because it is an eprescribing system.*

Agree	*The system allows for general prescribing of standard common medications. The system is less able to prescribe complex regimes.*

Medicines Administration Role

Responses related to medicines administration roles are shown in Table 4.14. and Table 4.15

Table 4.14 MEDS ADMIN - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines administration.

	MEDS ADMIN - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines administration (47% users/n=9)
Strongly Agree	4
Agree	2
Neutral	2
Disagree	1
Strongly Disagree	0

Table 4.15 MEDS ADMIN - Please describe why you feel the ePMA system does or doesn't allow you to do the medicines administration tasks required for your role.

MEDS ADMIN - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines administration. Please describe why you feel the ePMA system does or does not allow you to do the medicines administration tasks required for your role	
Strongly agree	*easier and **more accurate** than paper chart*
Strongly agree	***Safer** system* *No ambiguity*
Strongly agree	*All prescribed medication can be accessed this way except intravenous fluids*
Strongly agree	*Administration is the best functionality of the system. It allows for the **accurate** recording of doses of medication with a full audit trail. The only thing it does not easily allow for is to defer/ delay a dose and document this.*
Agree	*Because it is designed for this. It is **not simple** however as I prescribe and administer at the same time sometime and this is **not at all obvious how to do**.*
Neutral	*Needs more **integration** - IVs and variable rate insulins etc*

Disagree	*I am sometimes unable to administer medications as the doctors do not prescribe them and it is stressing me out as I am constantly chasing them*

Medicines Reconciliation Role

Responses related to medicine reconciliation are shown in Table 4.16 and Table 4.17.

Table 4.16 RECONCILIATION - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines reconciliation.

	RECONCILIATION - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines reconciliation. (37% users/n=7)
Strongly Agree	0
Agree	3
Neutral	3
Disagree	0
Strongly Disagree	1

Table 4.17 RECONCILIATION - Please describe why you feel the ePMA system does or doesn't allow you to do the medicines reconciliation tasks required for your role.

RECONCILIATION - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines reconciliation. Please describe why you feel the ePMA system does or does not allow you to do the medicines reconciliation tasks required for your role. (see for glossary of terms)	
Agree	*Verify medications* *Flag DHx (drug history) medications* *Record Meds Rec in a note* *Add notes to specific drugs*
Agree	*It allows me to flag medications which I reconcile as the patient having taking on admission. However**, I wish this appeared on the inpatient Rx (prescription) chart** so you don't have to click on each individual medication to see if it has been flagged or not.* *It allows me to add a medicines reconciliation note.*
Neutral	*Meds rec (reconciliation) could be recorded in the meds rec functionality within the system but it is not currently up to par with **ways of working and is not flexible enough**. Meds rec has to be documented within a free text note that is **not integrated** to anything else on the drug chart. In the Health Board **functionality has been lost** from the ability to import meds from the GP record into the drug history.*

	The system does allow but it is not intuitive and **requires a lot of jumping around various screens**
Strongly disagree	*It would be helpful to be able to **import information from other systems** i.e.. WCP, DAL'S,CHEMOCARE. We have to leave a lot of notes for Dr etc to review which aren't always actioned. **Needs two screens** to navigate effectively to look at meds rec (reconciliation) and chart.*

Medicines Ordering Role

Responses in relation to medicines ordering role are shown in Table 4.18 and Table 4.19.

Table 4.18 ORDERING - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines ordering.

	ORDERING - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines ordering (32% users/n=7)
Strongly Agree	1
Agree	1
Neutral	5
Disagree	1
Strongly Disagree	0

Table 4.19 ORDERING - Please describe why you feel the ePMA system does or does not allow you to do the ordering medicines tasks required for your role.

ORDERING - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines ordering. Please describe why you feel the ePMA system does or does not allow you to do the ordering medicines tasks required for your role.	
Strongly agree	***Easy*** *to contact pharmacy with requests.*
Agree	*The system allows for meds to be ordered for individual patients but is linked to the pharmacy stock control system in such a way that it has to be additionally* ***manipulated adding time*** *to the ordering process.*
Neutral	*Ideally we would be able to order straight from ePMA rather than a separate program.*
Neutral	*Its relatively* ***straight forward*** *to order medication. If stock lists are up to date, non stock items are ordered automatically unfortunately patients admitted to **Hospital A** first, the stock list from the admitted ward stays attached to the patient so we cannot rely on the automatic function once transferred to **Hospital B**.*
Neutral	*This is not a straight forward process due to needing to log in to the old "**" system to print orders.* ***Nothing is easy*** *with this system*
Neutral	*I find this task* ***over complicated****. You have to click through about 4 tabs before you can order something, when you do you still have to* ***go into another system*** *to print the order off. Also, if I ask for x3 of a medication to be ordered for example, when*

	the order goes through it only ever states 1 order (this could be 1 original pack or 1 box of 28 tablets for example).
Disagree	***Slightly complicated****/long-winded ordering process.*
*** indicates - Identifiable information has been removed*	

Medicines Review Role

Responses related to the medicine review role are shown in Table 4.20 and Table 4.21.

Table 4.20 MEDICINES REVIEW - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines review.

	REVIEW - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines review (32% users/n=7)
Strongly Agree	1
Agree	6
Neutral	3
Disagree	0
Strongly Disagree	0

Table 4.21 MEDICINES REVIEW - Please describe why you feel the ePMA system does or doesn't allow you to do the medicines review tasks required for your role.

REVIEW - I feel that the ePMA system allows me to do the medicines related tasks required for my role for medicines review. Please describe why you feel the ePMA system does or does not allow you to do the medicines review tasks required for your role.	
Strongly agree	*Easy when checking datix /med errors/ missing medication to use MAP report and see who is on which medication*
Agree	*The tasks are listed but there **could be improved functionality with regards to antibiotic prescribing** and other flags to task prioritisation and improved visuals*
Agree	*I am able to **check the medications quickly** as long as they are prescribed*
Agree	***You can see** the list of currently **prescribed medications** and separately a list of **discontinued medications**. **You can see** what has been reviewed by a pharmacist. It is difficult to see what doses a patient has had over a period of time without **additional manipulation**.*
Agree	*Again, it requires **jumping around screens** to get all the information required*
Agree	*Takes a bit of adjusting to in relation to paper charts, reviewing PRNs etc.*

Neutral	*I can easily and clearly review medications and add an under review icon as needed.* ***I wish however that there was a function which enabled the inpatient drug chart and the notes page to pop up side by side each other. When I have two screens this isn't a problem as I can copy the note onto a word document and put on my 2nd screen, however when on a laptop with only 1 small screen for example, when I'm up on the ward it makes this task more complicated, timely and unnecessarily difficult****.*
Neutral	*I think it* ***works well*** *for me to review medications but* ***I don't think it provides*** *a strong enough prompt to prescribers when I flag medications for review. Perhaps when the prompts appear, the prescriber must have to resolve the issue before continuing to use the drug chart.*

Other roles

Responses in relation to other roles are shown in Table 4.22 and Table 4.23.

Table 4.22 OTHER - I feel that the ePMA system allows me to do the medicines related tasks required for my role for what you stated as "other".

	OTHER - I feel that the ePMA system allows me to do the medicines related tasks required for my role for what you stated as "other" (26% users/n=5)
Strongly Agree	1
Agree	2
Neutral	3
Disagree	0
Strongly Disagree	0

Table 4.23 OTHER - Please describe why you feel the ePMA system does or doesn't allow you to do the "other" tasks required for your role.

OTHER - I feel that the ePMA system allows me to do the medicines related tasks required for my role for what you stated as "other". Please describe why you feel the ePMA system does or does not allow you to do the "other" tasks required for your role.	
Strongly agree	*Auditing of drug errors and medication utilising MAP and then edge search facility for the drug - so **much time saved** from manual check of all medications on the ward.*
Agree	*For **training purposes** it is a relatively simple system but does require lots of clicks. Improved functionality for example in insulin prescribing and with infusions would make it a lot better. As currently having to use mixed methods (paper and electronic).*
Agree	*The system allows me to offer support to users and **training** for new users.*
Neutral	*Again, there is a **need to use more than one system to complete the task***

Acceptability of the tasks imposed by the system.

Responses in relation to acceptability of the system related tasks are shown in Table 4.24.

Table 4.24 Responses for acceptability of tasks imposed by technology.

	I feel that these tasks that using the ePMA system requires from me are acceptable	Percentage	
Strongly Agree	2	10.53%	57.89%
Agree	9	47.37%	
Neutral	6	31.58%	31.58%
Disagree	2	10.53%	10.53%
Strongly Disagree	0	0.00%	

Out of the 19 respondents some provided a narrative (n=12, 63%) as further information for this question (Table 4.25).

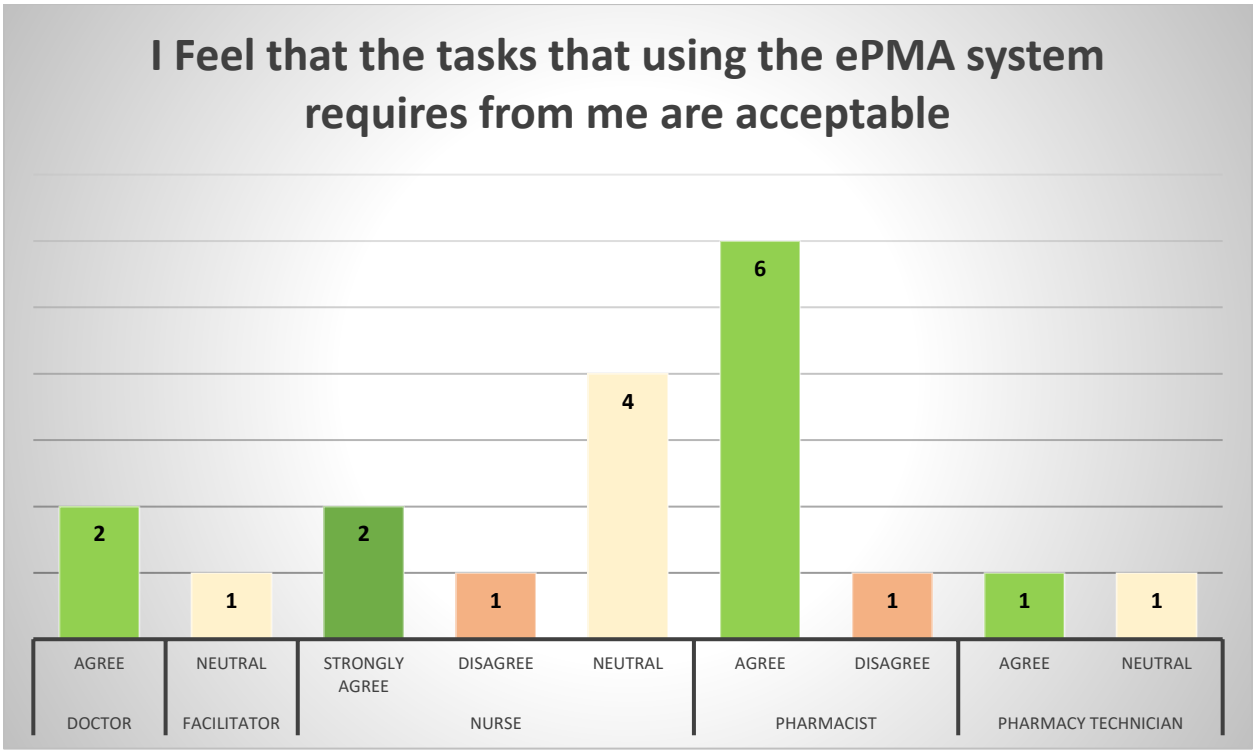

Figure 4.5 Acceptability of ePMA tasks against user profession.

Figure 4.5 represents the overall recorded response in terms of individual professions and whether they found tasks that the ePMA system required of them acceptable.

Table 4.25 Responses relating to the statement "I feel that the tasks that using the ePMA system requires from me are acceptable".

I feel that these tasks that using the ePMA system requires from me are acceptable (How the system affects how you do the task)	**Description as to why?**	**Recorded tasks that user has indicated they use the ePMA system for:**
Strongly agree	*It doesn't ask us to do anything out of our responsibility.*	Medicines Administration
Strongly agree	***No change in time** needed to do medication round.*	Medicines Administration
Agree	*Able to **create reports** that **help with workload** such as the **prioritisation report**.*	Training; Reporting; Medicines Prescribing
Agree	*They **enable outstanding tasks** to be clearly seen.*	Medicines Prescribing; Medicines Administration; Medicines Reconciliation; Medicines Ordering
Agree	*Improved **safety checks** and **governance, treatment** won't be made unless all steps are completed.*	Medicines Prescribing
Agree	*VTE scoring should be done for every patient.*	Medicines Prescribing; Medicines Administration
Agree	***Ensure medication safety***	Medicines Reconciliation; Medicines Ordering; Medicines Review

Agree	*Only because **I am a long time EPMA user** and used to adapting ways of working. No system is perfect and whichever EPMA system is in use ways of working will have to change.*	Medicines Review; Medicines Ordering; Medicines Reconciliation; Medicines Administration; Medicines Prescribing
Agree	*They help **ensure the tasks** I am required to do in my role are completed.*	Medicines Reconciliation; Medicines Review; Medicines Ordering;
Neutral	*I understand why they are there, it is just **more time consuming and not so visible** at a first glance.*	Medicines Reconciliation; Medicines Ordering
Disagree	*I feel that it is **taking me longer to sort out medications** for our patients* in * *(*identifiable information removed*) ** , our **staffing level** does not always give us room to "faf" about.	Medicines Administration;
Disagree	*There is a **demand for additional screens**, the system should be designed to allow you to work with one screen*	Medicines Reconciliation; Medicines Review; Discharges;
** - indicates identifiable information has been removed		

Has the system changed the way of working?

Responses demonstrated 14 (74%) users thought the system had changed the way they worked and 5 (26%) did not think this. Comments are shown in Table 4.26.

Table 4.26 Comments related to describing how respondents felt ePMA has changed the way they work (Only shows Yes or No answers where a comment was given)

Has the ePMA system changed the way you work?	Please describe how you feel it has changed the way you work.
Yes	*I cover a low secure ward which is off-site and visit once a week but am able to make changes from **(another site).*
Yes	*It **allows sharing of information across the SWW region** as cancer is managed by both two **Health Boards (HB) jointly (some patients are under **one HB consultants or attend here for specialist treatment despite living in the **another HB region). Prescribing can be done remotely so there is no need to ask random Drs to make changes to scripts if the specialist team aren't on site, improved cross cover for medics, access on call, acute oncology triage line.* *It has allowed us to **standardise practice with agreed templates**. It allows us to "police" prescribing by restricting regimens to their funded indications and evidence based use. Junior prescribers cannot go outside agreed protocols but senior consultants have the option to do so for unusual cases. Doses are calculated, modified and carried over automatically to avoid calculation or transcription errors. **The data is extremely useful for service improvement, clinical audit and governance**.*
Yes	*We **can run reports** now instead of having to look at every chart every day just in case of an amendment/new item etc.* *We aren't on the ward as much which is possibly not a good thing.*
Yes	*I am just getting used to the system but I think it is good as the doctors can **prescribe remotely**. My issue is the constant chasing for the doctors to prescribe which causes delays and takes me away from my patient...*
Yes	*It has slowed down my anaesthetic time and distracts me from giving an anaesthetic!*
Yes	***I no longer have to search for drug charts***
Yes	***more accurate and legible** than paper charts*
Yes	*Unfortunately it has led to **less time spent on the wards** however I believe it does **reduce the time taken** to complete work.*
Yes	*Pros - ability to **remote review of drug chart**, accurate audit trail of prescriber details* *Cons - as a pharmacist it has **increased time to complete meds rec** compared to the All Wales drug chart documentation*
Yes	***Less patient contact*** ***Unable to create the same clear picture of the patients medication***

	journey as you had on a paper chart ***slowed down*** *all parts of the process*
Yes	*It has made completing the previous task on the whole easier, however it has meant I* ***spend less time on the ward*** *and more time sedentary which I dislike.*
** - indicates identifiable information has been removed	

Has the system introduced new tasks?

Responses demonstrated 11 (58%) users felt the system had introduced new tasks and 8 (43%) did not. Comments are shown in Table 4.27

Table 4.27 Comments related to the describing new tasks that ePMA system may have introduce.

Do you feel the ePMA system has introduced new tasks (tasks that you would not have done before the ePMA system was introduced)	Can you describe the tasks it has introduced (things that you would not have done before the ePMA system, e.g. finding a computer)?
Yes	*New task - More readily data available (more audit work) and live reporting*
Yes	*Checking antibiotic review report for patients due for antibiotic reviews* *Checking Warfarin report for patients with an outstanding Warfarin dose* *Checking prioritisation report for pharmacy related tasks* *Checking discharge complete report for any discharges completed by prescribers that will need to be processed by pharmacy*
Yes	*not as straight forward and easy to see at a glance changes that have been made to the chart.* ***We had all the information we needed on the chart without having to look through different areas/tabs****.*
Yes	***Finding a computer*** *if the app is not on our PC at the bedside. Having to find trainers for doctors who are not up and running on the system,* ***takes me away from patient care*** *as I am chasing doctors to prescribe,* ***having to find a second person to sign in opioids each time we give it...***
Yes	*If a patient comes to theatre with no VTE assessment done (this is common as patients are admitted on day of surgery) then* ***I can't prescribe anything until this is done****. This role should be done by surgical team on ward pre-op but is now often being done by me.*

Yes	***Finding a computer**, one with a battery life long enough for my needs* *Changing the way meds rec is documented to **fit within the limits of the system***
Yes	***laptop essential*** *more than one screen is pretty much essential if covering a whole ward* *need to record stock levels of drugs somewhere other than the drug chart*
Yes	***Using a computer.*** *It helps enforce tasks which were sometimes missed prior to the ePMA system. For example, completing allergy status.*
Yes	*Syringe driver prescribing is more time consuming*

Responses in relation to whether users thought the system had removed tasks are shown in Figure 4.6 and Table 4.28.

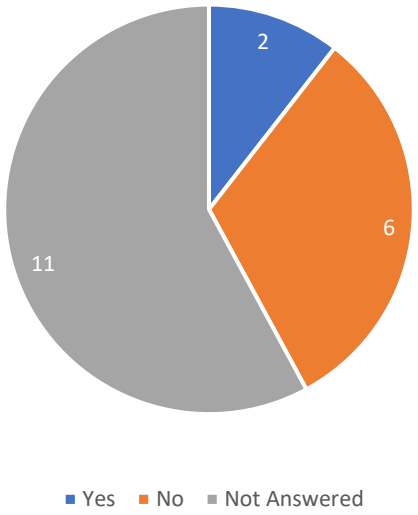

Figure 4.6 Do you feel the ePMA system has removed tasks (tasks that you would have done before the ePMA system was introduced) (Yes 10% n=2, No 32% n=6, Not Answered 58% n=11)

Table 4.28 Comments related to whether the user feels the ePMA system has removed tasks.

Do you feel the ePMA system has removed tasks (tasks that you would have done before the ePMA system was introduced)	Can you explain what tasks you no longer have to do (e.g. finding the paper chart)?
Yes	***re-writing drug charts**, extremely beneficial!*
Yes	***Checking blood results** (automatically pulled into system, checked against the agreed range and flagged ok/not ok.* ***Filling out a list of bloods** and go ahead/delayed to fax to pharmacy.* ***Looking for paper notes**, everything needed is within the system, includes some notes.* ***Faxing old paper scripts** to other units when patients move, the record moves with them.* ***Dose banding and rounding**, **correcting fluids**, etc.*

Introduction of new tasks vs finding the system complex

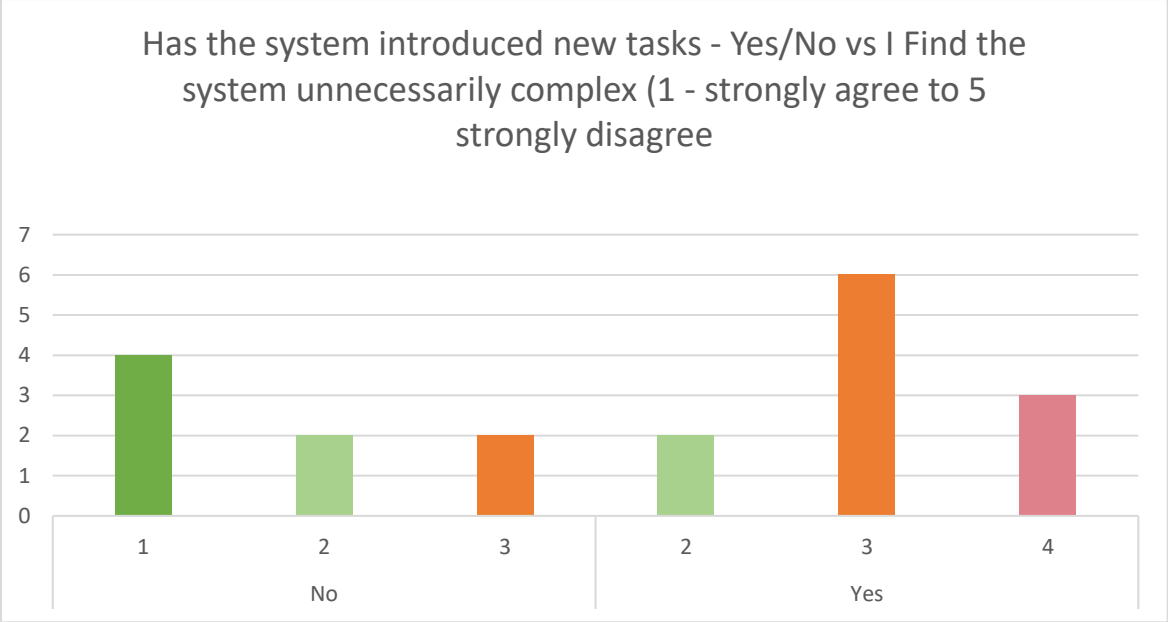

Figure 4.7 Those who either said "Yes" or "No" to has the system introduced new tasks and the answer given for SUS question 2. I find the system unnecessarily complex. Key - 1. Strongly Agree, 2. Agree, 3. Neutral, 4. Disagree, 5. Strongly Disagree

4.5 Thematic FITTE Analysis of results

In addition to questionnaire data, a total of 3 users – 2 pharmacists, 1 nurse - were interviewed using the questions detailed (Appendix 9), for approximately 8-10 minutes. Both information from narrative aspects of the questionnaire and the interviews was used to form themes and these were categorised into the dimensions of the FITTE framework (Table 4.29).

Table 4.29 Themes and challenges coded into FITT framework dimensions.

FITTE Dimensions	Themes	Identified /Mentions	Positive Aspects	Mentions
Fit between individual and technology	**Problems with usability, technical issues and functionality that is missing**	5	**Availability of system.**	2
	Difficulty changing work practices and processes, resistance	3		
	Negative experience	3		
	Shortage of training	2		
	Shortage of technical support	1		
	Availability of technology - needing to find a computer or suitable device	4		
	Additional work due to not enough interoperability, needing to use other systems, or screens or paper	10	**Allows Information sharing**	1
	Not a good fit with working practices - i.e. not all working practices covered, loss of functionality, time away from patient. Workflow.	8	**Works well**	3
Fit between the role and task	**Not simple or increased complexity**	5		
	Increased time: Mandatory fields and system navigation. Medicines Reconciliation	8	**Reduced time**: e.g. Finding charts, prioritising patients.	5
	Not easy to use	2	**Easy, able to do something.**	7
	Finding a computer	4	**Safer - more accurate, legible**	7
Fit between Environment/Organisation and technology	**Not enough knowledge** about the potential functionality	2	**Standardisation of practice**	1
	Limited resources	1		

4.6 Conclusion

The results demonstrated an overall SUS score of 67.5 with a lower 95% confidence interval of 57.96 and an upper 95% confidence interval of 77.04, marginal but bordering on acceptable.

The identified themes and their relationship to FITTE are shown in (Table 4.29), the main themes relating to workarounds and interoperability.

5. Discussion

5.1 Introduction

This study achieved the overall objective of assessing the usability of an ePMA system across an acute health economy in a Wales Health Board. Multidisciplinary feedback was achieved, and SUS scores calculated. In addition, thematic analysis from questionnaire responses were supplemented by interviews using the FITTE framework.

A number of relevant observations about system, environment, training and experience were identified and could either be explored further or interventions could be made.

5.2 Professions and Use of the system

The results demonstrated that each profession uses the system for specific purposes with overlap between profession and purpose (Figure 4.2). Doctors reported using the ePMA system for prescribing, medicines administration, and medicines review. Nurses mainly use the system for medicines administration, followed by medicines review and reporting. Pharmacy recorded using the system for many purposes, including prescribing, medicines reconciliation, medicines review, medicines administration, ordering, reporting, and support and training. Medicines reconciliation and ordering were only observed from pharmacy and medicines administration was largely a task carried out by nursing. However, more responses may have seen nurses prescribing and ordering medicines.

Among the professions pharmacy seem to use the ePMA system for all its intended purposes. Whilst each profession has a predominant purpose, there is a commonality in pharmacy that spans functionality, especially medicine reconciliation, review and ordering.

When looking at the professions usability scores there were differences in the overall means between the main three groups, doctors, nursing and pharmacy (Table 4.10), possibly indicating that doctors found the ePMA system less easy to use and on the margins of being unacceptable. Nurses found the system much more acceptable and pharmacy found the system within the marginally acceptable levels of usability. However, statistical comparison between these groups was inconclusive, due to low responses. In addition, different professions used different aspects of the system making direct comparison difficult.

5.3 Previous Experience

The results demonstrated that having previous experience with the ePMA system does not guarantee confidence with using a new system and the learning curve seems similar for both experienced and new users. There was no definitive difference between the groups with previous experience and those without. Indeed, one of the users with previous experience indicated that they did not agree that they were confident using the system, no such indication was given from those without experience. This is something

that should be considered, especially when both those with and without prior experience answered, “I learned to use the system very quickly,” very similarly.

The analysis shows there were no obvious differences in usability amongst those familiar with an ePMA system and those new to ePMA. Both groups found the tasks they needed "easy" to complete. Digital literacy is likely to be more important, as a beneficial factor, than specific knowledge of a particular system (Devine *et al.*, 2014) (Cornford *et al.*, 2009).

5.4 System Usability Scale analysis

The overall results from the SUS give a score of 67.5, with a lower 95% Confidence interval of 57.96 and an upper of 77.04. Based on previous studies typical scores fall between 68 to 70.5, with anything above 68 being considered above average and anything below, being considered below average. Thus, the ease of use of the ePMA system could be considered below average in comparison to other systems.

When considering user acceptance, this score indicates that the usability of the ePMA system could be interpreted in the upper end of marginally acceptable (using Bangor *et al.* 2008). When considering the adjectives description and interpretation (using Bangor *et al*. 2009), the system is between “OK” and “Good”, graded as “C”, and between the 0.29 and 0.56 score percentiles (using Sauro and Lewis, 2016) meaning this also compares as below average system for ease of use when compared to other systems.

It is important to consider when interpreting a SUS score, especially when using the adjective method, that if something is considered as “OK” or “Good”, that this does not necessarily mean that no improvements are needed (Bangor *et al.*, 2009) nor that something is wholly satisfactory. This is one of the reasons why it is key to use more than one method when making this interpretation. The results determine with confidence that the usability of the system is marginally acceptable but falls below average in comparison with other systems. This means that there is room for improvement and the system could be made better. This would be good justification for further analysis and user study. In addition, the results from the perspective of the dimensions of the FITTE, discussed further in this, should help to provide further insight.

5.5 Feedback related to tasks and acceptability.

Each participant was able to include comments on the reason why they had selected a choice from their statements of agreement, around system purposes and tasks (Table 4.24, Table 4.25). Alongside individual responses, thematic analysis was undertaken on both the responses of the survey and from the interviews (Table 4.29), which allowed for further insight when looking at the FITTE model.

Prescribing

Prescribing functionality, used by 37% of the respondents, consists of the tasks essential for safely and effectively prescribing with clear instruction (GMC, 2021).

Whilst 86% affirmed that the system supports this role, citing clear reasons for doing so, they also suggested improvements were made for dose ranges, antibiotic prescribing and complex regimes. Time constraints within this area and inflexibility were noted due to mandatory field and system navigation. Interestingly, a paper by Shemilt *et al.* (2017), a study of ePMA systems in NHS England, recognised an increase in time taken for prescribing and administration, but noted time-savings such as those related to reporting and audit, *e.g.* task list prioritisation. It is also necessary to have complete information to ensure other related functionality such as decision support can work as intended. Interestingly the ability of reporting to help streamline work via task lists was not a theme noted in the response to the survey or the interviews. These aspects may become more apparent as the system matures.

Medicines administration

Medicines Administration, functionality used by 37% of the respondents, consists of the tasks necessary to ensure that a patient receives their prescribed medication correctly and safely. This workflow is a core aspect of ePMA systems and is linked to demonstrable benefits and significant reductions in medication administration errors (Franklin *et al.*, 2010). The level of impact among ePMA systems, can be variable and the effects of system and configuration on these errors is not well investigated (Gates *et al.*, 2020).

Feedback in Table 4.15, reveals difficulties in delaying or recording deferred doses and in simultaneous prescribing and administration and concurs with Baysari *et al.* (2018) findings. Some users expressed workflow frustrations particularly around medications not being prescribed, suggesting that more integration is needed. Complex prescriptions such as those for intravenous injections and variable rate insulins exacerbated these issues. Some ePMA systems deal with complex infusions and variable doses better than others. In addition, it was noted in a response and setting (theatre) that medicines administration recording was double accounted in two different systems leading to delays (ePMA and TOMS). Baysari *et al.* (2018) indicates that in these situations' workarounds tend to develop as well as adding the possibility of delayed medication. This is contrary to Van Wilder *et al.* (2016) view that whilst they saw an increase in documentation noted they saw no overall delay in medicine administration rounds which was in an inpatient setting. Thus, when considering further study, it would be important to examine whether there are relationships between these settings, the way users use the system and the relationship to patient outcomes (Baysari *et al.*, 2018).

Medicines Reconciliation and Workflow

Medicines reconciliation, in conjunction with interoperability between systems is well recognised as an important process helping to improve safety at transitions of care (NICE, 2015; Redmond *et al.*, 2018; World Health Organization, 2019; Healthcare Safety Investigation Branch, 2019). Pharmacy professionals were the only users to use

the ePMA system for medicines reconciliation. Challenges were fed back (Table 4.16) around system inflexibility and the need for multiple steps, clicks or switching between screens to undertake reconciliation properly and thus causing an increase in time taken, in findings similar to Adams et al. (2021), Iqbal et al. (2021) and Baysari *et al.* (2018). Thus, workflow disruption and increase in the time taken for tasks like medicines reconciliation had an apparent impact on pharmacy staff.

Clinical workflow is a key attribute towards safe, efficient healthcare delivery (Cain and Haque, 2008). The order and manner in which tasks are carried out is highly important to clinical workflow and any adaptations easily disturb these processes (Zheng *et al.*, 2015). Thus, changes to the situational context, cognitive tasks and the way a workflow must be undertaken will become more apparent in HIT implementation if not done well. Users commented that functionality in terms of how they were working before had been lost with regards to being able to import medicines from GP records to create a medicines history. This may reflect adequacy – or otherwise – of the "current state" and "future state" process maps collected during the business change process (Williams *et al.*, 2022). In addition, one user reported that although there was functionality that indicated the status of medicines reconciliation, they wished this information were present in the context of the prescription chart because they had to otherwise click on each individual medicine to see this information as they undertook each step of their work process.

The concerns reported from users seem to concur with a commonality in literature and evidence, which highlight that such problems can branch from an array of issues, including poor usability, poor integration and dependency between systems, and how well the system is embedded into organisational and sociotechnical behaviours (Zheng *et al.*, 2020). User feedback offered suggestions around improvements highlighting the ability and need to re-use information and integrate appropriately.

In terms of interoperability and integration standards, a study by Elliott *et al.* (2023), identified that in NHS England, the number of patients experiencing an error at transitions of care was estimated to be 370,000 per year and that by introducing digital information standards these figures can be reduced leading to a 40% reduction in the numbers affected and significant reduction in associated costs (Table 5.1). This highlights the importance of medicines reconciliation as a process and the need to be able to see and integrate data in an interoperable and re-usable manner.

Table 5.1 Harm from Errors at Transitions of Care Figures from Elliot et al (2023), with proportional estimate for Wales - not accounting for local variances.

	No Digital Interoperable Standards		With Standards	
Transitions of Care	England	Estimated Adjustment for Wales	England	Estimated Adjustment for Wales
Incidents	370000	20084	220000	11942
Experiencing Harm	31000	1683	19000	1031
Additional Stays	36000	1954	22000	1194
Cost (£)	17,400,000	944493	10800000	586237
Deaths	45	2	25	1
Populations	57,110,000	3100000		

Medicines Review

Medicines review (used by 37% respondents) relates to the tasks and workflow for reviewing medications, ensuring that it is still appropriate to be prescribed and/or given, checking whether circumstances have changed and whether the medication has been prescribed safely. It often leads to changes in medication regimes and can reduce harm (Stephens, 2011; Onatade *et al.*, 2016) (Royal Pharmaceutical Society, 2013). In sentiments that echo the concerns related to reconciliation functionality, the responses to medicines review (Table 4.21), indicate that challenges exist with the systems ease of use, particularly the need to navigate multiple screens to gather information. There was also a view that notes suggested that medication management should all be on one system, implying it currently required more than one. This was more of an issue where users undertaking this role only had one screen.

Therefore, this identifies that one hardware and software configuration and setup may not be suitable for all uses and scenarios. There are further views from other feedback that also highlights an importance on the availability of the right devices (Table 4.27) and that finding an appropriate and working device introduces a new task, in itself. The number of screens, for example, was not an issue reported in any of the medicines administration feedback. This also seems to indicate that the impact of the ePMA system itself may impose a change in usual practice, an observation seen by Onatade *et al.* (2016), in relation to clinical pharmacy in secondary care.

Around the same functionality, there were also improvement suggestions made as to how the system might be able to prompt a prescriber. However, including prompts without full workflow analysis and user research may be detrimental. Alert fatigue and excess pop up messages are well-known causes of user frustration, leading to many being ignored and therefore imposing a safety risk (Marcilly *et al.*, 2023).

Medicines Ordering

Medicines ordering is a hospital workflow involving requesting medication from the pharmacy for inpatients or for take home supplies. Feedback, mainly from pharmacists (Table 4.18 and Table 4.19), suggested that there may be challenges with the ordering process citing issues in relation to workarounds and it being time-consuming and complicated due to poor integration with the pharmacy stock control system.

Marcilly *et al.* (2023) and Elliott *et al.* (2023) support these findings, identifying that integration issues can have a detrimental impact on pharmacist workload, patient outcomes and cost efficiency. In Marcilly ***et al.'s*** (2023) study, examples of having to copy and paste data was cited, and more time was lost then the system saved. The inefficiencies overshadowed the systems usefulness. This emphasises the need for improved interoperability in medicines supply process.

Other aspects of the system

The ePMA system is used for reporting and training, with a nurse and pharmacist each reporting using it for audits, error checks and workload management. The importance of being able to undertake data analysis was reported, especially longer term prescribing trends and relating these to patient outcomes. This has been demonstrated against data in a systemic anti-cancer therapy (SACT) system with ePMA functionality, in use in NHS Wales (Kahan *et al.*, 2024).

Using the system for the purposes of training was reported as being straightforward, however users noted an increase in the number of clicks and still requiring the need for both paper and digital methods for complex regimes, functionality that does not yet exist in this system. This further ratifies previous cross professional statements around workflow, and difficulties around more complicated medicines regimes which remain a key issue.

An interview participant reported that they observed familiarity with the system improving over time, despite some ongoing challenges such as dose timing restrictions, but recognised they were there for safety.

Acceptability

Feedback relating to system acceptability was mixed (Table 4.24 and Figure 4.5), 58% found it acceptable whilst 11% did not. Those that found it acceptable cited no significant changes in their workflow or responsibilities. Further feedback (Table 4.25), identified that some users reported an increase in time for tasks such as sorting

medication, medicines reconciliation and medicines ordering, exacerbated by staffing levels.

When responding to acceptability, sentiments were repeated regarding additional screens, integration and workload. Users highlighted usability issues around workflow prioritisation and processes like medicines reconciliation, review, ordering and discharges. However, some affirmations reported that the system allowed creating reports for prioritisation of tasks, improving safety and governance, although it was evident that these were not integrated into every workflow. Notably, one of the comments relating to an increase in time was from a user who was based in a more complex area with staffing issues. Thus, any additional workload or "clicks" will increase cognitive load in an already pressured environment.

System design has the potential to impact and increase workload (Marcilly *et al.*, 2023), cognitively and in terms of time. In one study improvements and careful consideration around systematically designing order sets, albeit constrained by the design of the underlying system, did not improve time or the amount of work (mouse clicks) required in terms of the task (Avansino and Leu, 2012), and thus may be indicative of flaws in the wider application user interface and workflow design.

Workflow interactions and support are usability issues identified in medication error reports in a study by Adams *et al.* (2021) and is an area that should be prioritised for further investigation and optimisation. Feedback from the SBUHB users highlighted certain areas and workflow processes, in particular medicines reconciliation, medicines review and ordering (including discharges) but was also reported by one user relating to medicines administration and having to "faf" (a colloquialism meaning - something that takes a lot of effort or causes slight problems) (Cambridge Free English Dictionary and Thesaurus, 2024) (Table 4.25).

Sittig *et al.* (2020) points out that when an application is being used correctly and it does not support the existing workflows or aims of the user in achieving their intended purpose then these need to be evaluated and adjusted to support safe and effective care. In addition, using technology safely, to improve safety itself is a key opportunity to improve healthcare overall (Singh and Sittig, 2016).

If design and integration should match the way in which the work task is performed (Marcilly *et al.*, 2023) then reliable evidence from usability studies should play a key part in designing and optimising ePMA workflows around key tasks such as prescribing, administration, reconciliation and ordering.

New and Removed Tasks

There were mixed perceptions among the responses regarding new or removed tasks (workflow changes). Whilst 58% users felt new tasks were introduced, 32% indicated that no tasks had been removed. Digitising and transforming from a paper process has enabled more readily available data access, enabling work prioritisation and improved

compliance with best practice such as ensuring allergy checking and venous thromboembolism (VTE) assessments were completed, the mandating of which was viewed both positively and negatively (Table 4.25 and Table 4.27).

Some new and unique tasks have been introduced such as locating usable computers, however this replaces time spent locating and managing paper medication charts.

5.6 Analysis against FITTE and Recommended Interventions

The results were used to identify key areas where there are issues and suggest appropriate interventions that may help improve them. It is evident that interventions are necessary to enhance alignment between individuals, tasks, technology and environment. Figure 5.1, provides a high level overview of this analysis.

Table 5.2 identifies whether the FITT barriers recognised by Zhai et al. (2022) are evident.

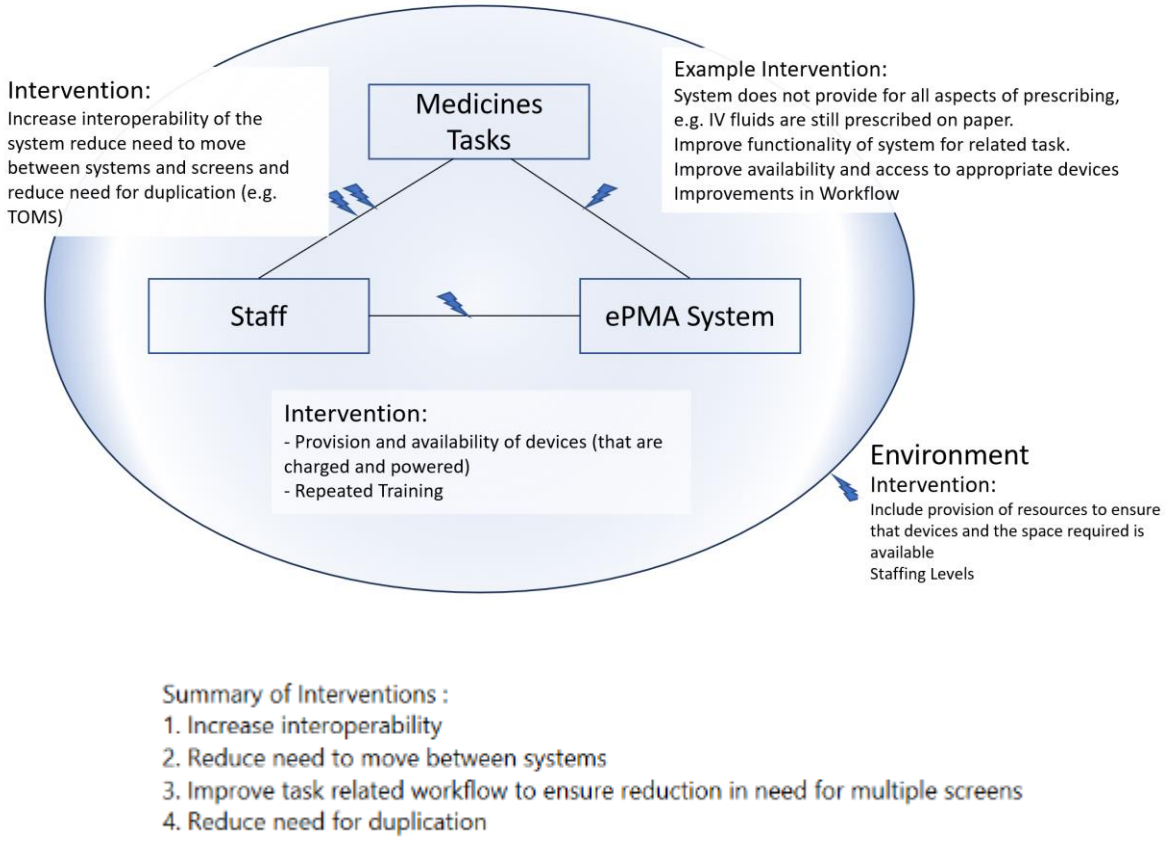

Figure 5.1 An analysis of the ePMA system using FITT-E Diagram identifying where interventions could be made. One arrow suggests minor problems with the fit and two arrows suggest larger problems.

Fit between individuals and task.

It is apparent that users identified a lack of integration between systems and available data, whether from using paper or HIT. This was especially apparent for medicines reconciliation, discharge and medicines ordering. It was also apparent that it was not easy to delay or defer a dose and record this, along with it not being obvious how to prescribe and administer medications at the same time.

Appropriate interventions might be to target training, but also to integrate and re-use existing data or workflows within context. For example, being able to re-utilise medicines history and reconciliation data without re-transcribing would help reduce duplication and use of more than one system.

Issues with workflow and interoperability, and the need to switch screens was a frequent theme that occurred from all responses, with n=10 (53%) mentions around interoperability and n=8 (42%) around workflow. Further exploration, workshops and discussion with stakeholders may help address these issues.

Fit between individuals and technology.

Previous experience with ePMA systems did not negate the need for users having to learn and should not lead to an assumption of intuitive competence when using another system. Whilst previous knowledge is beneficial there are many systems, that are configured and used differently across different settings (Mozaffar *et al.*, 2014; Mozaffar *et al.*, 2017; Pontefract *et al.*, 2018). It was apparent that not all functionality was supported by the technology, or it was complicated to undertake some tasks, such as complex regimes, dose ranges and IV fluid prescribing. These have been previously reported to the supplier, but further exploration is still warranted.

Fit between task and technology.

The results identified that there were issues in terms of lack of functionality or complexity and number of steps required to undertake a task. In some cases, a lack of available or appropriate devices contributed to this frustration. There was also negativity around mandated functionality, and concerns around “flicking” between screens, consequently causing prescribing delays. Whilst mandated functions are placed to support safety, the way in which they are incorporated into workflow needs careful consideration.

Feedback relating to devices highlights the importance of the right device being available for the right situation, maintained and usable. In some contexts, there is a desire to have everything that is needed to fulfil certain tasks available on one screen e.g. bedside, or treatment rooms, whereas more than one screen might be appropriate away from the patient. Differences in HIT effectiveness between settings and the physical environment has been observed in the way that decision support is utilised; Bell *et al.* (2019) reports prompts being more likely to be ignored whilst a prescriber is

on a ward round than if they were at a desk. This is a concept happening that could be explored further.

At each of the medication process stages, there is a possibility for error, indeed this has been evidenced in literature with errors occurring at ordering, review, administration and prescribing stages (Adams *et al.*, 2021). Thus, focussing interventions on these aspects could help to reduce such errors. Evidently there has been a reduction in errors since system implementation (SBUHB, 2022), however the relationship to usability and whether there is more to do could be explored further.

Environment

There was little feedback in relation to organisational and environmental factors, however, the provision of devices and the number of interdependent systems is an aspect influenced by the wider organisation. Also, the provision of policies such as mandatory allergy recording, VTE risk assessments, and witnessing, affect how the system is used and perceived. There is evidence that making these mandatory has increased the amount that are completed (SBUHB, 2022), but this has not been triangulated against outcomes.

Thus, there are aspects relating to all the FITTE domains which may influence user satisfaction but where a balance of risk/benefits needs to be justified. Therefore, there might be several interventions that could be made to address these aspects. A summary can be seen in Figure 5.1.

Table 5.2 FITTE Comparison to Zhai et al. (2022) FITT barriers.

FITTE Barriers	Fit between attributes within the FITTE framework	Reported/Details
Interface design issues	*Task and Technology*	*Seen – need to use more the one screen during a workflow. Stages in workflow incongruent*
Information linkage issues	*Task and Technology*	*Seen – Interoperability and data integration reported issue*
Acceptance of the system	*Individual and Technology*	*Mixed views*
Inter-professional barriers	*Not matched* ***(Environment)***	*Not reported*
Standards of practice (lacking)	*Individual and Task,* ***Environment***	*Standardisation of practice was not reported as lacking.* *However, system enforcement of mandatory policy was seen as both a benefit but also something that interrupted workflow. Clearly this has an overall benefit for the patient but further discussion and understanding is needed in terms of the risk and benefits and "pinch points". Allergy recording, VTE risk assessments and witnessing all increased since ePMA implementation but this has not triangulated against patient outcomes.*
Increase workload	*Individual and Task*	*Reported – especially when this went hand in hand with a lack of data integration and duplication of data entry.* *e.g. seen in at least one case for medicines administration, but more so for medicines reconciliation, review, medicines ordering and the discharge processes.*

Interoperability

Interoperability and integration can be seen as a key area where interventions to improve usability and safety could be made. Improving interoperability can help improve communication of clinical information and workflows, and have an impact on the way data is able to be utilised both for research and improving value, outcomes and safety (Lehne *et al.*, 2019; Elliott *et al.*, 2023).

Usability Challenges – Were they seen in the project results?

The usability challenges were summarised in view of the challenges identified by (Pruitt *et al.*, 2022; Iqbal *et al.*, 2021; Adams *et al.*, 2021) (Table 5.3)

Table 5.3 Usability Challenges vs those identified by Pruitt et al., (2022); Iqbal et al., (2021) and Adams et al., (2021)

Usability Challenge	Detail	Theme	Evidenced in Project Results?
Alerting	Issues related to excessive or inappropriate alerts.	Refers to alerts popping up or happening at inappropriate times, or for inappropriate issue, that are either excessive or not needed. This can lead to alert fatigue and ignoring of alerts. Right alert is needed at the right time in the right context.	Not reported Nothing was reported in terms of decision support alerts. (Mandatory process not called out as alerts – but could be investigated further)
Availability of Information	The clinician cannot access clinically relevant information because it is not available	This refers to availability within the system where it is needed to undertake a task.	Reported – Reconciliation, Additional notes next to medicines
Data Entry	The clinician cannot enter data easily or at all because the clinical workflow does not allow the clinician to enter the information they want.	Also including the need to enter the same data in a different system.	Reported – No place to put additional notes next to medicine. (is in separate section out of context)
Display/Visual Clutter	The information displayed is confusing, messy, or inaccurate, making it hard to understand the information.	Refers to the way things look on screen and also how relates to workflow.	Reported – The need for multiple screens or to be able to show everything that is needed within the workflow.
Interoperability	The health IT component does not communicate well with other parts of the same health IT component or with different health IT components, preventing the exchange of information.	Transfer of data between care settings	Reported – This was evidenced for medicine reconciliation, medicines review and medicines ordering. Duplicating data entry on another system.
System automation and defaults	The health IT component automatically fills in or defaults to information that the clinician does not expect, predict, or see.	e.g. Automatic dosing schedule	No issues reported
Workflow Support	The health IT component does not support the workflow because it does not match the clinical goal of the end user.		Reported Pharmacy Workflow - Medicines Reconciliation Workflow - Medicines Review Workflow - Medicines Ordering - Mandatory Fields - Duplication

5.7 Limitations

The project combined both a quantitative and qualitative techniques using a questionnaire and interviews. Maramba *et al.* (2019) indicates that it is also useful to consider additional approaches and evaluation techniques, however, further research is needed to understand which techniques might be more suitable for different applications. The approach was justified by a literature review and sound methodology however the dissemination was limited due to lack of physical presence and reliance on digital communication.

The number of responses to the questionnaire were very limited and were received or undertaken digitally. It is recognised that there may be a large degree of digital exclusion, even though paper was offered, the invite was digital in the first place. There was also a reluctance to put any posters up on wards, due to infection control policy, which may have helped sign post the evaluation. Thus, there may be a degree of skew in the response. This has been recognised in the statistical analysis of the SUS score but is difficult to adjust for in the qualitative responses.

With 19 responses, the use of the statistical methods identified by Clarke *et al.* (2021) enabled a significance overall SUS score, however it was unable to make meaningful differentiation between groups. A response rate of 20 per group would have enabled significant comparisons to be made between SUS scores and whether there was any obvious difference between professions, recognising that this would most likely be due to functionality specific to the profession rather than any constraint of a particular group.

The small numbers may have also limited analysis of users and professions doing specific tasks; however, the primary analysis was based on overall usability.

5.8 Further research

These results are comparable to other publications on HIT usability.

The project captures the state of play at this point in the ePMA system implementation in SBUHB and it would be useful to repeat in the future and undertake at multiple time points following implementation, such as demonstrated by Baysari *et al.* (2018). In addition, the results will be fed back to the ePMA programme in SBUHB, with further discussion on the issues and interventions identified and how they will be taken forward, if not already being addressed.

It would be good to understand the error rates and patient outcomes and see if these are correlated to any links between usability and related fit between tasks, individual and the technology, within the hospital setting such as identified by Adams *et al.* (2021). Indeed, the study by Adams *et al.* (2021) identified that usability plays a significant role in HIT associated medication errors and unfortunately, many of these errors directly impact patients. Thus, this highlights that prioritising and addressing usability issues related to data entry, workflow support and alerting may help to reduce medication

errors. This is an important follow up consideration especially as workflow was identified as a key concern from this project.

The effect of usability challenges and impact on medication errors is clearly an avenue for further research (Adams *et al.*, 2021; Iqbal *et al.*, 2021; Pruitt *et al.*, 2022; Howe *et al.*, 2018). Whilst there were no immediate concerns relating to safety, the project did not specifically look for them. Therefore, combining this usability study with a study of medication errors and any apparent contribution would be a useful piece of work (Adams *et al.*, 2021). In addition, it may be useful to compare SUS scores against other ePMA systems.

Whilst there were no concerns mentioned in relation to safety, overall, 37% (n=7) respondents considered the system safer than paper mainly because of better legibility and less change of prescribing something twice.

The marginal SUS usability score is indicative of the challenges of getting definitive results from mixed method research and strategies to increase numbers of respondents needs to be at the core of future evaluation and research.

6. Conclusion

This project aimed to assess the usability of the ePMA system, implemented at Swansea Bay University Health Board (SBUHB), and was able to show the usability of the system as marginally acceptable and in need of improvement. The SUS score used enable comparison with similar systems (Brooke, 1996; Bloom *et al.*, 2021) and potentially supports repeated assessment after configuration changes or upgrades. In addition, the FITTE analysis highlighted interventions that could be made Figure 6.1:

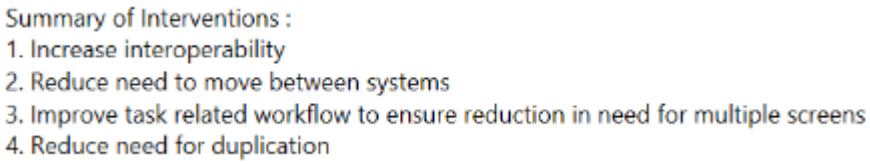

Figure 6.1 Summary of FITTE interventions.

The usability of the ePMA system was evaluated through two complementary approaches: The use of the SUS score combined with a qualitative questionnaire and interviews to support a FITTE analysis. The FITTE analysis enabled a view from the perspective of the relationships between the user, the technology and the tasks they need to undertake within their professional environment (Table 6.1). This enabled more nuanced understanding in terms of the technological alignment and relationship to the fit between the individual, task, technology and environment.

The responses enabled an overall SUS score of 67.5 with a lower 95% confidence interval of 57.96 and an upper 95% confidence interval of 77.04, classifying the system as marginal in terms of acceptance and below average in comparison to other systems. The project was able to provide statistical confidence in the SUS score but was inconclusive in terms of any correlations between the individual aspects of the SUS score questions and relevant groups e.g. profession. When examined qualitatively there were clear emerging themes that linked and that would be useful for further research. For example, there was an unexpected observation between the number of users who had previous experience with an ePMA system and how well they scored against needing training or having to learn a lot of new things before using the system. This aspect highlighted that previous experience cannot be taken for granted when introducing a new ePMA system.

Table 6.1 Summary of main themes identified in relation to FITTE analysis.

FITTE Dimensions	Issues/Themes Identified (n= number of times identified)
Fit between individual and technology	Problems with usability, technical issues and functionality that is missing (n-5)
	Difficulty changing work practices and processes, resistance (n=3)
	Negative experiences noted. (n=3)
	Shortage of training for specific aspects e.g. IV (n=2)
	Shortage of technical support (n=1)
	Availability of technology - needing to find a computer or suitable device (n=4)
	Additional work due to not enough interoperability, needing to use other systems, or screens or paper (n=10)
	Not a good fit with working practices - i.e. not all working practices covered, loss of functionality, time away from patient. Workflow. (n=8)
Fit between the role and task	Not simple or increased complexity (n=5)
	Increased time taken (n=8) to undertake processes like medicines reconciliation, completing mandatory fields and system navigation.
	Not easy to use (n=2)
	Needing to find a computer (n=4)
Fit between Environment/Organisation and technology	Not enough knowledge about the potential functionality (n=2)
	Limited resources (n=1)

Users still need to be trained regarding specific functionality, policies and configuration of the system in relation to the health board and the difference between systems and releases. Between health organisations, there are many different ePMA systems available with many different releases, variations and configurations of those systems (Mozaffar *et al.*, 2014; Pontefract *et al.*, 2018).

Workflow and the tasks associated with undertaking professional roles such as medicines administration need to be fully considered, especially in cases where double accounting - recording the same thing in two different places - takes place. Whilst this project did not probe for workarounds, Baysari *et al.* (2018) have demonstrated the

potential for complex workflows requiring duplication leading to concerning workarounds, concurring with Adams *et al.* (2021). This is a key area for further investigation.

It was clear from the FITTE analysis and responses, that where multiple pieces of information were required in a workflow, or where something was recorded in more than one place, that a lack of integration between data sources caused a negative sentiment, especially when time critical. Thus, further work around both data integration and workflow integration will be valuable to help improve overall systems acceptability and ease of use. Interoperability has been identified as particularly important around transitions of care and for digital medicine use cases, both in terms of safety and cost (Elliott *et al.*, 2023) and overall workflow integration identified as a key factor in improving safety and acceptability (Adams *et al.*, 2021; Awad *et al.*, 2023; Baysari *et al.*, 2018; Devine *et al.*, 2014; Lehne *et al.*, 2019). This is apparent in the results of this project, especially around acceptability and FITTE.

Although the SUS scores varied between professional group, supposedly indicating that doctors may have found the system less easy to use, and nursing finding the system easy to use, the number of responses per group was not powered enough to make conclusions, a consideration for future research. However, any differences may be another indicator of the associations between workflow and the number of different tasks associated with the user role.

The FITTE analysis identified that there were issues in relation to workflow and the tasks that users needed to undertake, exaggerated by lack of integration with data from other systems, but also due to complex or missing functionality, for example around intravenous fluid prescribing and administration. In concordance with evidence seen in literature, devices and the way that they are used, dependent on the task, was a key attribute in relation to user acceptability. There were frustrations over appropriate devices not being available or not fully charged.

Interventions that were suggested by users included improved interoperability between systems, reducing the need to move between different applications and screens, but also to reduce any situations where data entry is duplicated.

Improving functionality of the system in relation to tasks such as prescribing IV fluids, dose-ranges and the complexity around being able to prescribe and administer at the same time would also be beneficial. Thus, there may be a need for workflow analysis to further clarify the specifics around functionality and understand the details of what has or has not been raised with the supplier.

With regards to the environment, there were clear concerns around the staffing numbers and increased pressures from the perceived time required to use the ePMA system or complete the associated professional tasks, particularly around medicines reconciliation but also around documentation, e.g. duplication. This may be alleviated

by improving integration, interoperability and the general functionality to be able to easily reuse relevant data within the system.

It is reassuring that the majority (58%, n=11) of respondents indicated that the system had changed the way they worked for the better, a crucial element that transformative HIT should aspire to (Cornford *et al.*, 2009).

In terms of the next steps, if revision and development of the ePMA system is possible, then attention should be focused on the way information is retrieved, used and repurposed. Again, this encompasses the appropriate use of interoperability, for which many open standards have been developed and indeed Welsh Government have advised the mandatory inclusion of specific standards for digital medicines for new and revised systems (Welsh Government, 2022). However, interoperability is only useful if the data is usable without adding additional steps such as transcription (Elliott *et al.*, 2023; Lehne *et al.*, 2019). Incorporating standardised data and terminology such as the full relational aspect of the dictionary of medicines and devices (dm+d)(Abbott, 2017), SNOMED clinical terminology (SNOMED International., 2022) and utilising open messaging standards such as the Health Level Seven, Fast Healthcare Interoperability Resources (HL7-FHIR) (Health Level Seven International, 2019) will help to make this possible. It is important that all systems involved in the digital medicines process also utilise the same standards.

Thus, usability and interoperability go hand in hand. Indeed, a lot of work has gone into consideration of user interfaces and functional design and many themes have been repeated in literature (Adams *et al.*, 2021; Iqbal *et al.*, 2021; Pruitt *et al.*, 2022).

In this project, the usability challenges of information availability, data entry, interoperability and workflow were all reported, however there were no reports around visual clutter, alerts, or system automation or defaults. Thus, the ePMA system appears to be on the margins of user acceptability but requires further research and improvements around interoperability, availability of information in context, data entry and workflow.

The findings of this project will be fed back to the SBUHB ePMA team, complete with the recommendations on how these could be taken forward, for example by facilitation of meetings between stakeholders to explore themes further.

7. References

Abbott, S. (2017) *NHS dictionary of medicines and devices Requirement Specification for SCCI0052*. Available at: http://www.nationalarchives.gov.uk/doc/open-government-licence/ (Accessed: 08/10/2023).

Adams, K. T., Pruitt, Z., Kazi, S., Hettinger, A. Z., Howe, J. L., Fong, A. and Ratwani, R. M. (2021) *Identifying Health Information Technology Usability Issues Contributing to Medication Errors Across Medication Process Stages*. Available at: www.journalpatientsafety.com (Accessed: 17/11/2023).

Adler-Milstein, J. (2019) 'Health informatics and health services research: reflections on their convergence', *Journal of the American Medical Informatics Association,* 26(10), pp. 903-904. DOI: 10.1093/jamia/ocz080 Available at: https://doi.org/10.1093/jamia/ocz080 (Accessed: 5/5/2023).

Akhloufi, H., Verhaegh, S. J. C., Jaspers, M. W. M., Melles, D. C., Van Der Sijs, H. and Verbon, A. (2019) 'A usability study to improve a clinical decision support system for the prescription of antibiotic drugs', *PLOS ONE,* 14(9), pp. e0223073. DOI: 10.1371/journal.pone.0223073 Available at: https://dx.doi.org/10.1371/journal.pone.0223073 (Accessed: 08/10/2023).

Ali, S. B., Romero, J., Morrison, K., Hafeez, B. and Ancker, J. S. (2018) 'Focus Section Health IT Usability: Applying a Task-Technology Fit Model to Adapt an Electronic Patient Portal for Patient Work', *Appl Clin Inform,* 9(1), pp. 174-184. DOI: 10.1055/s-0038-1632396 Available at: https://www.ncbi.nlm.nih.gov/pubmed/29539648 (Accessed: 08/10/2023).

Ammenwerth, E., Iller, C. and Mahler, C. (2006) 'IT-adoption and the interaction of task, technology and individuals: a fit framework and a case study', *BMC Medical Informatics and Decision Making,* 6(1). DOI: 10.1186/1472-6947-6-3 Available at: https://dx.doi.org/10.1186/1472-6947-6-3 (Accessed: 5/5/2023).

Avansino, J. and Leu, M. G. (2012) 'Effects of CPOE on Provider Cognitive Workload: A Randomized Crossover Trial', *Pediatrics,* 130(3), pp. e547-e552. DOI: 10.1542/peds.2011-3408 Available at: https://doi.org/10.1542/peds.2011-3408 (Accessed: 17/11/2023).

Awad, S., Amon, K., Baillie, A., Loveday, T. and Baysari, M. T. (2023) 'Human factors and safety analysis methods used in the design and redesign of electronic medication management systems: A systematic review', *Int J Med Inform,* 172, pp. 105017. DOI: 10.1016/j.ijmedinf.2023.105017 Available at: https://www.ncbi.nlm.nih.gov/pubmed/36809716 (Accessed: 13/11/2023).

Bangor, A., Kortum, P. and Miller, J. (2009) 'Determining what individual SUS scores mean: adding an adjective rating scale', *J. Usability Studies,* 4(3), pp. 114–123.

Bangor, A., Kortum, P. T. and Miller, J. T. (2008) 'An Empirical Evaluation of the System Usability Scale', *International Journal of Human-Computer Interaction,* 24(6), pp. 574-594. DOI: 10.1080/10447310802205776 Available at: https://dx.doi.org/10.1080/10447310802205776 (Accessed: 5/5/2023).

Baysari, M. T., Hardie, R. A., Lake, R., Richardson, L., McCullagh, C., Gardo, A. and Westbrook, J. (2018) 'Longitudinal study of user experiences of a CPOE system in a pediatric hospital', *Int J Med Inform,* 109, pp. 5-14. DOI: 10.1016/j.ijmedinf.2017.10.018 Available at: https://www.ncbi.nlm.nih.gov/pubmed/29195706 (Accessed: 08/10/2023).

Bell, H., Garfield, S., Khosla, S., Patel, C. and Franklin, B. D. (2019) 'Mixed methods study of medication-related decision support alerts experienced during electronic prescribing for inpatients at an English hospital', *European Journal of Hospital Pharmacy,* 26(6), pp. 318-322. DOI: 10.1136/ejhpharm-2017-001483 Available at: https://dx.doi.org/10.1136/ejhpharm-2017-001483 (Accessed: 23/12/2023).

Blackwood, B., O'Halloran, P. and Porter, S. (2010) 'On the problems of mixing RCTs with qualitative research: the case of the MRC framework for the evaluation of complex healthcare interventions', *Journal of Research in Nursing,* 15(6), pp. 511-521.

Bloom, B. M., Pott, J., Thomas, S., Gaunt, D. R. and Hughes, T. C. (2021) 'Usability of electronic health record systems in UK EDs', *Emergency Medicine Journal,* 38(6), pp. 410-415. DOI: 10.1136/emermed-2020-210401 Available at: https://dx.doi.org/10.1136/emermed-2020-210401 (Accessed: 08/10/2023).

Brooke, J. (1996) 'SUS-A quick and dirty usability scale', *Usability evaluation in industry,* 189(194), pp. 4-7. Available at: https://hell.meiert.org/core/pdf/sus.pdf Available at: https://hell.meiert.org/core/pdf/sus.pdf (Accessed: 31/01/2022).

Brooke, J. (2013) 'SUS: a retrospective', *Journal of usability studies,* 8(2), pp. 29-40.

Brown, C. L., Mulcaster, H. L., Triffitt, K. L., Sittig, D. F., Ash, J. S., Reygate, K., Husband, A. K., Bates, D. W. and Slight, S. P. (2016) 'A systematic review of the types and causes of prescribing errors generated from using computerized provider order entry systems in primary and secondary care', *Journal of the American Medical Informatics Association,* 24(2), pp. 432-440. DOI: 10.1093/jamia/ocw119 Available at: https://doi.org/10.1093/jamia/ocw119 (Accessed: 12/15/2023).

Cain, C. and Haque, S. (2008) 'Advances in Patient Safety Organizational Workflow and Its Impact on Work Quality', in Hughes, R.G. (ed.) *Patient Safety and Quality: An Evidence-Based Handbook for Nurses*. Rockville (MD): Agency for Healthcare Research and Quality (US).

Cambridge Free English Dictionary and Thesaurus (2024) *Cambridge Free English Dictionary and Thesaurus*: Cambridge University Press & Assessment Available at: https://dictionary.cambridge.org/dictionary/. (Accessed: 03/04/2024).

Carayon, P., Du, S., Brown, R., Cartmill, R., Johnson, M. and Wetterneck, T. B. (2017) 'EHR-related medication errors in two ICUs', *J Healthc Risk Manag,* 36(3), pp. 6-15. DOI: 10.1002/jhrm.21259 Available at: https://www.ncbi.nlm.nih.gov/pubmed/28099789 (Accessed: 27/10/2023).

Cattell, M., Hyde, K., Bell, B., Dawson, T., Hills, T., Iyen, B., Khimji, A. and Avery, A. (2023) 'Retrospective review of medication-related incidents at a major teaching hospital and the potential mitigation of these incidents with electronic prescribing and medicines administration', *Eur J Hosp Pharm*. DOI: 10.1136/ejhpharm-2022-003515 Available at: https://www.ncbi.nlm.nih.gov/pubmed/36868849 (Accessed: 03/11/2023).

Chuenyindee, T., Montenegro, L. D., Ong, A. K. S., Prasetyo, Y. T., Nadlifatin, R., Ayuwati, I. D., Sittiwatethanasiri, T. and Robas, K. P. E. (2022) 'The perceived usability of the learning management system during the COVID-19 pandemic: Integrating system usability scale, technology acceptance model, and task-technology fit', *Work,* 73(1), pp. 41-58. DOI: 10.3233/WOR-220015 Available at: https://www.ncbi.nlm.nih.gov/pubmed/35871387 (Accessed: 03/11/2023).

Clark, N., Dabkowski, M., Driscoll, P. J., Kennedy, D., Kloo, I. and Shi, H. (2021) 'Empirical Decision Rules for Improving the Uncertainty Reporting of Small Sample System Usability Scale Scores', *International Journal of Human–Computer Interaction,* 37(13), pp. 1-16. DOI: 10.1080/10447318.2020.1870831 Available at: https://dx.doi.org/10.1080/10447318.2020.1870831 (Accessed: 5/5/2023).

Cornford, T., Dean, B., Savage, I., Barber, N. and Jani, Y. (2009) *Electronic prescribing in hospitals-challenges and lessons learned*: NHS Connecting for Health.

Cresswell, K., Williams, R. and Sheikh, A. (2020) 'Developing and Applying a Formative Evaluation Framework for Health Information Technology Implementations: Qualitative Investigation', *Journal of Medical Internet Research,* 22(6). DOI: 10.2196/15068 Available at: https://dx.doi.org/10.2196/15068 (Accessed: 10/11/2023).

Creswell, J. W., Klassen, A. C., Plano Clark, V. L. and Smith, K. C. (2011) 'Best practices for mixed methods research in the health sciences', *Bethesda (Maryland): National Institutes of Health,* 2013, pp. 541-545 (Accessed: 19/05/2023).

Davis, F. D. (1993) 'User acceptance of information technology: system characteristics, user perceptions and behavioral impacts', *International Journal of Man-Machine*

Studies, 38(3), pp. 475-487. DOI: 10.1006/imms.1993.1022 Available at: https://dx.doi.org/10.1006/imms.1993.1022 (Accessed: 03/04/2023).

Devine, E. B., Lee, C.-J., Overby, C. L., Abernethy, N., McCune, J., Smith, J. W. and Tarczy-Hornoch, P. (2014) 'Usability evaluation of pharmacogenomics clinical decision support aids and clinical knowledge resources in a computerized provider order entry system: A mixed methods approach', *International Journal of Medical Informatics,* 83(7), pp. 473-483. DOI: 10.1016/j.ijmedinf.2014.04.008 Available at: https://dx.doi.org/10.1016/j.ijmedinf.2014.04.008 (Accessed: 27/10/2023).

Dishaw, M. T. and Strong, D. M. (1999) 'Extending the technology acceptance model with task–technology fit constructs', *Information & management,* 36(1), pp. 9-21.

Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W. S., Wilson, J. R. and Van Der Doelen, B. (2012) 'A strategy for human factors/ergonomics: developing the discipline and profession', *Ergonomics,* 55(4), pp. 377-395. DOI: 10.1080/00140139.2012.661087 Available at: https://dx.doi.org/10.1080/00140139.2012.661087 (Accessed: 27/10/2023).

Elliott, R. A., Camacho, E., Jankovic, D., Sculpher, M. J. and Faria, R. (2021) 'Economic analysis of the prevalence and clinical and economic burden of medication error in England', *BMJ Quality & Safety,* 30(2), pp. 96-105. DOI: 10.1136/bmjqs-2019-010206 Available at: https://dx.doi.org/10.1136/bmjqs-2019-010206 (Accessed: 06/10/2023).

Elliott, R. A., Camacho, E. M., Gavan, S. P., Keers, R. N. and Chuter, A. (2023) *Estimating the impact of enabling NHS information systems to share patients' medicines information digitally MAIN REPORT Estimating the impact of enabling NHS information systems to share patients' medicines information digitally* (Accessed: 15/03/2024).

Ellsworth, M. A., Dziadzko, M., O'Horo, J. C., Farrell, A. M., Zhang, J. and Herasevich, V. (2017) 'An appraisal of published usability evaluations of electronic health records via systematic review', *J Am Med Inform Assoc,* 24(1), pp. 218-226. DOI: 10.1093/jamia/ocw046 Available at: https://www.ncbi.nlm.nih.gov/pubmed/27107451 (Accessed: 17/11/2023).

Fong, A., Adams, K. T., Gaunt, M. J., Howe, J. L., Kellogg, K. M. and Ratwani, R. M. (2018) 'Identifying health information technology related safety event reports from patient safety event report databases', *J Biomed Inform,* 86, pp. 135-142. DOI: 10.1016/j.jbi.2018.09.007 Available at: https://www.ncbi.nlm.nih.gov/pubmed/30213556 (Accessed: 17/11/2023).

Franklin, B. D., Jacklin, A. and Barber, N. (2010) 'The impact of an electronic prescribing and administration system on the safety and quality of medication administration', *International Journal of Pharmacy Practice,* 16(6), pp. 375-379.

DOI: 10.1211/ijpp.16.6.0006 Available at: https://doi.org/10.1211/ijpp.16.6.0006 (Accessed: 04/04/2024).

Friedman, C. P., Wyatt, J. and Ash, J. S. (2022) *Evaluation methods in biomedical and health informatics.* Springer.

Gates, P. J., Hardie, R.-A., Raban, M. Z., Li, L. and Westbrook, J. I. (2020) 'How effective are electronic medication systems in reducing medication error rates and associated harm among hospital inpatients? A systematic review and meta-analysis', *Journal of the American Medical Informatics Association,* 28(1), pp. 167-176. DOI: 10.1093/jamia/ocaa230 Available at: https://doi.org/10.1093/jamia/ocaa230 (Accessed: 04/04/2024).

Gates, P. J., Hardie, R.-A., Raban, M. Z., Li, L. and Westbrook, J. I. (2021) 'How effective are electronic medication systems in reducing medication error rates and associated harm among hospital inpatients? A systematic review and meta-analysis', *Journal of the American Medical Informatics Association,* 28(1), pp. 167-176. DOI: 10.1093/jamia/ocaa230 Available at: https://dx.doi.org/10.1093/jamia/ocaa230.

GMC (2021) *Good Practice in Prescribing and Managing Medicines and Devices*. Available at: https://www.gmc-uk.org/-/media/documents/prescribing-guidance-updated-english-20210405_pdf-85260533.pdf (Accessed: 05.04.2024).

Goddard, J. (2023). Dissertation Analysis Plan – Evaluation of the usability and technological fit of an implemented ePMA solution. *BMDS7004*. UWTSD. Unpublished Coursework.

Gomes, K. M. and Ratwani, R. M. (2019) 'Evaluating Improvements and Shortcomings in Clinician Satisfaction With Electronic Health Record Usability', *JAMA Network Open,* 2(12), pp. e1916651-e1916651. DOI: 10.1001/jamanetworkopen.2019.16651 Available at: https://doi.org/10.1001/jamanetworkopen.2019.16651 (Accessed: 12/22/2023).

Goodhue, D. L. and Thompson, R. L. (1995) 'Task-Technology Fit and Individual Performance', *MIS Quarterly,* 19(2), pp. 213. DOI: 10.2307/249689 Available at: https://dx.doi.org/10.2307/249689.(Accessed: 10/11/2023).

Health Level Seven International (2019) *HL7 FHIR Release 4*. https://www.hl7.org/fhir/. Available at: https://www.hl7.org/fhir/ (Accessed: 29/04/2022 2022).

Health Research Authority (2020) *Do I need NHS Ethics approval?* Available at: https://www.hra-decisiontools.org.uk (Accessed: 05.05.2023).

Healthcare Safety Investigation Branch (2019) *Electronic Prescribing and Medicines Administration Systems and Safe Discharge*. Available at: https://www.hsib.org.uk/investigations-cases/epma-systems-and-safe-discharge/final-report/.

Hesse-Biber, S. (2015) 'Mixed methods research: The “thing-ness” problem', *Qualitative health research,* 25(6), pp. 775-788 (Accessed: 01/12/2023).

Holden, R. J. and Karsh, B.-T. (2010) 'The Technology Acceptance Model: Its past and its future in health care', *Journal of Biomedical Informatics,* 43(1), pp. 159-172. DOI: 10.1016/j.jbi.2009.07.002 Available at: https://dx.doi.org/10.1016/j.jbi.2009.07.002 (Accessed: 04/04/2023).

Hong, Q. N., Pluye, P., Fàbregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., Gagnon, M.-P., Griffiths, F. and Nicolau, B. (2018) 'Mixed methods appraisal tool (MMAT), version 2018', *Registration of copyright,* 1148552(10).

Howe, J. L., Adams, K. T., Hettinger, A. Z. and Ratwani, R. M. (2018) 'Electronic Health Record Usability Issues and Potential Contribution to Patient Harm', *JAMA,* 319(12), pp. 1276-1278. DOI: 10.1001/jama.2018.1171 Available at: https://doi.org/10.1001/jama.2018.1171 (Accessed: 12/22/2023).

Iqbal, A. R., Parau, C. A., Kazi, S., Adams, K. T., La, L., Hettinger, A. Z. and Ratwani, R. M. (2021) 'Identifying Electronic Medication Administration Record (eMAR) Usability Issues from Patient Safety Event Reports', *Jt Comm J Qual Patient Saf,* 47(12), pp. 793-801. DOI: 10.1016/j.jcjq.2021.09.004 Available at: https://www.ncbi.nlm.nih.gov/pubmed/34657817 (Accessed: 17/11/2023).

ISMP (2019) 'Institute for Safe Medication Practices - Guidelines for safe and electronic communication of medication information'

ISO (2009) 'ISO 9241-210: 2010. Ergonomics of human system interaction-Part 210: Human-centred design for interactive systems', *International Standardization Organization (ISO). Switzerland*. Available at: https://www.iso.org/standard/77520.html Available at: https://www.iso.org/standard/77520.html (Accessed: 27/10/2023).

Kahan, J., Rolles, M., Povey, G. and Banner, R. (2024) 'Cisplantin in head and neck chemoradiotherapy: A real-world survival and compliance analysis of weekly vs 3-weekly regimes'. *In:* Centre, S.W.C. (ed.). ICHNO.

Kutney-Lee, A., Carthon, J. M. B., Sloane, D. M., Bowles, K. H., McHugh, M. D. and Aiken, L. H. (2021) 'Electronic health record usability: associations with nurse and patient outcomes in hospitals', *Medical care,* 59(7), pp. 625.

Lee, Y., Bahn, S., Shin, G. W., Jung, M. Y., Park, T., Cho, I. and Lee, J. H. (2021) 'Development of safety and usability guideline for clinical information system', *Medicine (Baltimore),* 100(13), pp. e25276. DOI: 10.1097/MD.0000000000025276 Available at: https://www.ncbi.nlm.nih.gov/pubmed/33787612 (Accessed: 17/11/2023).

Lehne, M., Sass, J., Essenwanger, A., Schepers, J. and Thun, S. (2019) Why digital medicine depends on interoperability. *npj Digital Medicine.* Nature Publishing Group.

Lepanto, L., Sicotte, C. and Lehoux, P. (2011) 'Assessing Task–Technology Fit in a PACS Upgrade: Do Users' and Developers' Appraisals Converge?', *Journal of Digital Imaging,* 24(6), pp. 951-958. DOI: 10.1007/s10278-011-9378-x Available at: https://dx.doi.org/10.1007/s10278-011-9378-x (Accessed: 5/5/2023).

Lewis, J. R. (2014) 'Usability: Lessons Learned … and Yet to Be Learned', *International Journal of Human-Computer Interaction,* 30(9), pp. 663-684. DOI: 10.1080/10447318.2014.930311 Available at: https://dx.doi.org/10.1080/10447318.2014.930311 (Accessed: 18/03/2023).

Maramba, I., Chatterjee, A. and Newman, C. (2019) 'Methods of usability testing in the development of eHealth applications: A scoping review', *International Journal of Medical Informatics,* 126, pp. 95-104. DOI: 10.1016/j.ijmedinf.2019.03.018 Available at: https://dx.doi.org/10.1016/j.ijmedinf.2019.03.018 (Accessed: 08/10/2023).

Marcilly, R., Ammenwerth, E., Roehrer, E., Nies, J. and Beuscart-Zephir, M. C. (2018) 'Evidence-based usability design principles for medication alerting systems', *BMC Med Inform Decis Mak,* 18(1), pp. 69. DOI: 10.1186/s12911-018-0615-9 Available at: https://www.ncbi.nlm.nih.gov/pubmed/30041647 (Accessed: 08/10/2023).

Marcilly, R., Colliaux, J., Robert, L., Pelayo, S., Beuscart, J.-B., Rousselière, C. and Décaudin, B. (2023) 'Improving the usability and usefulness of computerized decision support systems for medication review by clinical pharmacists: A convergent, parallel evaluation', *Research in Social and Administrative Pharmacy,* 19(1), pp. 144-154. DOI: https://doi.org/10.1016/j.sapharm.2022.08.012 Available at: https://www.sciencedirect.com/science/article/pii/S1551741122002789 (Accessed: 27/10/2023).

Marcilly, R., Schiro, J., Beuscart-Zephir, M. C. and Magrabi, F. (2019) 'Building Usability Knowledge for Health Information Technology: A Usability-Oriented Analysis of Incident Reports', *Appl Clin Inform,* 10(3), pp. 395-408. DOI: 10.1055/s-0039-1691841 Available at: https://www.ncbi.nlm.nih.gov/pubmed/31189203 (Accessed: 08/10/2023).

Marien, S., Legrand, D., Ramdoyal, R., Nsenga, J., Ospina, G., Ramon, V. and Spinewine, A. (2019) 'A User-Centered design and usability testing of a web-based medication reconciliation application integrated in an eHealth network', *Int J Med Inform,* 126, pp. 138-146. DOI: 10.1016/j.ijmedinf.2019.03.013 Available at: https://www.ncbi.nlm.nih.gov/pubmed/31029255 (Accessed: 08/10/2023).

Mathieson, K., Peacock, E. and Chin, W. W. (2001) 'Extending the technology acceptance model: The influence of perceived user resources', *Database for Advances in Information Systems,* 32(3), pp. 86-112. Available at: https://www.proquest.com/trade-journals/extending-technology-acceptance-model-influence/docview/196631426/ Available at: https://www.proquest.com/trade-journals/extending-technology-acceptance-model-influence/docview/196631426/ (Accessed: 08/10/2023).

Melnick, E. R., Dyrbye, L. N., Sinsky, C. A., Trockel, M., West, C. P., Nedelec, L., Tutty, M. A. and Shanafelt, T. (2020) 'The Association Between Perceived Electronic Health Record Usability and Professional Burnout Among US Physicians', *Mayo Clinic Proceedings,* 95(3), pp. 476-487. DOI: 10.1016/j.mayocp.2019.09.024 Available at: https://dx.doi.org/10.1016/j.mayocp.2019.09.024 (Accessed: 22/12/2023).

Middleton, B., Bloomrosen, M., Dente, M. A., Hashmat, B., Koppel, R., Overhage, J. M., Payne, T. H., Rosenbloom, S. T., Weaver, C., Zhang, J. and American Medical Informatics, A. (2013) 'Enhancing patient safety and quality of care by improving the usability of electronic health record systems: recommendations from AMIA', *J Am Med Inform Assoc,* 20(e1), pp. e2-8. DOI: 10.1136/amiajnl-2012-001458 Available at: https://www.ncbi.nlm.nih.gov/pubmed/23355463 (Accessed: 17/11/2023).

Mozaffar, H., Cresswell, K. M., Williams, R., Bates, D. W. and Sheikh, A. (2017) 'Exploring the roots of unintended safety threats associated with the introduction of hospital ePrescribing systems and candidate avoidance and/or mitigation strategies: a qualitative study', *BMJ Qual Saf,* 26(9), pp. 722-733. DOI: 10.1136/bmjqs-2016-005879 Available at: https://www.ncbi.nlm.nih.gov/pubmed/28174319 (Accessed: 06/10/2023).

Mozaffar, H., Williams, R., Cresswell, K., Morison, Z., Slee, A. and Sheikh, A. (2014) 'Product diversity and spectrum of choice in hospital ePrescribing systems in England', *PLoS ONE,* 9(4). DOI: 10.1371/journal.pone.0092516 (Accessed: 06/10/2023).

NICE (2012) *Identifying the evidence: literature searching and evidence submission*. The guidelines manual NICE: NICE. Available at: https://www.nice.org.uk/process/pmg6/chapter/identifying-the-evidence-literature-searching-and-evidence-submission. (Accessed: 17/11/2023).

NICE (2015) 'Medicines optimisation: the safe and effective use of medicines to enable the best possible outcomes'.

NICE (2022) *Medicines Optimisation*: National Institute for Health and Care Excellence. Available at: https://bnf.nice.org.uk/medicines-guidance/medicines-optimisation/ (Accessed: 20.10.2023 2022).

Nohr, C., Borycki, E. and Kushniruk, A. (2016) 'Human Factors for More Usable and Safer Health Information Technology: Where Are We Now and Where do We Go from Here?', *Yearbook of Medical Informatics,* 25(01), pp. 120-125. DOI: 10.15265/iy-2016-024 Available at: https://dx.doi.org/10.15265/iy-2016-024 (Accessed: 27/10/2023).

Onatade, R., Miller, G. and Sanghera, I. (2016) 'A quantitative comparison of ward-based clinical pharmacy activities in 7 acute UK hospitals', *International Journal of Clinical Pharmacy,* 38(6), pp. 1407-1415. DOI: 10.1007/s11096-016-0386-2 Available at: https://doi.org/10.1007/s11096-016-0386-2 (Accessed: 15/03/2024).

Orfanou, K., Tselios, N. and Katsanos, C. (2015) 'Perceived usability evaluation of learning management systems: Empirical evaluation of the System Usability Scale', *The International Review of Research in Open and Distributed Learning,* 16(2). DOI: 10.19173/irrodl.v16i2.1955 Available at: https://dx.doi.org/10.19173/irrodl.v16i2.1955 (Accessed: 5/5/2023).

Pontefract, S. K., Hodson, J., Slee, A., Shah, S., Girling, A. J., Williams, R., Sheikh, A. and Coleman, J. J. (2018) 'Impact of a commercial order entry system on prescribing errors amenable to computerised decision support in the hospital setting: a prospective pre-post study', *BMJ Qual Saf,* 27(9), pp. 725-736. DOI: 10.1136/bmjqs-2017-007135 Available at: https://www.ncbi.nlm.nih.gov/pubmed/29572298 https://qualitysafety.bmj.com/content/qhc/27/9/725.full.pdf (Accessed: 06/10/2023).

Prgomet, M., Georgiou, A., Callen, J. and Westbrook, J. (2019) 'Fit between individuals, tasks, technology, and environment (FITTE) framework: A proposed extension of FITT to evaluate and optimise health information technology use', in *MEDINFO 2019: Health and Wellbeing e-Networks for All*: IOS Press, pp. 744-748.

Pruitt, Z., Howe, J. L., Krevat, S. A., Khairat, S. and Ratwani, R. M. (2022) 'Development and pilot evaluation of an electronic health record usability and safety self-assessment tool', *JAMIA Open,* 5(3), pp. ooac070. DOI: 10.1093/jamiaopen/ooac070 Available at: https://www.ncbi.nlm.nih.gov/pubmed/35919379 (Accessed: 17/11/2023).

Rabiei, R., Moghaddasi, H., Asadi, F. and Heydari, M. (2018) 'Evaluation of computerized provider order entry systems: assessing the usability of systems for electronic prescription', *Electronic Physician,* 10(8), pp. 7196-7204. DOI: 10.19082/7196 Available at: https://dx.doi.org/10.19082/7196 (Accessed: 08/10/2023).

Randhawa, G. K., Garnett, A., Huang, S., Dhot, P. and Fyfe, M. L. (2019) 'Evidence-Based Usability Principles for Safe Computerized Provider Order Entry (CPOE)

Interface Design', *Stud Health Technol Inform,* 264, pp. 1947-1948. DOI: 10.3233/shti190727 (Accessed: 10/11/2023).

Ratwani, R. M., Fairbanks, R. J., Hettinger, A. Z. and Benda, N. C. (2015) 'Electronic health record usability: analysis of the user-centered design processes of eleven electronic health record vendors', *Journal of the American Medical Informatics Association,* 22(6), pp. 1179-1182 (Accessed: 06/10/2023).

Ratwani, R. M., Savage, E., Will, A., Fong, A., Karavite, D., Muthu, N., Rivera, A. J., Gibson, C., Asmonga, D., Moscovitch, B., Grundmeier, R. and Rising, J. (2018) 'Identifying Electronic Health Record Usability And Safety Challenges In Pediatric Settings', *Health Aff (Millwood),* 37(11), pp. 1752-1759. DOI: 10.1377/hlthaff.2018.0699 Available at: https://www.ncbi.nlm.nih.gov/pubmed/30395517 (Accessed: 08/10/2023).

Redmond, P., Grimes, T. C., Mcdonnell, R., Boland, F., Hughes, C. and Fahey, T. (2018) 'Impact of medication reconciliation for improving transitions of care', *Cochrane Database of Systematic Reviews,* 2018(8). DOI: 10.1002/14651858.cd010791.pub2 (Accessed: 05/03/2024).

Reid, A.-M., Brown, J. M., Smith, J. M., Cope, A. C. and Jamieson, S. (2018) 'Ethical dilemmas and reflexivity in qualitative research', *Perspectives on Medical Education,* 7(2), pp. 69-75. DOI: 10.1007/s40037-018-0412-2 Available at: https://dx.doi.org/10.1007/s40037-018-0412-2 (Accessed: 5/5/2023).

Royal Pharmaceutical Society (2013) 'Medicines optimisation: helping patients to make the most of medicines.'

Russ, A. L., Jahn, M. A., Patel, H., Porter, B. W., Nguyen, K. A., Zillich, A. J., Linsky, A. and Simon, S. R. (2018) 'Usability evaluation of a medication reconciliation tool: Embedding safety probes to assess users' detection of medication discrepancies', *J Biomed Inform,* 82, pp. 178-186. DOI: 10.1016/j.jbi.2018.05.002 Available at: https://www.ncbi.nlm.nih.gov/pubmed/29751104 (Accessed: 08/10/2023).

Sabooniha, N., Toohey, D. and Lee, K. (2012) 'An evaluation of hospital information systems integration approaches', *Proceedings of the International Conference on Advances in Computing, Communications and Informatics*, Chennai, India: Association for Computing Machinery, 498–504.

Sauro, J. (2011) *A practical guide to the system usability scale: Background, benchmarks & best practices.* Measuring Usability LLC.

Sauro, J. and Lewis, J. R. (2016) *Quantifying the user experience: Practical statistics for user research.* Morgan Kaufmann.

SBUHB (2022) *Hospital E-Prescribing and Medicines Administration (HEPMA) Evaluation*, Unpublished: Swansea Bay University Health Board.

Schmidtchen, L., Villis, M., Christoph, J. and Rödle, W. (2023) 'Usability Analysis of a Medication Visualization Tool for Decision Support', in: IOS Press.

Scott, P. J. (2016) 'Mixed Methods: A Paradigm for Holistic Evaluation of Health IT', in Ammenwerth, E. and Rigby, M. (eds.) *Evidence-Based Health Informatics*: IOS Press.

Scott, P. J. and Briggs, J. S. (2009) 'A pragmatist argument for mixed methodology in medical informatics', *Journal of Mixed Methods Research,* 3(3), pp. 223-241.

Séroussi, B., Hollis, K. F. and Soualmia, L. F. (2020) 'Transparency of Health Informatics Processes as the Condition of Healthcare Professionals' and Patients' Trust and Adoption: the Rise of Ethical Requirements', *Yearbook of Medical Informatics,* 29(01), pp. 007-010. DOI: 10.1055/s-0040-1702029 Available at: https://dx.doi.org/10.1055/s-0040-1702029 (Accessed: 21/04/2023).

Shemilt, K., Morecroft, C. W., Ford, J. L., Mackridge, A. J. and Green, C. (2017) 'Inpatient prescribing systems used in NHS Acute Trusts across England: a managerial perspective', *Eur J Hosp Pharm,* 24(4), pp. 213-217. DOI: 10.1136/ejhpharm-2016-000905 Available at: https://www.ncbi.nlm.nih.gov/pubmed/31156943 (Accessed: 05/03/2024).

Sheridan, S., Sherman, H., Kooijman, A., Vazquez, E., Kirk, K., Metwally, N. and Cardinali, F. (2021) 'Patients for Patient Safety', in *Textbook of Patient Safety and Clinical Risk Management*: Springer, Cham, pp. 67-79.

Singh, H. and Sittig, D. F. (2016) 'Measuring and improving patient safety through health information technology: The Health IT Safety Framework', *BMJ Quality & Safety,* 25(4), pp. 226-232. DOI: 10.1136/bmjqs-2015-004486 Available at: http://qualitysafety.bmj.com/content/25/4/226.full.pdf (Accessed: 15/03/2024).

Sittig, D. F. and Singh, H. (2015) 'A New Socio-technical Model for Studying Health Information Technology in Complex Adaptive Healthcare Systems', in Patel, V.L., Kannampallil, T.G. and Kaufman, D.R. (eds.) *Cognitive Informatics for Biomedicine: Human Computer Interaction in Healthcare*. Cham: Springer International Publishing, pp. 59-80.

Sittig, D. F., Wright, A., Coiera, E., Magrabi, F., Ratwani, R., Bates, D. W. and Singh, H. (2020) 'Current challenges in health information technology–related patient safety', *Health Informatics Journal,* 26(1), pp. 181-189. DOI: 10.1177/1460458218814893 Available at: https://dx.doi.org/10.1177/1460458218814893 (Accessed: 17/11/2023).

Slight, S. P., Tolley, C. L., Bates, D. W., Fraser, R., Bigirumurame, T., Kasim, A., Balaskonis, K., Narrie, S., Heed, A., Orav, E. J. and Watson, N. W. (2019) 'Medication errors and adverse drug events in a UK hospital during the optimisation of electronic prescriptions: a prospective observational study', *The*

Lancet Digital Health, 1(8), pp. e403-e412. DOI: https://doi.org/10.1016/S2589-7500(19)30158-X Available at: https://www.thelancet.com/pdfs/journals/landig/PIIS2589-7500(19)30158-X.pdf (Accessed: 03/11/2023).

SNOMED International. (2022) *SNOMED International's Confluence*. Available at: https://confluence.ihtsdotools.org/ (Accessed: 12/05/2022 2022).

Staggers, N., Elias, B. L., Makar, E. and Alexander, G. L. (2018) 'The Imperative of Solving Nurses' Usability Problems With Health Information Technology', *J Nurs Adm,* 48(4), pp. 191-196. DOI: 10.1097/NNA.0000000000000598 Available at: https://www.ncbi.nlm.nih.gov/pubmed/29570144 (Accessed: 08/10/2023).

Stephens, M. (2011) *Hospital pharmacy.* Pharmaceutical Press.

Sujan, M. A., Huang, H. and Braithwaite, J. (2017) 'Learning from incidents in health care: Critique from a Safety-II perspective', *Safety Science,* 99, pp. 115-121. DOI: 10.1016/j.ssci.2016.08.005 Available at: https://dx.doi.org/10.1016/j.ssci.2016.08.005 (Accessed: 27/03/2023).

Thomas, P. and Macredie, R. D. (2002) Introduction to the new usability. ACM New York, NY, USA.

Thomas, V. G. and Campbell, P. B. (2020) *Evaluation in today's world: Respecting diversity, improving quality, and promoting usability.* Sage Publications.

Turney, S. (2022) *Student's Table (Free Download) Guide and Examples*. Available at: https://www.scribbr.com/statistics/students-t-table/ (Accessed: 23.02.2024 2023).

Van Wilder, A., Bell, H. and Franklin, B. D. (2016) 'The effect of electronic prescribing and medication administration on nurses' workflow and activities: an uncontrolled before and after study', *Safety in Health,* 2(1). DOI: 10.1186/s40886-016-0023-8 (Accessed: 04/04/2024).

Venkatesh, V., Brown, S. A. and Bala, H. (2013) 'Bridging the qualitative-quantitative divide: Guidelines for conducting mixed methods research in information systems', *MIS quarterly*, pp. 21-54

Welsh Government (2022) *Data Standards Change Notice - Medicines, Allergies and Intolerances Interoperability Standards*, DHCW2022/76). Available at: https://dhcw.nhs.wales/information-services/information-standards/data-standards/data-standards-files/data-standard-change-notices-docs/dscns-2022/20221117-dscn-2022-76-medicines-and-allergy-intol-interop-standards-v1-0pdf/ (Accessed: 05.04.2024).

Williams, J., Malden, S., Heeney, C., Bouamrane, M., Holder, M., Perera, U., Bates, D. W. and Sheikh, A. (2022) 'Optimizing Hospital Electronic Prescribing Systems: A Systematic Scoping Review', *Journal Patient Safety,* 18(2). Available at:

www.journalpatientsafety.com Available at: www.journalpatientsafety.com (Accessed: 03/11/2023).

World Health Organization (2019) *Medication safety in transitions of care: technical report*: World Health Organization. Available at: https://www.who.int/initiatives/medication-without-harm (Accessed: 04/12/2023).

Zapata, B. C., Fernández-Alemán, J. L., Idri, A. and Toval, A. (2015) 'Empirical Studies on Usability of mHealth Apps: A Systematic Literature Review', *Journal of Medical Systems,* 39(2). DOI: 10.1007/s10916-014-0182-2 Available at: https://dx.doi.org/10.1007/s10916-014-0182-2 (Accessed: 20/10/2023).

Zhai, Y., Yu, Z., Zhang, Q. and Zhang, Y. (2022) 'Barriers and facilitators to implementing a nursing clinical decision support system in a tertiary hospital setting: A qualitative study using the FITT framework', *Int J Med Inform,* 166, pp. 104841. DOI: 10.1016/j.ijmedinf.2022.104841 Available at: https://www.ncbi.nlm.nih.gov/pubmed/36027798 (Accessed: 26/01/2024).

Zhang, J. and Walji, M. F. (2011) 'TURF: toward a unified framework of EHR usability', *Journal of biomedical informatics,* 44(6), pp. 1056-1067.

Zheng, K., Ciemins, E., Lanham, H., Lindberg, C. and Man, D. (2015) 'Examining the relationship between health IT and ambulatory care workflow redesign', *Rockville, MD: Agency for Healthcare Research and Quality,*

Zheng, K., Ratwani, R. M. and Adler-Milstein, J. (2020) 'Studying Workflow and Workarounds in Electronic Health Record-Supported Work to Improve Health System Performance', *Ann Intern Med,* 172(11 Suppl), pp. S116-s122. DOI: 10.7326/m19-0871 (Accessed: 08/03/2024).

8. Appendices

Appendix 1 PG2 Ethics Form

Appendix 2 UWTSD Data collection - Approval to Go ahead.

Appendix 3 Ethics Correspondence

Appendix 4 Ethics and IG Correspondence

Appendix 5 MRC HRA – Is my Study Research Tool – Outcome

Appendix 6 Questionnaire Participant Information Sheet

Appendix 7 Interview Participant Information Sheet

Appendix 8 Questionnaire

Appendix 9 Interview Questions

Appendix 10 Glossary

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

PG2 / E1 FORM

7	Student Number:	2111623
8	Programme of Study:	MSc Digital Transformation for the Health and Care Professionals
9	Director of Studies/Supervisor:	Paul Curley

SECTION B: Approval for Research Activity

1	Has the research activity received approval in principle? (please check the Guidance Notes as to the appropriate approval process for different levels of research by different categories of individual)		**YES**	☐	**NO**	☒
					Date	
2	If Yes, please indicate source of approval (and date where known): ***Approval in principle must be obtained from the relevant source prior to seeking ethical approval***	Research Degrees Committee		☐		
		Institute Research Committee		☐		
		Other (write in)		☐		

SECTION C: Internal and External Ethical Guidance Materials

	Please list the core ethical guidance documents that have been referred to during the completion of this form (including any discipline-specific codes of research ethics, location-specific codes of research ethics, and also any specific ethical guidance relating to the proposed methodology). Please tick to confirm that your research proposal adheres to these codes and guidelines. You may add rows to this table if needed.	
1	**UWTSD Research Ethics & Integrity Code of Practice**	☒
2	**UWTSD Research Data Management Policy**	☒
3	*[List any other relevant documents here]*	☐

SECTION D: External Collaborative Research Activity

If there are external collaborators then you should gain consent from the contact persons to share their personal data with the university. If there are no external collaborators then leave this section blank and continue to section E.

1	Institution					
2	Contact person name					
3	Contact person e-mail address					
4	Is your research externally funded?		**YES**	☐	**NO**	☐
5	Are you in receipt of a KESS scholarship?		**YES**	☐	**NO**	☐
6	Are you specifically employed to undertake this research in either a paid or voluntary capacity?	Voluntary	**YES**	☐	**NO**	☐
7		Employed	**YES**	☐	**NO**	☐
8	Is the research being undertaken within an existing UWTSD Athrofa Professional Learning Partnership (APLP)?	If YES then the permission question below does not need to be answered.	**YES**	☐	**NO**	☐

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

PG2 / E1 FORM

9	Has permission to undertake the research has been provided by the partner organisation?	(If YES attach copy) If NO the application cannot continue	**YES**	☐	**NO**	☐

Where research activity is carried out in collaboration with an external organisation

10	Does this organisation have its own ethics approval system?	**YES**	☒	**NO**	☐
	If Yes, please attach a copy of any final approval (or interim approval) from the organisation (this may be a copy of an email if appropriate). RE_ MSc Dissertation - ePMA				

SECTION E: Details of Research Activity

1	Indicative title:	Evaluation of the Usability and Technological Fit of an Implemented ePMA solution		
2	Proposed start date:	October 2023	Proposed end date:	May 2023
	Introduction to the Research (maximum 300 words per section) **Ensure that you write for a Non-Specialist Audience when outlining your response to the points below:** *Purpose of Research Activity* *Proposed Research Question* *Aims of Research Activity* *Objectives of Research Activity* Demonstrate, briefly, how **Existing Research** has informed the proposed activity and explain *What the research activity will add to the body of knowledge* *How it addresses an area of importance.*			
3	**Purpose of Research Activity** The proposal seeks to evaluate and explore the usability and technological fit of an ePMA solution currently implemented in Swansea Bay University Health Board. Such tools have been established as being able to improve patient safety and bring benefits around the prescribing and administration process itself. However, there is very limited usability data around ePMA systems and usability can be clearly linked to clinical safety. (this box should expand as you type)			
4	**Research Question** Seeks to gain a better understanding of any successes or perceived failures within complex sociotechnical environment of the ePMA roll-out and to see if there are any links between usability scores and individual assessments made in terms of how users perceived how well the technology fitted the everyday tasks around medicines reconciliation, prescribing, verification and medicines administration. (this box should expand as you type)			
5	**Aims of Research Activity**			

	This will better inform any future implementations, increase understanding, possible mitigations and approaches to clinical risk management and help inform methods for use in procurement evaluations. (this box should expand as you type)
6	**Objectives of Research Activity** 1. Produce an standardised usability score using the System Usability Scale (SUS) score (from more than 20 results) 2. Understand the current fit between technology, user and task of the electronic prescribing and medicines administration (ePMA) solution. 3. Explore relationships and themes between individual SUS scores and individual responses to questionnaire around fit between technology, user and task. For example, between task complexity and the usability of the interface. Might this have an effect on cognitive load? 4. Identify areas for improvement or further evaluation or research. (this box should expand as you type)
	Proposed methods (maximum 600 words) Provide a brief summary of all the methods that **may** be used in the research activity, making it clear what specific techniques may be used. If methods other than those listed in this section are deemed appropriate later, additional ethical approval for those methods will be needed. You do not need to justify the methods here, but should instead describe how you intend to collect the data necessary for you to complete your project.
7	The evaluation will involve the use of a questionnaire – initially designed for MS Forms and disseminated and completed electronically. This will seek to answer specific and validated system usability scoring questions (SUS) with the addition to questions that will help to understand any biases and/or correlations. For example, system users who are champions and who might "like" the system might be more inclined to answer positively and those that feel they "don't like" the system might be inclined to answer negatively, etc. There will be additional questions around ascertaining information on a framework based on the fit between individuals, task, technology and environment. (FITTE). The SUS scoring tool involves the use of ten questions that have a minimum score of 1 and maximum score of 5. The odd numbered questions, 1,3,5,7,9, are more positively positioned, e.g. "*I thought the system was easy to use*" and the even numbered questions, 2,4,6,8,10, are more negatively positioned, e.g. "*I found the system unnecessarily complex*". When each question is scored the contribution to the overall score for that question will span between 0 to 4. For the odd numbers this is the scale response given, minus 1. For example, the respondent decides to score a 5 for question 1, then the result for that question will be 5 – 1 = 4. The score from the even numbers is worked out by subtracting the scale response given from 5. For example, the respondent decides to score a 4 for question 2, then the result for that question will be 5 – 4 = 1. The scores are then added up and multiplied by 2.5 to give the final value. The overall scale used in the SUS measure spans from 0 (worst) to 100 (best), and the industry average is 68, thus this is now adopted as the lower limit of acceptable usability.

SUS Questions and scoring method

No.	Question	Strongly Disagree to Strongly Agree	Scoring Method
1.	I like using the system	1 2 3 4 5	Respondent Answer - 1
2.	I find the system unnecessarily complex	1 2 3 4 5	5 – Respondent Answer
3.	I think the system is easy to use	1 2 3 4 5	Respondent Answer - 1

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

PG2 / E1 FORM

4.	I need the support of a technical person to use the system	1 2 3 4 5	5 – Respondent Answer
5.	I find the various functions in the system are well integrated	1 2 3 4 5	Respondent Answer - 1
6.	I think there is too much inconsistency in the system	1 2 3 4 5	5 – Respondent Answer
7.	I learnt to use the system very quickly	1 2 3 4 5	Respondent Answer - 1
8.	I find the system very cumbersome/awkward to use	1 2 3 4 5	5 – Respondent Answer
9.	I feel very confident using the system	1 2 3 4 5	Respondent Answer - 1
10.	I needed to learn a lot of things before I could get going with this system	1 2 3 4 5	5 – Respondent Answer

In addition to the FITTE questions and the SUS score, a smaller number of semi-structured interviews may take place. The results of the questionnaires will help to provide the initials themes for the interviews and then a thematic analysis will be undertaken.

The SUS score will be presented with a mean of the score alongside a standard confidence interval and a mean score of overall satisfaction of the solution. This may be reported on against different staff groups and roles, e.g. prescribers vs those administering medication etc.

Thus, relationships between the quantitative data of the SUS scoring and the qualitative aspects of the evaluation will be explored.

(this box should expand as you type)

Location of research activity
Identify all locations where research activity will take place.

8 Swansea Bay University Health Board Staff who will be participating in:
Online Questionnaire.
Virtual Interviews.

(this box should expand as you type)

Research activity outside of the UK
If research activity will take place overseas, you are responsible for ensuring that local ethical considerations are complied with and that the relevant permissions are sought. Specify any local guidelines (e.g. from local professional associations/learned societies/universities) that exist and whether these involve any ethical stipulations beyond those usual in the UK (provide details of any licenses or permissions required). Also specify whether there are any specific ethical issues raised by the local context in which the research activity is taking place, for example, particular cultural and/or legal sensitivities or vulnerabilities of participants. If you live in the country where you will do the research then please state this.

9 N/A

(this box should expand as you type)

10	Use of documentation not in the public domain: Are any documents **NOT** publicly available?	**NO**	☒
		YES	☐

11	If Yes, please provide details here of how you will gain access to specific documentation that is not in the public domain and that this is in accordance with the current data protection law of the country in question and that of England and Wales. *(this box should expand as you type)*		

	Does your research relate to one or more of the seven aims of the Well-being of Future Generations (Wales) Act 2015?	YES	NO
12	A prosperous Wales	☒	☐
13	A resilient Wales	☒	☐
14	A healthier Wales	☒	☐
15	A more equal Wales	☐	☐
16	A Wales of cohesive communities	☒	☐
17	A Wales of vibrant culture and thriving Welsh language	☐	☐
18	A globally responsible Wales	☐	☐
19	If YES to any of the above, please give details:		

Evaluating usability and technological "fit" has inference and influence in all of the following:

A prosperous Wales – ePMA allows us to monitor medicine usage cost at the prescribing level and guide more cost-effective prescribing on a real time basis. This will provide information to more accurately support good prescribing, governance and practice and save costs. It is estimated that HEPMA systems can save between 2-10% of prescribing budgets. Therefore, it will be helpful to understand usability as by inference the more usable the system the more efficiently and effectively, the data pertaining to and the policies relating to governing medicines usage, can be implemented.

A Resilient Wales – ePMA offers greater flexibility in terms of access to prescribing medicines for secondary care with system and medication record accessible wherever you are. This allows for flexibility on staffing demands by providing the possibility for mobile working and remote access. Physical paper charts often go missing and can often take 15 minutes to find. They can only be used in one place at one time, unlike EPMA.

A healthier Wales – ePMA will be an enabler for seamless care between settings and be an essential part of the tools required to provide shared and consistent presentation of medicines data, which in turn can be used to undertake national analysis. It also lays foundations for the potential to develop patient facing portals.

A Wales of cohesive communities – Better consistent data will enable us to compare and contrast and understand our communities in a better way. Identifying unique trends and prescribing patterns faster and enable cohesiveness between communities.

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

PG2 / E1 FORM

	(this box should expand as you type)

SECTION F: Scope of Research Activity

	Will the research activity include:	YES	NO
1	Use of a questionnaire or similar research instrument?	☒	☐
2	Use of interviews?	☒	☐
3	Use of focus groups?	☐	☒
4	Use of participant diaries?	☐	☒
5	Use of video or audio recording?	☒	☐
6	Use of computer-generated log files?	☒	☐
7	Participant observation with their knowledge?	☐	☒
8	Participant observation without their knowledge?	☐	☒
9	Access to personal or confidential information without the participants' specific consent?	☐	☒
10	Administration of any questions, test stimuli, presentation that may be experienced as physically, mentally or emotionally harmful / offensive?	☐	☒
11	Performance of any acts which may cause embarrassment or affect self-esteem?	☐	☒
12	Investigation of participants involved in illegal activities?	☐	☒
13	Use of procedures that involve deception?	☐	☒
14	Administration of any substance, agent or placebo?	☐	☒
15	Working with live vertebrate animals?	☐	☒
16	Procedures that may have a negative impact on the environment?	☐	☒
17	Other primary data collection methods. Please indicate the type of data collection method(s) below.		
	Details of any other primary data collection method: (this box should expand as you type)	☐	☒

If NO to every question, then the research activity is (ethically) low risk and **may** be exempt from **some** of the following sections (please refer to Guidance Notes).

If YES to any question, then no research activity should be undertaken until full ethical approval has been obtained.

SECTION G: Intended Participants

If there are no participants then do not complete this section, but go directly to section H.

	Who are the intended participants:	YES	NO

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

PG2 / E1 FORM

1	Students or staff at the University?	☐	☒
2	Adults (over the age of 18 and competent to give consent)?	☒	☐
3	Vulnerable adults?	☐	☒
4	Children and Young People under the age of 18? (Consent from Parent, Carer or Guardian will be required)	☐	☒
5	Prisoners?	☐	☒
6	Young offenders?	☐	☒
7	Those who could be considered to have a particularly dependent relationship with the investigator or a gatekeeper?	☐	☒
8	People engaged in illegal activities?	☐	☒
9	Others. Please indicate the participants below, and specifically any group who may be unable to give consent.		
	Details of any other participant groups: (this box should expand as you type)	☐	☒

	Participant numbers and source Provide an estimate of the expected number of participants. How will you identify participants and how will they be recruited?	
10	How many participants are expected?	~100 *(this box should expand as you type)*
11	Who will the participants be?	Nurses, Doctors, Pharmacy Staff and other Healthcare professionals who use the system for prescribing. *(this box should expand as you type)*
12	How will you identify the participants?	Study participants will be identified through the Swansea Bay University Health Board secondary care ePMA clinical reference group and an invitation will be sent out asking for the leads to disseminate out to users in each of the 4 hospitals where ePMA has been implemented or is being implemented. *(this box should expand as you type)*

	Information for participants:	**YES**	**NO**	**N/A**
13	Will you describe the main research procedures to participants in advance, so that they are informed about what to expect?	☒	☐	☐
14	Will you tell participants that their participation is voluntary?	☒	☐	☐
15	Will you obtain written consent for participation?	☒	☐	☐
16	Will you explain to participants that refusal to participate in the research will not affect their treatment or education (if relevant)?	☒	☐	☐
17	If the research is observational, will you ask participants for their consent to being observed?	☐	☐	☒
18	Will you tell participants that they may withdraw from the research at any time and for any reason?	☒	☐	☐

19	With questionnaires, will you give participants the option of omitting questions they do not want to answer?	☒	☐	☐
20	Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?	☒	☐	☐
21	Will you debrief participants at the end of their participation, in a way appropriate to the type of research undertaken?	☒	☐	☐
22	If NO to any of above questions, please give an explanation			
	(this box should expand as you type)			

	Information for participants:	**YES**	**NO**	**N/A**
24	Will participants be paid?	☐	☒	☐
25	Is specialist electrical or other equipment to be used with participants?	☐	☒	☐
26	Are there any financial or other interests to the investigator or University arising from this study?	☐	☒	☐
27	Will the research activity involve deliberately misleading participants in any way, or the partial or full concealment of the specific study aims?	☐	☒	☐
28	If YES to any question, please provide full details			
	(this box should expand as you type)			

SECTION H: Anticipated Risks

	Outline any anticipated risks that may adversely affect any of the participants, the researchers and/or the University, and the steps that will be taken to address them. If you have completed a full risk assessment (for example as required by a laboratory, or external research collaborator) you may append that to this form.		
1	**Full risk assessment completed and appended?**	**Yes**	☐
		No	☒
2	**Risks to participants** For example: sector-specific health & safety, emotional distress, financial disclosure, physical harm, transfer of personal data, sensitive organisational information		
	Risk to participants: Transfer of Physical Data and Personal Data.	*How you will mitigate the risk to participants:* Data from questionnaires is stored within the secure MS365 environment and will be anonymised and reported in a way that ensures it can not be triangulated or the data constructed back to the individual. No unnecessary data will be collected.	
	Sensitive Organisational Data *(this box should expand as you type)*	There is no plan to specifically name any areas within the organisation other than the organisation itself. Any ward areas or staff groups will be reported on under a category, e.g. "a surgical ward", or "pharmacists" and if an area is so unique that it could be easily identified from the category then it will not be named or categorised. Any sensitive	

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

PG2 / E1 FORM

		organisational data, e.g. that might be controversial or bring the NHS or certain professions into disrepute will be checked with the organisation and omitted if necessary. *(this box should expand as you type)*
3	If research activity may include sensitive, embarrassing or upsetting topics (e.g. sexual activity, drug use) or issues likely to disclose information requiring further action (e.g. criminal activity), give details of the procedures to deal with these issues, including any support/advice (e.g. helpline numbers) to be offered to participants. Note that where applicable, consent procedures should make it clear that if something potentially or actually illegal is discovered in the course of a project, it may need to be disclosed to the proper authorities	
	N/A *(this box should expand as you type)*	
4	**Risks to the investigator** For example: personal health & safety, physical harm, emotional distress, risk of accusation of harm/impropriety, conflict of interest	
	Risk to the investigator: Conflict of Interest *(this box should expand as you type)*	*How you will mitigate the risk to the investigator:* The evaluator will complete the necessary disclosure forms when needed to declare the evaluation. E.g. if taking part in a procurement that involves the system being evaluated. Reflexivity will also be used throughout the evaluation. *(this box should expand as you type)*
5	**University/institutional risks** For example: adverse publicity, financial loss, data protection	
	Risk to the University: N/A *(this box should expand as you type)*	*How you will mitigate the risk to the University:* *(this box should expand as you type)*
6	**Environmental risks** For example: accidental spillage of pollutants, damage to local ecosystems	
	Risk to the environment: N/A *(this box should expand as you type)*	*How you will mitigate the risk to environment:* *(this box should expand as you type)*

	Disclosure and Barring Service			
	If the research activity involves children or vulnerable adults, a Disclosure and Barring Service (DBS) certificate must be obtained before any contact with such participants.	**YES**	**NO**	**N/A**
7	Does your research require you to hold a current DBS Certificate?	☐	☒	☐
8	If YES, please give the certificate number. If the certificate number is not available please write "Pending"; in this case any ethical approval will be subject to providing the appropriate certificate number.			

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

PG2 / E1 FORM

SECTION I: Feedback, Consent and Confidentiality

1	**Feedback** What de-briefing and feedback will be provided to participants, how will this be done and when?
	Once the evaluation has been completed a report will be produced summarising the key findings. This will be completed in May 2023 and made available to participants as a report provided to the Swansea Bay ePMA clinical reference group. *(this box should expand as you type)*
2	**Informed consent** Describe the arrangements to inform potential participants, before providing consent, of what is involved in participating. Describe the arrangements for participants to provide full consent before data collection begins. If gaining consent in this way is inappropriate, explain how consent will be obtained and recorded in accordance with prevailing data protection legislation.
	The invitation to participate will include a participant information sheet and consent will be captured as part of the data collection for the MS forms questionnaire and separately for any interviews. *(this box should expand as you type)*
3	**Confidentiality / Anonymity** Set out how anonymity of participants and confidentiality will be ensured in any outputs. If anonymity is not being offered, explain why this is the case.
	All information will be kept safe and secure on the NHS Wales MS365 platform. Once finished the study, we will keep some of the data and any reported data will be fully anonymised. Any interviews will be transcribed and the subject details and any personally identifiable information removed. Reports will be written in a way that no-one can work out the individuals that took part. *(this box should expand as you type)*

SECTION J: Data Protection and Storage

	Does the research activity involve personal data (as defined by the General Data Protection Regulation 2016 "GDPR" and the Data Protection Act 2018 "DPA")?	**YES**	**NO**
1	***"Personal data"*** *means any information relating to an identified or identifiable natural person ('data subject'). An identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person. Any video or audio recordings of participants is considered to be personal data.*	☒	☐
	If YES, provide a description of the data and explain why this data needs to be collected:		
2	To assess inclusivity and diversity it may be necessary to classify an age group, and or ethnic background. Professional roles will also be recorded for the same reasons along with the hospital site and category of ward that the person works on. It is not necessary to report any names or any other demographic or PII details. Interviews may be recorded using the MS teams function and a transcription recorded. Once the transcription has been verified, anonymised and stored separately the video will be deleted. *(this box should expand as you type)*		
	Does it involve special category data (as defined by the GDPR)?	**YES**	**NO**

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

PG2 / E1 FORM

16	Export of data outside the UK or importing of data from outside the UK?	☐	☒
17	Use of personal addresses, postcodes, faxes, emails or telephone numbers?	☐	☒
18	Publication of data that might allow identification of individuals?	☐	☒
19	Use of data management system?	☐	☒
20	Data archiving?	☐	☒
21	If YES to any question, please provide full details, explaining how this will be conducted in accordance with the GDPR and Data Protection Act (2018) (and any international equivalents, where appropriate):		
	Data will be collected and stored using the NHS Wales Microsoft 365 environment which is a secure cloud based environment. It will not be "transferred" as such but will be accessible wherever the correct credentials and authentication can be provided. Only data that is relevant and necessary for the evaluation will be collected and processed. *(this box should expand as you type)*		
22	List all who will have access to the data generated by the research activity:		
	DHCW NHS Wales – Administrative Access Users James Goddard – Post-grad Student (doing the activity) *(this box should expand as you type)*		
23	List who will have control of, and act as custodian(s) for, data generated by the research activity:		
	James Goddard – Post-grad Student (doing the activity) *(this box should expand as you type)*		
24	Give details of data storage arrangements, including security measures in place to protect the data, where data will be stored, how long for, and in what form. Will data be archived – if so how and if not why not.		
	Data will be held on the secure NHS Wales Microsoft 365 cloud environment. It will be stored until the evaluation is completed and the consequent dissertation write up and MSc awarded, expected to be by the end of 2024. After this point any PII will be completely removed from all remaining data sets and retained for at least 10 years, after which it will be archived or deleted. *(this box should expand as you type)*		
25	Please indicate if your data will be stored in the UWTSD Research Data Repository (see https://researchdata.uwtsd.ac.uk/). If so please explain. (*Most relevant to academic staff)*		
	(this box should expand as you type)		
26	Confirm that you have read the UWTSD guidance on data management (see https://www.uwtsd.ac.uk/library/research-data-management/)	**YES**	☒
27	Confirm that you are aware that you need to keep all data until after your research has completed or the end of your funding	**YES**	☒

8.6 Appendix 6 Questionnaire Participant Information Sheet

QUESTIONNAIRE PARTICIPANT INFORMATION SHEET

Study Title: - System usability and service evaluation of the electronic prescribing and administration system (ePMA)

Invitation and summary

As a staff member and user who actively uses the ePMA system at your hospital, I would like to offer you the opportunity to participate in the questionnaire to help understand and measure the system usability and learn about your experiences and opinions of the ePMA system. The questionnaire will also help identify any themes that could be evaluated further, and your responses will be invaluable.

Should you wish, I am happy to go through this with you and answer any potential questions that may arise.

Purpose and background to the evaluation.

This evaluation is part of an MSc, exploring the usability and applicability of the implemented solution to the underlying tasks, whilst critically analysing the benefits and limitations of the product, and identifying key areas that pose challenges.

What would taking part involve?

1. You have been contacted by me to offer you the opportunity of participating in the questionnaire phase of the study.
2. You will be required to answer a short 5 minute questionnaire that includes a system usability scoring section, and a section that allows you to answer using your own words.
3. The responses will be collated and any identifiable data will be anonymised.
4. The responses will then be analysed to determine an overall system usability score and to understand applicability of the ePMA system to the tasks required of it.
5. The questionnaire will be analysed to identify common themes expressed and these themes will be grouped and summarised for the study report.
6. Themes may be illustrated in the study report with direct quotes from participants, but the quotes will be anonymous.
7. Themes may also form the basis for questioning around any possible future semi-structure interviews.

Data security

People who do not need to know who you are will not be able to see your name or contact details unless you provide them. Should you do so, any information about you will be kept safe and secure. Once the study has been finished, some of the data will be kept so that the results can be checked and any reported data will be fully anonymised. If taking part in

an interview, these will be transcribed, and the subject details and any personally identifiable information removed. Reports will be written in a way that no-one can work out that you took part in the study.

Next steps

Please complete the online survey, which is anonymous unless you choose to identify yourself with details to be contacted for further evaluation.

Your completion and return of the survey via MS Forms or teams will imply your consent.

If you are willing to participate in this study, please answer the questions in the MS forms link:

https://forms.office.com/e/88YddvMsmV

If you have any further questions about the evaluation study, please contact James Goddard

Further information

Participation in this evaluation is voluntary and should you choose not to participate, this will not impact upon your relationship with the researcher. You can stop being part of the evaluation at any time, without giving a reason.

Thank you for taking the time to read this Participant Information Sheet.

8.7 Appendix 7 Interview Participant Information Sheet

INTERVIEW PARTICIPANT INFORMATION SHEET

Study Title: - System usability and service evaluation of the electronic prescribing and administration system (ePMA)

Invitation and summary

You have received this invite as you completed a questionnaire on ePMA usability and agreed that you would be happy to be contacted about taking part in a follow-up interview.

I would like to offer you the opportunity to participate in a follow-up interview to help understand further and learn about your experiences and opinions of the ePMA system with regards to its usability.

Purpose and background to the evaluation.

This evaluation is part of an MSc, exploring the usability and applicability of the implemented solution to the underlying tasks, whilst critically analysing the benefits and limitations of the product, and identifying key areas that pose challenges.

What would taking part involve?

1. You have been contacted by me to offer you the opportunity of participating in the interview phase of the evaluation.
2. You will be required to answer questions that may be related to themes that have been developed from the questionnaires.
3. The interview will be recorded and transcribed using MS Teams transcription function.
4. The transcript will be checked against the recording – for accuracy and the recording deleted.
5. Any identifiable information will be removed from the transcript, and they will be anonymised.
6. Themes and direct quotes will be collated but not attributed to any individual.
7. The responses will then be analysed to evaluate and to understand the applicability of the ePMA system to the tasks required of it.
8. The interview transcripts will be analysed to identify common themes expressed and these themes will be grouped and summarised for the study report.
9. Themes may be illustrated in the study report with direct quotes from participants, but the quotes will be anonymous.

Data security

People who do not need to know who you are will not be able to see your name or contact details. All information about you will be kept safe and secure. Once the study has been finished, some of the data will be kept so that the results can be checked and any reported data will be fully anonymised. Interviews will be transcribed, and the subject details and

any personally identifiable information removed. The report will be written in a way that no-one can work out that you took part in the study.

Next steps

If you have any further questions about the evaluation study, please contact James Goddard

If you are willing to participate in an interview, then please agree a time slot/reply to this invitation.

It is anticipated that the interview will last up to 30mins.

Further information

Participation in this evaluation is voluntary and should you choose not to participate, this will not impact upon your relationship with the evaluator. You can stop being part of the evaluation at any time, without giving a reason.

Thank you for taking the time to read this Participant Information Sheet.

8.8 Appendix 8 Questionnaire

ePMA Usability and FITT Evaluation Questionnaire

(FITT = **F**it between **I**ndividual, **T**ask and **T**echnology)

This questionnaire is to inform a study for an MSc dissertation which is evaluating the usability and suitability of fit between technology, the tasks involved and the individual.

The responses will be analysed to determine an overall system usability score and to understand applicability of the ePMA system to the tasks required of it. The findings will be used to identify common themes expressed, these themes will be grouped and summarised for the study report.

Any information provided, results, themes from this questionnaire will be anonymised. Completion of the survey will imply your consent.

Section 1: About you
A bit about you (anonymous)

Section 2: Usability Scoring
Please answer 1 to 5 - 1 (strongly disagree) to 5 (strongly agree)

Section 3/4: System Tasks and Ways of Working
Please answer as best you can - don't worry if you feel unable to answer a question.

Section 5:
Contact information if wish to provide for possible follow up interview.

It is estimated that this questionnaire will take 9 mins to complete.

* Required

A bit about you and where you work

(This is anonymous and will be anonymised should you choose to identify yourself later on)

1. What hospital site do you mainly use ePMA in? *

- ◯ Neath Port Talbot
- ◯ Singleton
- ◯ Morriston Hospital
- ◯ Gorseinon
- ◯ Other

2. Have you had previous experience using ePMA in another hospital?

- ◯ Yes
- ◯ No

3. Which hospital/s, and what system?

4. What directorate/speciality do you use ePMA in?

5. What is your profession? *

- [ ] Doctor
- [ ] Nurse
- [ ] Pharmacist
- [ ] Pharmacy Technician
- [ ] AHP
- [ ] Other

6. I describe my role as

7. How many years experience have you had in your current role?

- ◯ Less then 1 year
- ◯ 1-3 years
- ◯ 4-6 years
- ◯ 7-10 years
- ◯ More then 10 years

8. Which category below includes your age?

- ◯ 18-20
- ◯ 21-29
- ◯ 30-39
- ◯ 40-49
- ◯ 50-59
- ◯ 60 or Older

System Usability Scoring

Please answer 1 to 5 - 1 (strongly disagree) to 5 (strongly agree)

9. I like using the system (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

10. I find the system unnecessarily complex (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

11. I think the system is easy to use (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

12. I need the support of a technical person to use the system (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

13. I find the various functions in the system are well integrated (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

14. I think there is too much inconsistency in the system (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

15. I learned to use the system very quickly (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

16. . I find the system very cumbersome to use (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

17. I feel very confident using the system (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

18. I needed to learn a lot of things before I could get going with this system (1 (strongly disagree) to 5 (strongly agree)) *

1	2	3	4	5

System Tasks

In this section please answer the following questions. **For questions 19-23 only answer the questions related to the purpose for which you use the system i.e. for what you answered in question 18..**

19. For what purpose/s do you mainly use the ePMA system for? (you can select more than one option if applicable)? *

- [ ] Medicines Prescribing
- [ ] Medicines Administration
- [ ] Medicines Reconciliation
- [ ] Medicines Ordering
- [ ] Medicines Review
- [ ] Other

20. I feel that the ePMA system allows me to do the medicines related tasks required for my role as a **prescriber** *

- ◯ Strongly agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly disagree
- ◯ N/A

21. I feel that the ePMA system allows me to do the medicines related tasks required for my role for **medicines administration** *

- ◯ Strongly agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly disagree
- ◯ N/A

22. I feel that the ePMA system allows me to do the medicines related tasks required for my role for **medicines reconciliation** *

- ◯ Strongly agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly disagree
- ◯ N/A

23. I feel that the ePMA system allows me to do the medicines related tasks required for my role for **medicines ordering** *

- ◯ Strongly agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly disagree
- ◯ N/A

24. I feel that the ePMA system allows me to do the medicines related tasks required for my role for **medicines review** *

- ◯ Strongly agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly disagree
- ◯ N/A

25. I feel that the ePMA system allows me to do the medicines related tasks required for my role for **what you stated as "other"** *

- ◯ Strongly agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly disagree
- ◯ N/A

26. Please describe why you feel the ePMA system **doesn't** allow you to do the **prescribing** tasks required for your role.

27. Please describe why you feel the ePMA system **allows** you to do the **prescribing** tasks required for your role.

28. Even though you stated "neutral" do you have any comments or thoughts in relation to whether the ePMA system allows you do do the **prescribing** tasks for your role?

29. Please describe why you feel the ePMA system doesn't allow you to do the **medicines administration** tasks required for your role.

30. Please describe why you feel the ePMA system allows you to do the **medicines administration** tasks required for your role.

31. Even though you stated "neutral" do you have any comments or thoughts in relation to whether the ePMA system allows you do do the **medicines administration** tasks related to your role?

32. Please describe why you feel the ePMA system doesn't allow you to do the **medicines reconciliation** tasks required for your role.

33. Please describe why you feel the ePMA system allows you to do the **medicines reconciliation** tasks required for your role.

34. Even though you stated "neutral" do you have any comments or thoughts in relation to whether the ePMA system allows you do do the **medicines reconciliation** tasks required for your role?

35. Please describe why you feel the ePMA system doesn't allow you to do the **ordering medicines** tasks required for your role.

36. Please describe why you feel the ePMA system allows you to do the **ordering medicines** tasks required for your role.

37. Even though you stated "neutral" do you have any comments or thoughts in relation to whether the ePMA system allows you do do the **ordering medicines** tasks for related to your role?

38. Please describe why you feel the ePMA system doesn't allow you to do the **medicines review** tasks required for your role.

39. Please describe why you feel the ePMA system allows you to do the **medicines review** tasks required for your role.

40. Even though you stated "neutral" do you have any comments or thoughts in relation to whether the ePMA system allows you do do the **medicines review** tasks related to your role?

41. Please describe why you feel the ePMA system doesn't allow you to do the **"other"** tasks required for your role.

42. Please describe why you feel the ePMA system allows you to do the **"other"** tasks required for your role.

43. Even though you stated "neutral" do you have any comments or thoughts in relation to whether the ePMA system allows you do do the **"other"** tasks for your role?

Ways of Working

44. Has the ePMA system changed the way you work? *

- ◯ Yes
- ◯ No

45. Please describe how you feel it has changed the way you work.

46. Do you feel the ePMA system has introduced new tasks (tasks that you would not have done before the ePMA system was introduced)

- ◯ Yes
- ◯ No

47. Do you feel the ePMA system has removed tasks (tasks that you would have done before the ePMA system was introduced)

- ◯ Yes
- ◯ No

48. Can you describe the tasks it has introduced (things that you would not have done before the ePMA system, e.g. finding a computer)?

49. Can you explain what tasks you no longer have to do (e.g. finding the paper chart)?

50. The ePMA will mean that you have to work in a particular way or undertake specific tasks that you may or may not have had to have done before. I feel that theses tasks that using the ePMA system requires from me are acceptable?
*

- ◯ Strongly agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly disagree

51. Please describe why the tasks required of you as a result of ePMA system are acceptable.

52. Please describe why the tasks required of you as a result of the ePMA are not acceptable.

53. Even though you stated "neutral" do you have any comments or thoughts in relation to whether the ePMA tasks required of you are acceptable?

54. Please can you describe any benefits you perceive the ePMA system brings?

55. Please can you describe any limitations/dis-benefits of the ePMA system?

56. Do you have any further comments or suggestions that you would like to make? For example, if you could change 3 things about the ePMA system what would these be? Please complete these below.
(This question is optional)

57. Would you be happy to be contacted about about taking part in an interview?

- ◯ Yes
- ◯ No

Contact Details - If happy to be considered for a follow-up interview.

58. Your name

59. Your E-mail address / contact number:

8.9 Appendix 9 Interview Questions

Semi-Structured Interview Questions:

No.	Question
1.	What is your overall impression of how the ePMA system is going?
2.	How has the ePMA system changed your prescribing/administration/review/ordering of medications?
3.	Do you think the ePMA system is safer or less safe than the paper system? Why?
4.	How is the ePMA system helping and/or hindering your work?
5.	Have any new problems or issues emerged?
6.	Can you think of any ways the ePMA system can be improved?
7.	Overall, do you think implementation of the ePMA system has been positive or negative for you as a health professional? For patients? For the organisation as a whole?

8.10 Appendix 10 Additional Results Tables and Figures

Table 8.1 Purposes for using the ePMA system.

Reported Purposes (that ePMA that users mainly used it for)	Count	% of overall users (n=19) who used this function
Meds Administration	9	47.37%
Prescribing	7	36.84%
Review	7	36.84%
Reconciliation	7	36.84%
Ordering	6	31.58%
Reporting	2	10.53%
Support and Training	2	10.53%

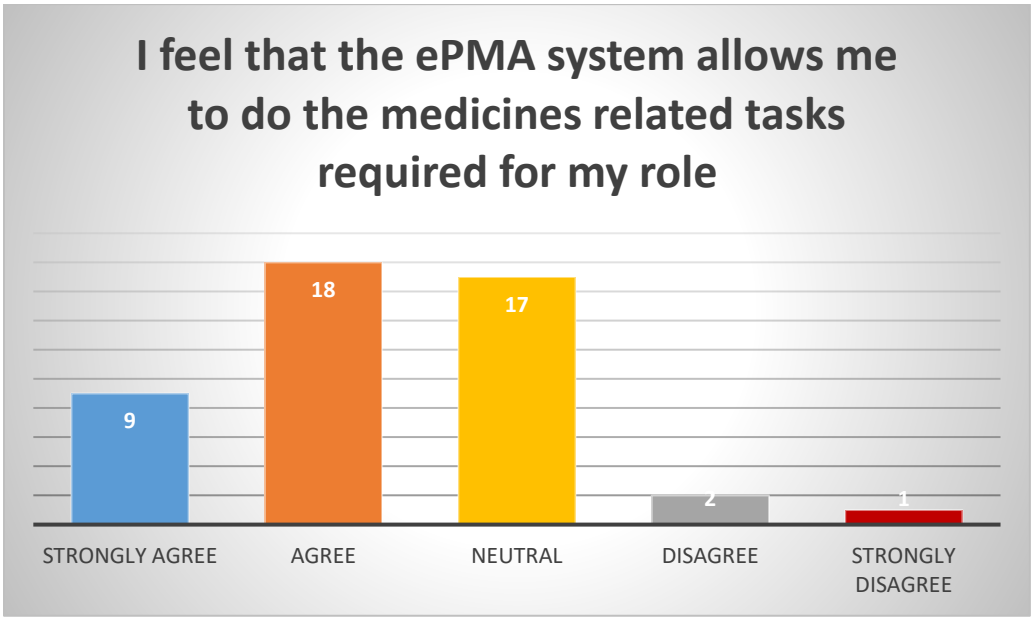

Figure 8.1 Summary of overall responses for medicines related tasks related to individual roles.

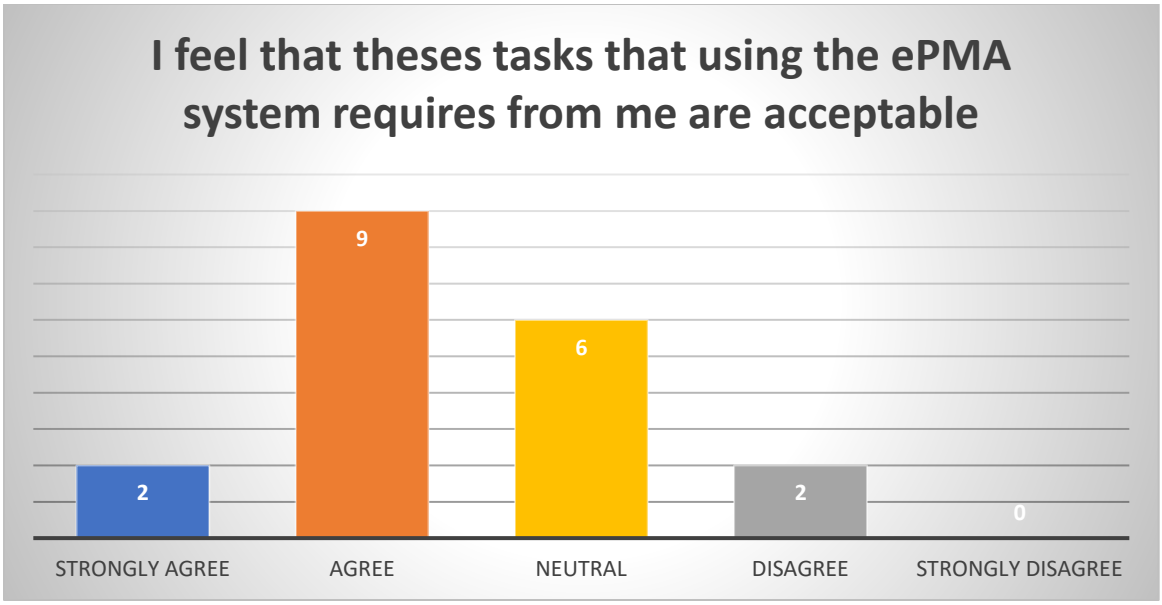

Figure 8.2 Acceptability of ePMA tasks

8.11 Appendix 11 Glossary

Term	Description
ADR	Allergy and adverse drug reaction
CCIO	Chief Clinical Information Officer
CDS	Clinical Decision Support
CDSS	Clinical Decision Support System
Chemocare™	This is a chemotherapy scheduling, prescribing and administration system – used specifically for the treatment of Systemic Anti-Cancer Therapy.
CPOE	Computerised Physician Order Entry
DALs	Discharge Advice Letters These are letters/records that are produced when a patient is discharged. They detail and summarise the medication and medication changes that a patient is discharged on and include other clinical narrative around the reason for admission and the treatment undertaken. These are mainly intended for GPs and Community Pharmacy.
Datix	Risk Management System
DHx	Drug History (Medication History)
EHR	Electronic Health Record\s
EMAR or eMAR	electronic Medication Administration Record
EMMS	Electronic Medicines Management System/s
EPMA or ePMA	Electronic Prescribing and Medicines Administration
FITT	Fit between individual, task and technology
FITTE	Fit between individual, task, technology, and environment
HIS	Health Information System
HIT	Health Information Technology
ISMP	Institute for Safe Medicines Practices (American)
Interoperability	Interoperability is defined by Sabooniha *et al.* (2012) as "*the ability of an information system to use services and data from another information system. This exchange allows these systems to achieve a specified task in each context and provides continuous exchange of information between collaborating HIS*."
IQR	Interquartile Range – A measure of variability for skewed distributions.
IV	Intravenous
LMS	Learning Management System
MAS	Medication Alerting System

MMAT	Mixed Methods Appraisal Tool
Order Sentence	Combination of multiple components required for a prescription that can be selected collectively e.g. “Flucloxacillin 500mg orally four times a day”.
Order Set	A group of one or more prescribing orders which a prescriber can select.
Rx	Prescription
SBUHB	Swansea Bay University Health Board
SUS	System Usability Scale
TAM	Technology Acceptance Model
TOMS	Theatre Operations Management System – Theatre management software that is used for the day to day running of theatres.
TPOM	Technology, People, Organizations, and Macroenvironmental factors
TTF	Task Technology Fit
USE	Usefulness, Satisfaction and Ease of Use
UX	User Interface
WCP	Welsh Clinical Portal This is a national electronic health record type portal that exists and is used in NHS Wales.