GENERATIVE ARTIFICIAL INTELLIGENCE IN PHARMACY SERVICES: EVALUATING PHARMACISTS' PERSPECTIVES AND RESPONSE ACCURACY

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KECERDASAN BUATAN GENERATIF DALAM PERKHIDMATAN FARMASI: PENILAIAN PERSPEKTIF AHLI FARMASI DAN KETEPATAN RESPONS

TAN CHEE HOONG

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DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged.

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TAN CHEE HOONG
P125655

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ABSTRAK

Ahli farmasi menghadapi cabaran dalam mendapatkan maklumat ubat menggunakan bahan rujukan konvensional seperti formulari ubat dan pangkalan data dalam talian. Lebihan barang rujukan sering membebankan ahli farmasi dengan maklumat berlebihan. Ini menyebabkan kekangan masa kerana ahli farmasi memerlukan masa lama untuk mengekstrak maklumat relevan untuk keputusan klinikal yang tepat pada masanya. Kecerdasan buatan generatif mampu menawarkan penyelesaian dengan memperkemas proses pencarian maklumat. Ia boleh menganalisis data dalam jumlah besar, memberikan respons segera dan meringkaskan maklumat yang kompleks. Walau bagaimanapun, terdapat halangan dalam penggunaan teknologi. Sebagai teknologi yang agak baru, wujud kajian terhad mengenai perspektif ahli farmasi terhadap penggunaannya dalam perkhidmatan farmasi. Selain itu, kekurangan ketelusan data yang digunakan dalam teknologi ini menimbulkan kebimbangan terhadap ketepatannya dalam menyediakan maklumat ubat. Kajian ini merapatkan jurang pengetahuan ini dengan menilai perspektif ahli farmasi di MOH Malaysia terhadap teknologi ini dan ketepatan tiga alat kecerdasan buatan generatif iaitu ChatGPT, Google Gemini dan Microsoft Copilot dalam menyediakan maklumat dos ubat. Kajian ini menggunakan reka bentuk kaedah campuran. Fasa pertama menggunakan soal selidik untuk menilai perspektif ahli farmasi dan ketepatan maklumat tiga alat kecerdasan buatan generatif. Ini diikuti dengan temu bual separa berstruktur dalam fasa kedua untuk mendapatkan pandangan yang lebih mendalam. Kajian ini mendedahkan jurang yang ketara antara kesedaran ahli farmasi tentang teknologi ini dan penggunaan sebenar dalam amalan harian mereka. Antara sebab penggunaan terhad ini termasuk kekurangan latihan dalam menggunakan teknologi ini, kebimbangan tentang ketepatan maklumat, implikasi etika dan cabaran praktikal yang berkaitan dengan penggunaan teknologi ini dalam kerja harian ahli farmasi. Kajian ini juga mendapati bahawa ChatGPT dan Microsoft Copilot mempunyai ketepatan yang lebih tinggi daripada Google Gemini dalam menyediakan maklumat dos ubat. Kajian ini menawarkan penemuan yang boleh membuka jalan untuk pembangunan dan aplikasi kecerdasan buatan generatif dalam perkhidmatan farmasi. Penemuan mengenai ciri-ciri UI utama khusus untuk keperluan ahli farmasi boleh digunakan untuk pembangunan UI yang disesuaikan dengan aliran kerja ahli farmasi. Di samping itu, kajian ini telah mencadangkan garis panduan amalan terbaik dalam menangani halangan yang dikenal pasti berkaitan aspek manusia, organisasi, proses dan teknologi untuk menggalakkan penggunaan lebih meluas teknologi ini dalam kalangan ahli farmasi.

ABSTRACT

Pharmacists face challenges in retrieving drug information using conventional reference materials like drug formularies and online databases. The vast amount of reference materials creates source overload, while the excessive information within each source leads to content overload. This necessitates significant time investment to extract the critical details needed for timely clinical decisions, contributing to time constraints. Generative AI offers a solution by streamlining information retrieval. It can analyze vast amounts of data, providing instant responses and summarizing complex information. Despite its potential, widespread adoption of generative AI faces barriers. As a relatively new technology, limited research exists on pharmacist perspectives towards its adoption in pharmacy services. Additionally, the lack of transparency in the data used to train generative AI raises concerns about their accuracy in providing reliable information. This research bridges this knowledge gap by evaluating the perspective of pharmacists in MOH Malaysia towards generative AI and the response accuracy of three generative AI tools, namely ChatGPT, Google Gemini and Microsoft Copilot, in providing drug dosing information. This research employed a cross-sectional two-phased, explanatory sequential mixed methods design. The first phase utilized questionnaires to assess pharmacist perspectives and response accuracy of the three generative AI tools, followed by semi-structured interviews in the second phase to gain deeper insights. This research revealed a significant gap between pharmacist's awareness of generative AI and its actual utilization in their daily practice. Reasons for this limited use include lack of training on using these tools, concerns about accuracy, ethical implications and practical challenges associated with integrating generative AI into existing workflows. This research also found that ChatGPT and Microsoft Copilot demonstrated significantly higher accuracy than Google Gemini in providing drug dosing information, suggesting they may be better suited for drug information retrieval. This research offers insights for future adoption of generative AI in pharmacy services. Findings on key features specific to pharmacists' needs can inform the development of user interface tailored to their workflow. Furthermore, this research has proposed a best practice guideline to encourage wider adoption of this technology among pharmacists by addressing identified barriers related to human, organization, process and technology aspects.

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LIST OF ABBREVIATIONS

4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
ANOVA	Analysis of variance
ChatGPT	Chat Generative Pre-Trained Transformer
GPT	Generative Pre-Trained Transformer
HSD	Honestly Significant Difference
LaMDA	Language Model for Dialogues Applications
MOH	Ministry of Health
MOHMF	Ministry of Health Medicines Formulary
MREC	Medical Research & Ethics Committee
NMRR	National Medical Research Register
RQ	Research question
TPC-OHCIS	Teleprimary Care and Oral Health Clinical Information System
UKM	Universiti Kebangsaan Malaysia
UI	User interface
UTAUT	Unified Theory of Acceptance and Use of Technology

CHAPTER I

INTRODUCTION

1.1 RESEARCH BACKGROUND

Malaysia's healthcare system is undergoing a digital transformation driven by the launch of National Fourth Industrial Revolution (4IR) Policy in 2021. This policy emphasizes utilizing advanced technologies like Artificial Intelligence (AI) to improve healthcare service delivery (Economic Planning Unit 2019). The National 4IR Policy has identified generative AI, a branch of artificial intelligence capable of creating new content based on vast amounts of data, as one of the emerging technologies in the 4IR period (Economic Planning Unit 2019). Generative AI has the potential to significantly benefit the pharmacy services by addressing challenges associated with current drug information retrieval methods.

Currently, pharmacists rely on conventional reference texts, such as published journals, clinical guidelines and drug formularies to answer drug-related queries (Chan et al. 1996). However, this approach presents several challenges. The vast amount of data within these texts can be overwhelming, leading to information overload and making it time-consuming for pharmacists to find what they need (Barker et al. 2019). Additionally, managing information from multiple sources can be cumbersome and lead to inconsistencies (Barker et al. 2019). Furthermore, keeping these reference materials current with the rapid development of drug therapies can be difficult, potentially leaving pharmacists with outdated information. These challenges can lead to delays in finding information and ultimately hinder pharmacists' ability to make critical decisions regarding drug use. Given these limitations of conventional reference materials, generative AI offers a promising solution to the challenges faced by pharmacists relying on them.

Generative AI boasts the potential to significantly improve drug information retrieval in several ways. Firstly, generative AI excels at faster information retrieval. By quickly searching and synthesizing information from various sources, generative AI can provide pharmacists with the information they need efficiently (Al-Ashwal et al. 2023; Olaronke & Olaleke 2015). This eliminates the time-consuming process of manually sifting through vast amounts of data in conventional reference materials. Secondly, generative AI can lead to improved efficiency. By reducing the time spent searching for information, pharmacists can dedicate more time to crucial patient care activities. This translates to a better overall experience for both pharmacists and patients. Finally, generative AI offers a more convenient experience for retrieving drug information. Unlike conventional methods that rely on complex search parameters, generative AI interacts with users in a human-like conversation format (Huang et al. 2024; Zawiah et al. 2023). This streamlines the information retrieval process and eliminates the need for pharmacists to have in-depth knowledge of specific search terms or databases. These potential benefits highlight the transformative potential of generative AI in Malaysian drug information services. Despite the potential benefits, limited research exists on two key aspects of adopting generative AI into drug information services which are pharmacist perspectives and response accuracy.

The successful integration of generative AI into pharmacy services depends heavily on understanding pharmacists' perspectives towards its adoption and use. These perspectives encompass various factors, such as their current knowledge, attitudes and practical experiences. These factors collectively shape how receptive pharmacists are to generative AI and their willingness to embrace this new technology. Research shows that some users are inherently resistant to change and adapting to new technologies (Sallam 2023). Conversely, users with positive attitudes are more likely to accept and integrate new technologies (Sallam et al. 2023b). This research aims to identify the perspectives of Malaysian pharmacists regarding generative AI in pharmacy services. By understanding these perspectives, we can identify potential barriers and opportunities that will influence the adoption of generative AI in this field.

Beyond pharmacist perspectives, response accuracy is another critical factor limiting the adoption of generative AI into pharmacy services. The reliability of drug information generated by generative AI hinges on the accuracy of the training data used. Concerns exist regarding the unknown origin and quality of this data, potentially leading to inaccurate and unreliable responses generated by generative AI tools. This phenomenon, known as artificial hallucinations, refers to situations where AI-generated responses appear correct but is factually inaccurate (Abu Hammour et al. 2023; Hosseini et al. 2023; Temsah et al. 2023). In the context of drug information retrieval, the accuracy of generative AI responses is paramount for pharmacists to trust it as a reliable information source. Therefore, this research will assess the accuracy of generative AI responses through comparative analyses with established conventional reference materials.

This research will address a significant gap in the literature concerning Malaysian pharmacists' perspectives on generative AI and the accuracy of its drug information responses. Currently, there are limited studies in this area. Understanding how pharmacists perceive and interact with generative AI, alongside assessing the information's reliability, are crucial steps towards its effective adoption in Malaysian pharmacy services. By exploring these areas, researchers and healthcare stakeholders can anticipate challenges and identify opportunities to optimize the implementation process. Addressing these research gaps through comprehensive studies will provide essential insights and groundwork necessary for the successful adoption and integration of generative AI in Malaysian pharmacy settings.

1.2 PROBLEM STATEMENT

The ever-increasing amount of drug information creates a significant challenge for pharmacists to find what they need quickly and efficiently. In today’s digital age, they have access to a vast array of reference materials including published journals, clinical guidelines, drug information databases and drug formularies. Pharmacists struggle to filter and sort relevant information from various sources within limited time constraints (Muralidharan et al. 2022; Shrestha et al. 2020). These challenges can be categorized as source overload, content overload and time constraints when utilizing conventional reference materials (Barker et al. 2019).

Source overload refers to the overwhelming abundance of reference materials available to pharmacists (Barker et al. 2019), ranging from published journals and clinical guidelines to drug information databases and formularies. Pharmacists have access to a vast array of resources, each containing valuable insights and data relevant to pharmacy practice. However, navigating through this plethora of sources can be daunting and time-consuming. Pharmacists may struggle to identify the most up-to-date information amidst the multitude of available options. This may leads to inefficiencies in information retrieval and decision-making processes. Source overload also leads to content overload which is another challenge for pharmacists working in drug information services.

Content overload arises from the exponential growth of knowledge and data in the pharmaceutical domain (Barker et al. 2019). As research and development in pharmaceutical industries advance, the volume of available drug-related information expands exponentially. This increases the burden of pharmacists with increasing pool of data to sift through. Drug content consists of a wide range of topics including indications, drug interactions, adverse effects and dosing guidelines. Pharmacists must contend with processing and synthesizing this extensive amount of information, often under time constraints, to provide accurate and timely guidance to patients and healthcare providers. Both source and content overload will burden pharmacists with time constraints in giving accurate information within stipulated time frame.

Time constraints represent a significant challenge faced by pharmacists when utilizing conventional reference materials (Barker et al. 2019). In the fast-paced environment of pharmacy practice, pharmacists are frequently tasked with balancing multiple responsibilities, including drug dispensing, patient counselling, and clinical consultations. With limited time available for each patient interaction, pharmacists must efficiently access and review relevant drug information to address patient inquiries and drug-related issues. However, the pressure to manage competing priorities and meet stringent time demands can impede pharmacists' ability to conduct comprehensive searches and critically evaluate information sources, potentially compromising the quality of patient care and decision-making processes. Generative AI has the potential to address the concerns of source overload, content overload and time constraints faced by pharmacists by streamlining drug information retrieval.

Generative AI tools offer rapid information generation capabilities, potentially streamlining drug information services. In the context of pharmacy services in Malaysia, the integration of generative AI presents both opportunities and challenges. One critical issue revolves around understanding the perspectives and attitudes of pharmacists towards the adoption of generative AI technologies. Limited research exists on this topic in Malaysia, hindering efforts to identify barriers to acceptance and devise strategies for effective adoption.

Without a comprehensive understanding of pharmacists' perspectives, healthcare stakeholders may struggle to navigate concerns related to usability, trust and ethical considerations associated with generative AI technologies. There is also uncertainties regarding the accuracy and reliability of AI-generated responses to drug-related queries which pose significant challenges to patient safety and clinical decision-making. The absence of standardized validation protocols and quality assurance measures exacerbates these concerns, raising the risk of disseminating inaccurate or misleading information to healthcare practitioners and patients.

This research aims to address these knowledge gaps regarding generative AI in Malaysian pharmacy services. First, this research will investigate pharmacist perspectives on generative AI. This involves understanding their knowledge, attitudes and perception in using generative AI for drug information retrieval. Second, this research will compare the accuracy of generative AI responses with conventional reference materials. This analysis will determine how reliable information retrieved from generative AI tools is for clinical decision-making in pharmacy services.

Additionally, the research will gather feedback from pharmacists to identify key user interface (UI) features tailored specifically to their needs. This will ensure a user-friendly and efficient interface that seamlessly integrates into their workflow. Finally, the findings from this research will contribute to the development of a best-practice guideline for the responsible use of generative AI in pharmacy services. This guideline will ultimately improve patient care and outcomes by ensuring patient safety and optimal utilization of this technology.

1.3 OBJECTIVE OF RESEARCH AND SCOPE OF WORKS

This research aims to address two (2) research questions related to generative AI in pharmacy services.

RQ1: What are the perspectives of pharmacists in Malaysia toward generative AI and response accuracy in drug information retrieval?

RQ2: What user interface (UI) design principles and best practices can optimize the adoption of generative AI for pharmacists in Malaysian pharmacy services?

1.3.1 General Objective

This research will explore four (4) objectives to answer the above research questions. Objectives 1 and 2 will answer RQ1 while objectives 3 and 4 will answer RQ2.

1. To assess the pharmacists perspectives on generative AI:
   This objective will investigate Malaysian pharmacists’ attitudes, concerns and perceived benefits of using generative AI for drug information retrieval. Understanding these perspectives is crucial for developing strategies to promote successful adoption.

2. To analyze the accuracy of generative AI responses:
   This objective will compare the accuracy of drug information retrieved from generative AI tools with established reference materials. This analysis will determine the trustworthiness of generative AI information for clinical decision-making.

3. To design a UI that prioritizes pharmacist efficiency and ease of use:
   This objective will focus on designing an intuitive and user-friendly interface for generative AI specific to pharmacists' needs in drug information services. This will optimize user experience and encourage seamless integration into their workflow.

4. To develop best practice guideline for generative AI integration:
   By synthesizing the findings from the previous objectives, this research will create a best-practice guideline to guide the responsible implementation of generative AI in Malaysian pharmacy services. This guideline will address ethical considerations, usability and quality assurance measures to ensure patient safety and optimal use of this technology.

1.3.2 Research Scope

This research will focus on pharmacists serving in Ministry of Health (MOH), Malaysia. We aim to assess their perspectives on generative AI and the accuracy of generative AI responses compared to conventional reference materials for drug information. Three generative AI tools will be used: ChatGPT-3.5, Google Gemini and Microsoft Copilot. These freely available tools will be used to analyse AI accuracy for a set of standardized questions related to common drug dose queries.

Potential limitations includes a modest sample size which can potentially lead to sampling and response bias. Moreover, the questions used in this research are specific to drug doses, which may not be generalizable to all drug information inquiries.

1.4 SIGNIFICANCE OF STUDY

This research has theoretical and practical implications. For theoretical implications, this research can contribute to the findings on pharmacists' perspectives towards generative AI and accuracy of generative AI tools in answering drug information related to drug doses. This research also compares the accuracy between three different generative AI models, namely ChatGPT-3.5, Google Gemini and Microsoft Copilot. Currently, there is limited study being conducted in Malaysia that assess perception of pharmacists generative AI and accuracies between the three generative AI tools in providing responses towards questions related to drug information. This will fill the current literature gap.

The findings from this research could provide references for future studies. Besides that, these findings could also contribute theoretical knowledge on the adoption of generative AI in healthcare settings and advances the field of health informatics in the pharmacy field. It will also redefine how the role of pharmacists and drug information services will evolves with the use of generative AI.

From the practical implication aspect, the findings could potentially improve the delivery of drug information services. Pharmacists may no longer need to refer to various conventional reference materials in seeking accurate answers. This could potentially leads to financial savings as some online databases are expensive to subscribe. Moreover, it will also solves the issues of content overload and source overload. Besides that, other healthcare providers could also utilize generative AI in seeking answers to drug questions, thus reducing the workload of pharmacists. Pharmacists can then concentrate more on medication management to improve patient's outcome.

Other than that, if it is found that generative AI could generate accurate information, it can be used in health promotion. Patients can be encouraged to use generative AI to seek answers to simple medical questions. If deemed accurate, the information generated by generative AI may be more reliable than other web sources that are not accredited.

1.5 ORGANIZATION OF THE PROJECT

This project consist of five chapters. The content of each chapters are outline as below:

1. Chapter 1: This chapter outlines a brief introduction of the research background, problem statement, research questions, research objectives, research scope and significance of the study.

2. Chapter 2: This chapter will present a comprehensive review of the literature on generative AI in drug information retrieval. The review will explore topics including response accuracy, user perspectives, UI design and ethical considerations.

3. Chapter 3: This chapter details and justifies the research methods employed in this research, including the data collection methods (mix-methods) and the statistical analysis techniques used to analyse the collected data.

4. Chapter 4: This chapter presents the findings of the research and discusses the results.

5. Chapter 5: This chapter concludes the project by summarizing its contents and presenting a concise overview of the key findings. It also acknowledges the limitations of the research and offers suggestions for future research in related topics.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Artificial intelligence (AI) is rapidly transforming numerous industries, and healthcare is no exception. This branch of computer science focuses on creating intelligent machines capable of mimicking human intelligence and cognitive functions in tasks like speech recognition, visual perception and decision making (Jarab et al. 2023; Sapci & Sapci 2020; Xuan et al. 2023). The concept of AI can be traced back to the 1950s when it was first introduced in a summer workshop at Dartmouth College in 1956 (Xuan et al. 2023). Since then, advancements in machine learning and neural networks have significantly propelled the field forward (Sallam 2023). The rapid advancement of AI has impacted and revolutionized various industries such as finance, manufacturing, education, transportation and healthcare globally (Chalasani et al. 2023; Zawiah et al. 2023), transforming how information is processed and utilized. Reflecting this global trend, Malaysia's National 4IR Policy was developed to drive digital transformation across various industries including healthcare (Dewadas et al. 2023). Today, AI is one of the disruptive technology in the healthcare industry (Sapci & Sapci 2020).

Healthcare industry has benefits greatly from AI through improve automation, disease diagnosis and clinical decision making (Bhattamisra et al. 2023). Healthcare, a data-driven field, has witnessed a surge in AI applications with the potential to revolutionize patient care and medication management. The recent Malaysia Health White Paper reinforces this notion by highlighting the importance of digitalization in healthcare (Dewadas et al. 2023). Some of the examples of AI branch that garners attention in healthcare industries includes the use of generative AI tools that are capable to generate contents in response to queries and inputs. In the pharmacy services, several studies has been conducted and shown that generative AI is capable in drug information retrieval. However, generative AI is potentially a double-edged sword. It is capable to increases the efficiency users through its generated response but at the same time has the risk of generating misinformation and biases (Hosseini et al. 2023). Thus, further researches on response accuracy and user's perspectives is needed before it can be fully adoption into any sectors.

This research investigates the adoption of generative AI within pharmacy services in the healthcare sector. Here, we focus on pharmacists' perspectives towards generative AI and response accuracy in providing drug information compared to conventional reference materials. To understand the potential applications and limitations of generative AI in pharmacy settings, a comprehensive review of existing literature on generative AI in healthcare is essential. This chapter will follow a structured approach, outlining the key areas of focus within the literature review.

This chapter begins by establishing a foundation of knowledge through a review of existing research on AI in healthcare. We will explore the various functionalities of generative AI in improving work efficiency and patient outcomes across various healthcare domains. Following the broader exploration of AI in healthcare, this chapter will then narrow its focus specifically to pharmacy services. Here, we will delve into how generative AI can be utilized for various tasks, including drug information retrieval, enhancing medication adherence and potentially improving medication safety.

Given the critical importance of reliable drug information in pharmacy services, we will then shift our focus to the accuracy of generative AI compared to conventional reference materials. While acknowledging the limited research directly on pharmacy services, this chapter will explore relevant studies from other healthcare domains. By examining these studies, we aim to gain valuable insights into potential methodologies for evaluating accuracy. While accuracy is undeniably crucial, successful adoption necessitates a comprehensive understanding of user perspectives as well.

Understanding how pharmacists view generative AI adoption is crucial for its successful integration into pharmacy workflows. After all, the successful adoption of any new technology hinges on user acceptance (Chan & Hu 2023). This section of the literature review will examine researches on factors influencing healthcare professionals' acceptance of new technologies. Here, we will focus specifically on pharmacists' perspectives, attitudes and concerns regarding generative AI. The review will explore how factors like knowledge, positive attitudes and perceived ease of use can facilitate adoption of this new technology.

This comprehensive review of existing literature serves as a strong foundation for the subsequent sections of this work. Following this comprehensive literature review, we will conduct a deeper examination of specific aspects influencing the successful adoption of generative AI in pharmacy services. These aspects include UI design, ethical considerations and research gaps. By thoroughly examining the existing literature, we can gain valuable insights to inform the development and implementation of generative AI tools within pharmacy settings, ultimately aiming to improve healthcare delivery and patient outcomes.

2.2 AI TECHNOLOGIES IN MALAYSIA

Malaysia's healthcare sector is undergoing a rapid digital transformation driven by initiatives like the National 4IR Policy and the Malaysia Health White Paper. These initiatives recognize the potential of AI to enhance service delivery, patient care and operational efficiency. The Covid-19 pandemic further accelerated AI adoption, with applications such as AI-assisted hotspot identification and medical image analysis for Covid-19 infections proving valuable tools for healthcare providers (Tung & Dong 2023). Notably, the National 4IR Policy specifically identifies generative AI as one of the disruptive technologies of the future (Economic Planning Unit 2019), underscoring its potential to further revolutionize Malaysian healthcare.

Generative AI is a powerful technology that utilize existing data to create new, human-like content such as texts, sounds and images (Chan & Hu 2023; Dixit & Jain 2023; Seth et al. 2023). It is trained on vast amounts of data, often sourced from websites and articles across the internet (Johnson et al. 2023). Based on this training, generative AI can then create new information and content relevant to the specific data it has been exposed to. Several publicly available generative AI tools exist in Malaysia, including ChatGPT (Chat Generative Pre-Trained Transformer), Google Gemini and Microsoft Copilot.

Released in November 2022 by OpenAI, ChatGPT leverages natural language processing platform to create a chatbot capable of human-like interaction and performing tasks like scripting, writing and answering questions (Arya et al. 2024). ChatGPT's training utilizes a Generative Pre-trained Transformer (GPT) neural network model trained on vast text and code datasets, including transcripts and human feedbacks (Arya et al. 2024). However, the training data only extends up to January 2022, creating knowledge gap for events that transpired afterwards (Arya et al. 2024). Users may receive inaccurate or incomplete information from ChatGPT for events after January 2022.

On the other hand, Microsoft Corporation developed Microsoft Copilot (Bhardwaz & Kumar 2023). Previously known as Bing AI, Microsoft Copilot is a generative AI that integrates with Microsoft Bing search engine (Arya et al. 2024). It likely leverages a GPT-like architecture that may be similar to OpenAI's model. The integration with search engine offers Microsoft Copilot a key advantage compared to ChatGPT. Microsoft Copilot are able to access publicly available information and online content directly from the web (Arya et al. 2024). However, the accuracy and reliability of this information can be a concern, as extracted information may not be independently verified (Arya et al. 2024).

In contrast, Google Gemini (previously known as Google Bard) is a generative AI developed by Google (Bhardwaz & Kumar 2023). While the specifics of its underlying neural network architecture remain undisclosed, it likely leverages a powerful transformer-based model similar to GPT (Bhardwaz & Kumar 2023). Google Gemini is further enhanced by LaMDA (Language Model for Dialogues Applications) technology, resulting in a user-friendly interface that prioritizes verified information from Google Search (Arya et al. 2024). Unlike some generative AI tools with static training data, Google Gemini continuously learns and updates in real-time through user input (Arya et al. 2024). This makes it a valuable tool for tackling evolving tasks and acquiring up-to-date knowledge.

Each generative AI utilizes different training data and information sources, thus responses generated by each generative AI tends to be different and may not be generalized across all topics (Caramancion 2023). However, generative AI is rapidly transforming healthcare, impacting everything from medical practice to education and pandemic response. The following sections will explore examples of how generative AI is being utilized in healthcare.

2.3 GENERATIVE AI IN HEALTHCARE

The applications of generative AI in healthcare are diverse, offering immense potential to improve work efficiency, medications management and overall patient care (Abu Hammour et al. 2023). It is postulated that generative AI may even outperform humans in certain tasks, potentially minimizing human errors (Yim et al. 2024). This has the potential to significantly improve various aspects of healthcare delivery. A systematic review by Yim et al. (2024) identified three key applications of generative AI in medical practice: assisting, guiding and automating medical work process.

One promising application of generative AI lies in assisting medical work. Various studies have established that generative AI may assist in diagnosing and disease detection through machine learning, deep learning and image analysis (Yim et al. 2024). It benefits fields like pathology and radiology by helping interpret results and minimizing errors caused by medical specialists (Tung & Dong 2023; Xuan et al. 2023). Besides that, Generative AI are also capable to assist physicians in analyzing and interpreting electrocardiogram, Doppler ultrasounds and electromyography readings for intensive care patients (Xuan et al. 2023). Generative AI also helps to guide medical decision in tandem with assisting medical work.

Multiple researches have shown that generative AI can guide medical decisions by recommending personalized treatment options based on patient's unique data set. These data set includes information from patient's medical history, genomics, imaging results and lab tests (Bhattamisra et al. 2023). By analyzing this data using various algorithms, generative AI can suggest personalized medicine tailored to individual patient's needs, potentially leading to better patient outcomes (Bhattamisra et al. 2023; Roosan et al. 2024; Sallam 2023). However, real-world implementation of personalized medicine using generative AI in healthcare facilities remains limited (Yim et al. 2024). Another application of generative AI that has been identified by Yim et al. (2024) is to automate medical practice.

By automating specific tasks within healthcare, generative AI can minimize healthcare providers involvement in repetitive such as updating patient's medical records and billing (Bhattamisra et al. 2023). Although AI automation in healthcare is still in its early stages (Yim et al. 2024), it shows promise due to its relative ease of programming and cost-effectiveness (Bhattamisra et al. 2023). When implemented correctly, AI automation can ensure consistent, reliable and standardized delivery of healthcare services, benefitting both patients and healthcare providers (Yim et al. 2024). Additionally, generative AI automation has the potential to alleviate healthcare workforce shortages by supplementing human capabilities in making valuable and timely clinical decision (Xuan et al. 2023). However, despite the potential for reduced operating costs and increased work efficiency, there are currently minimal instances of generative AI automation within healthcare facilities (Yim et al. 2024).

Healthcare information and knowledge are constantly evolving with new evidences and researches. Generative AI can serves as a valuable tool for healthcare providers by enhancing information retrieval and simplifying complex medical concepts (Dhanvijay et al. 2023; Sallam et al. 2023a). For example, healthcare providers can simply ask generative AI questions with relevant details to access information about diseases, diagnoses and potential treatment suggestions (Alanzi 2023). This enables them to understand complex concept quickly and make informed clinical decisions in a timely manner (Johnson et al. 2023). Notably, research suggests that generative AI, in particularly ChatGPT, can achieve passing or near passing scores on the United States

Medical Licensing Exam, demonstrating their potential as reliable medical information sources and clinical decision support tools (Johnson et al. 2023).

Beyond these applications, generative AI is also gaining traction in healthcare education. Studies have shown that generative AI is capable to personalize learning for medical students by tailoring content, information and assessments to individual needs (Sallam et al. 2023a). Generative AI can also functions as an interactive learning tool, providing instant feedback and quick answers to medical students practicing clinical reasoning and evidence-based decision-making (Sallam et al. 2023a). Ultimately, this can promote continuous self-directed learning, improve analytical skills and encourage critical thinking among future healthcare providers (Dhanvijay et al. 2023).

In addition to medical practice and healthcare education, generative AI usage has also been explored in pharmacy services. The following sections will delve deeper into specific applications of generative AI within pharmacy services.

2.4 GENERATIVE AI IN PHARMACY SERVICES

The pharmaceutical sector is undergoing significant digital transformation fuelled by advancements in technology like AI (Jarab et al. 2023). AI holds immense potential in tow key areas: drug discovery and improving pharmacy practice in healthcare facilities (Chalasani et al. 2023; Jarab et al. 2023). Drug discovery is a complex multi-step process involving target drug identification, preclinical development and regulatory approval (Sharma & Thakur 2023). Traditionally, researchers rely heavily on computational chemistry for tasks like screening potential drug compounds, predicting efficacy, postulating side effects and discovering new drug compounds (Sharma & Thakur 2023). According to Sharma and Thakur (2023), generative AI tools like ChatGPT can be valuable tools in drug discovery.

Generative AI can tackle complex computational questions and generate predictions relevant to the discovery process (Sharma & Thakur 2023). ChatGPT are also capable to predict pharmacokinetic and pharmacodynamic properties of potential new drug compounds, streamlining researchers' workflows (Zhao & Wu 2023). While not without limitations, generative AI is emerging as a useful tool for accelerating drug discovery (Sharma & Thakur 2023). Beyond drug discovery, generative AI is transforming pharmacy services in healthcare facilities.

Pharmacies within healthcare facilities play a crucial role in ensuring safe and effective medication use for patients. Services like clinical pharmacy, inpatient and outpatient pharmacy, therapeutic drug monitoring, total parenteral nutrition, cytotoxic drug reconstitution and drug information services are all part of their core functions. Current pharmacy workflows often involve manual processes, burdening staffs as prescription volumes and medication complexity increases. Reliance on manual tasks alongside rising prescription volume and complexity of medication regimens creates a significant risk of medication errors, jeopardizing patient safety. Driven by the need to minimize medication errors, pharmacy services are undergoing digital transformation. Generative AI offers significant potential to optimize workflows by eliminating redundancy and streamlining unnecessary procedures (Raza et al. 2022).

Generative AI can be potentially applied in pharmacy services to improve medication therapy management. Medication therapy management focuses on tailoring a patient’s medication regimen to maximize treatment success (Roosan et al. 2024). This includes gathering patient’s health information, prescribing or modifying medication plans and providing resources to improve medication adherence (Roosan et al. 2024). By integrating with electronic health records, generative AI can streamline medical record keeping, tracking patient medication histories and recommend evidence-based therapies tailored to individual health issues (Chalasani et al. 2023; Raza et al. 2022; Roosan et al. 2024). By analyzing vast amounts of patient data and medication plans, generative AI can potentially expedite and streamline the medication therapy management process.

Furthermore, generative AI can improve medication adherence (Salama 2024), a critical aspect of medication management. Missed dose or incorrect doses can compromise treatment outcomes (Salama 2024). Generative AI such as ChatGPT can be programmed to send personalized medication reminders and provide clear instructions tailored to each patient’s specific needs (Salama 2024). This customization enhances the effectiveness of the reminders and instructions, ultimately improving medication adherence (Salama 2024).

In addition to that, generative AI can be used to analyze and predict potential drug interactions between medications (Chalasani et al. 2023; Roosan et al. 2024). Traditionally, this crucial safety check requires pharmacists to manually screen every prescription for potential drug interactions. Trained on vast drug interaction databases, generative AI can analyze a patient's entire medication regimen and automatically alerts pharmacists to any potential interactions (Roosan et al. 2024). By automating this process, generative AI improves patient safety by efficiently reducing the occurrence of drug interactions.

The applications of generative AI in the pharmaceutical sector are still evolving, but its potential to revolutionize drug discovery, streamline pharmacy workflows and enhance patient care is undeniable. Besides that, generative AI's capabilities extend beyond drug discovery and workflow optimization. Studies have shown its effectiveness in information retrieval, improving the delivery of drug information services.

2.5 DRUG INFORMATION SERVICES

Drug information services play a crucial role in healthcare facilities. They provide accurate, up-to-date and unbiased information on medications to both healthcare providers and patients (Shrestha et al. 2020). Pharmacists manage these specialized services within healthcare facilities (Alamri et al. 2017; Muralidharan et al. 2022). The rapid development of new medications and treatment regimens has create large amounts of data regarding medications and diseases (Muralidharan et al. 2022). This can create a medication information gap for both healthcare providers and patients, potentially leading to incorrect medication use (Muralidharan et al. 2022).

Drug information services bridge this gap by ensuring both healthcare providers and patients have access to accurate medication information for safe and effective use. These services provide quick responses and information to queries by healthcare providers and consumers regarding medication-related details such as drug doses, indications, side effects and drug safety profile (Muralidharan et al. 2022). Empowered by drug information services, healthcare providers can make more rational prescribing decisions while consumers gain the confidence to safely navigate their medication use (Alamri et al. 2017; Muralidharan et al. 2022; Shrestha et al. 2020).

A study by Alamri et al. (2017) in Saudi Arabia found that physicians and pharmacists are the primary users of drug information services, followed by nurses and patients. This aligns with the data from the Pharmaceutical Service Division, MOH Malaysia. Their 2022 annual report indicated a total of 250,514 queries received across all healthcare facilities within the MOH Malaysia. Notably, healthcare providers within the Ministry submitted 96.05% of these queries, with patients or the public constituting the remaining 3.62% (Figure 2.1). This data demonstrates that healthcare providers are the main target users of drug information services, likely due to their frequent encounters with drug-related questions during patient care. The report also revealed that drug doses and administration were the most frequent topics of inquiry (Figure 2.2).

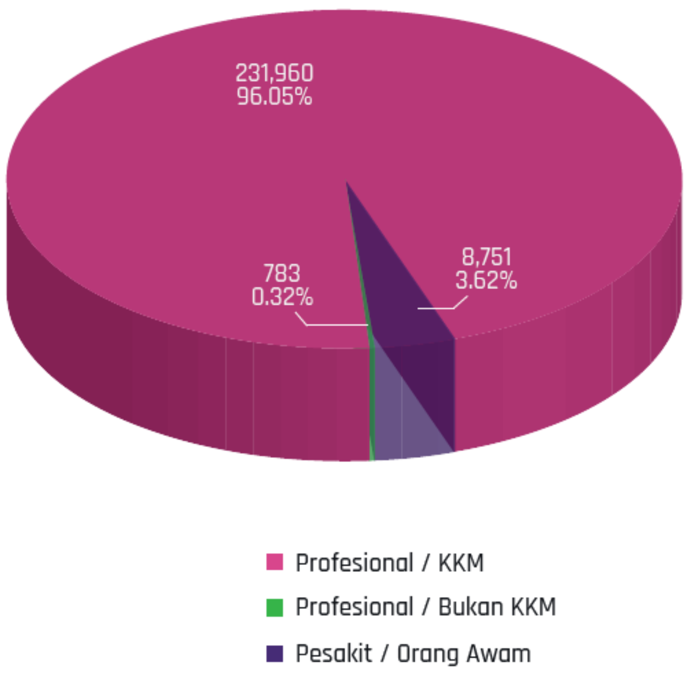


Figure 2.1 Drug queries received in MOH Malaysia facilities

Source: Pharmaceutical Services Programme (2023)

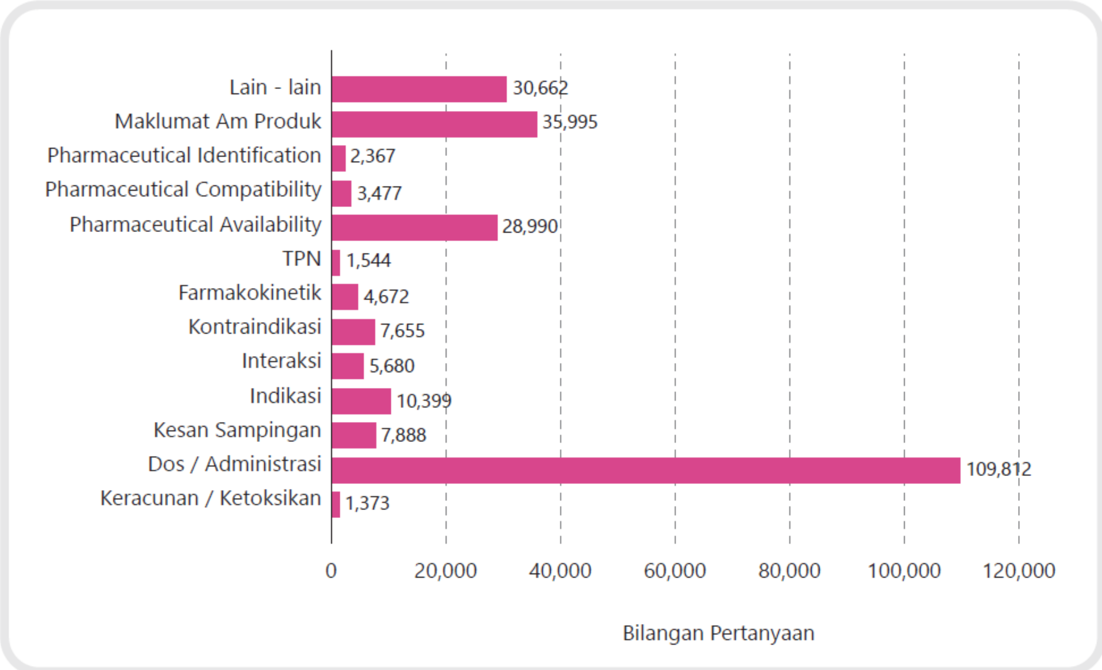


Figure 2.2 Drug queries by topics

Source: Pharmaceutical Services Programme (2023)

Pharmacists rely on their knowledge and various reference materials to answer drug information queries (Chan et al. 1996). These reference materials can be broadly categorized as primary sources, secondary sources, tertiary sources and other sources (Muralidharan et al. 2022). Primary sources consists of original, published clinical studies, research papers and other clinical event records (Muralidharan et al. 2022). Examples include adverse drug documentations, randomized controlled clinical trials and cohort studies (Muralidharan et al. 2022).

Secondary sources are published works that provide overview, interpretation and analysis of primary research findings (Muralidharan et al. 2022). These resources often come in the form of academic journals, review articles, systematic reviews, meta-analyses, books and other form of literatures. Drug information services typically subscribe to databases like UpToDate, Micromedex and Pubmed to assess these secondary sources quickly and efficiently (Muralidharan et al. 2022).

Finally, tertiary sources refers to general literature or compilations of secondary sources (Muralidharan et al. 2022). This includes textbooks and clinical practice guidelines (Muralidharan et al. 2022), serving as a convenient general reference materials. Each type of sources have different distinctive purposes in drug information services, with primary sources providing original data, secondary sources offering analysis of primary sources and tertiary sources providing broad overviews and summaries. In addition, drug information services may also consult information from pharmaceutical companies and government websites to obtain the most current or specific details on a medication (Muralidharan et al. 2022). Despite this variety being a valuable asset, it also presents challenges for pharmacists. These challenges includes source overload, content overload and time constraints (Barker et al. 2019).

Pharmacists often face sources overload due to the variety and large amount of reference materials available (Barker et al. 2019). Due to digital transformation, pharmacists have access to many information sources through the internet. These sources includes primary and secondary sources. Some tertiary sources may have digital copy and accessible through the internet as well. Source overload causes struggle and challenges for pharmacists to identify the most relevant and up-to-date information sources. In addition, source overload also leads to content overload.

Content overload occurs when there is too much information being retrieved from the reference materials (Barker et al. 2019). Medications related information are constantly updated and added as there is constant advancement in the pharmaceutical sectors. Although pharmacists are able to retrieved information through variety of sources, not all information retrieved are relevant to the queries received by pharmacists. Therefore, pharmacists requires time to sift through and extract the relevant information. Content overload increases the workload of pharmacists in extracting and synthesizing the relevant information. Moreover, due to other responsibilities such as dispensing and medication counselling, pharmacists often face time constraints to extract the relevant information and accurate response within the stipulate time frame (Barker et al. 2019).

While some healthcare facilities boast a wealth of drug information resources, other face limitations in this regard. A lack of sufficient reference materials has been identified as a constraint for some hospital pharmacists (Chan et al. 1996). Subscription fees for essential primary and secondary sources can be a significant financial hurdle for some healthcare facilities, limiting their access to the most up-to-date drug information (Shrestha et al. 2020). On the other hand, information from tertiary sources may have limitations in their update frequency (Shrestha et al. 2020). This can leads to dissemination of outdated information, potentially compromising patient care.

The digital age has revolutionized how healthcare providers access drug information. For example, healthcare providers nowadays uses smartphones as it contains a variety of functionalities (Muralidharan et al. 2022; Shrestha et al. 2020). Many drug information apps have been developed and healthcare providers can access information on their fingertips (Shrestha et al. 2020). Beyond apps, healthcare providers are increasingly leveraging the internet and exploring innovative tools such as generative AI to find the latest drug information, expanding their access to a wider range of resources (Morath et al. 2023). The following section will delve into the specific applications of generative AI in drug information services.

2.6 GENERATIVE AI IN DRUG INFORMATION SERVICES

Drug information services rely on a vast library of conventional reference materials, including databases, medical journals, textbooks and online resources (Muralidharan et al. 2022). While these materials offer comprehensive information, they come with limitations as mentioned in the previous section. Pharmacists can face information overload, struggling to identify the most relevant details amidst a sea of data (Barker et al. 2019). Additionally, the sheer volume of information often requires significant time investment to sift through and synthesize (Olaronke & Olaleke 2015). Furthermore, printed materials like textbooks may not be updated frequently, potentially leading to outdated information.

Generative AI presents exciting possibilities for streamlining information retrieval and enhancing drug information services. One of its key strengths lies in processing vast amounts of data from diverse sources. It can act as a powerful information retrieval tool to aid pharmacists in searching and summarizing information. For example, ChatGPT has shown promise in delivering drug information and summarizing medical literature (Som 2023).

Pharmacists often spend a considerable amount of time searching for information on new medications, drug updates and complex clinical scenarios. Generative AI can be trained on various drug information databases, clinical guidelines and medical literature. This training allows generative AI tools to generate concise and relevant summaries of information almost instantly in response to pharmacist queries (Al-Ashwal et al. 2023; Olaronke & Olaleke 2015). This eliminates the need for pharmacists to sift through numerous references, saving valuable time and allowing them to focus on patient care and other responsibilities. Studies indicate that a significant portion of pharmacists utilizing generative AI as a drug information source find it as valuable, or even more advantageous than conventional reference materials (Abu Hammour et al. 2023). The ability to answer medication-related questions of varying complexity suggests that the use of generative AI in drug information services is likely to increase in the future (Morath et al. 2023).

Another strength of generative AI lie in its ability to simulate human-like conversation in response to queries or prompts (Huang et al. 2024; Zawiah et al. 2023). This allows for dynamic conversations (Zhang & Kamel Boulos 2023), where generative AI can address follow-up questions. Some users report finding generative AI more convenient for complex queries compared to search engines (Dixit & Jain 2023). Unlike search engines that return a list of links, generative AI offers a more convenient experience for complex queries by interacting with users in a natural conversation. Generative AI utilizes coherent, well-structured and grammatically correct sentences, streamlining the information retrieval process (Dixit & Jain 2023). Additionally, generative AI provides real-time answers (Y. et al. 2023), enabling healthcare providers to obtain information instantly which is beneficial in situations requiring urgent clinical decisions.

Studies investigating the performance of generative AI in clinical pharmacy settings have shown promising results. For instance, research on ChatGPT found it excels in providing accurate and comprehensive information on drug-related topics such as dosing regimens, drug indications and common adverse reactions (Huang et al. 2024). Huang et al. (2024) concluded that ChatGPT can be a valuable information source to aid pharmacists in their information searches. However, the research also highlighted a potential drawback: ChatGPT's human-like responses can sometimes be overly technical, lacking clarity for those without a strong medical background (Huang et al. 2024).

Further research in Taiwan assessed the suitability of ChatGPT in answering drug-related questions from both the general public and healthcare providers (Hsu et al. 2023). Hsu et al. (2023) found that ChatGPT provided appropriate answers in 64% of the 80 questions analyzed. Interestingly, the study also revealed a higher success rate for responses directed at the general public compared to healthcare providers (Hsu et al. 2023). The difference in performance might be due to the nature of the queries. Healthcare providers often pose more complex questions that necessitate access to specialized data, such as evidence-based medicine databases and paid resources, which ChatGPT might not have been trained on (Hsu et al. 2023).

Another study conducted in community pharmacy settings found that ChatGPT's accuracy varied depending on the category of drug information (Salama 2024). Salama (2024) reported the following accuracy rates for ChatGPT: recommending drug alternatives (80%), adverse drug effects (65%), drug dosing (35%) and drug interactions (30%). These findings differ slightly from the previous studies, suggesting that ChatGPT may perform better in hospital settings compared to community pharmacies, possibly due to the different complexity of queries in each environment.

The studies above have convincingly demonstrated the potential of generative AI to revolutionize drug information services. By adopting this technology in their daily routines, pharmacists can significantly enhance their workflow. However, full adoption hinges on addressing key challenges like response accuracy, user perceptions and ethical considerations. We will delve deeper into these challenges in the following sections. By acknowledging these challenges and implementing effective strategies, we can unlock the full potential of generative AI in pharmacy services. In the following section, we will explore the crucial issue of response accuracy.

2.7 EVALUATION OF GENERATIVE AI ACCURACY

Generative AI holds immense potential for revolutionizing drug information services. However, a critical challenge lies in ensuring the accuracy and reliability of the information it provides. This is paramount as inaccurate information can have serious consequences for clinical decisions and patient safety. One key concern is the phenomenon of hallucination in generative AI. This occurs when the generative AI generates nonsensical, inaccurate or scientifically false (Sallam et al. 2023a; Takagi et al. 2023)**.** These responses are often made-up and fabricated (Liu et al. 2023)**,** but sounds plausible and credible to individuals lacking expertise in the domain (Sallam 2023). Studies also indicate that hallucination can occur in any generative AI tools, regardless of the complexity of the query, affecting both simple and complex queries (Caramancion 2023; Hsu et al. 2023).

Beside hallucination, other potential errors in generative AI responses have been identified in the field of nuclear medicine. These include delusion (persistently with false information even after correction), illusion (seemingly reasonable but incorrect responses), delirium (nonsense or irrelevant responses), confabulation (fabrication of information to fill knowledge gaps), extrapolation (drawing incorrect conclusions based on existing data) and miscalculation (incorrect calculations despite having the right formula and data) (Currie & Barry 2023). The limited quality of training data sets can contribute to these inaccuracies (Sallam et al. 2023a). Poor quality data sets, including those that are limited, inaccurate or biased, can lead to inaccurate generated responses. The possibility of errors necessitates the evaluation and proofreading of all responses generated by generative AI (Hosseini et al. 2023).

Several studies have investigated the accuracy of generative AI in drug information services compared to conventional reference materials. The results are mixed, with varying levels of accuracy reported for different generative AI tools and studies. For example, Huang et al. (2024) found ChatGPT to be capable of providing accurate drug information, while Hsu et al. (2023) and Salama (2024) reported accuracy ranges between 30% - 80%. Notably, Morath et al. (2023) found only 26% of ChatGPT responses in their study to be accurate, suggesting the need for further development. However, a benefit noted by Morath et al. (2023) is that ChatGPT responses tend to be comprehensive, even if inaccurate.

Comparative studies have also been conducted to assess the accuracy of different generative AI tools in pharmacy services. Al-Ashwal et al. (2023) found Microsoft Bing has the highest accuracy for detecting drug interactions, followed by Google Bard and ChatGPT. The authors suggest that Microsoft Bing's ability to access additional information from the web contributes to its superior performance (Al-Ashwal et al. 2023).

Researches outside pharmacy services have yielded similarly diverse findings. For instance, Rahsepar et al. (2023) reported higher accuracy for ChatGPT compared to Google Bard in answering lung cancer questions. In contrast, Raimondi et al. (2023) found Microsoft Bing to outperform both ChatGPT and Google Bard in ophthalmology exams. Dhanvijay et al. (2023) observed the opposite trend in physiology, with ChatGPT achieveing the highest accuracy. These findings remind pharmacists that different generative AI tools may work better for different areas of medicine. By keeping this in mind when evaluating tools for drug information services, pharmacists can choose the best option for their needs and ensure they get reliable information about medications.

The successful adoption of generative AI into drug information services hinges on its accuracy. Further research is crucial, with comparative studies evaluating the responses of different AI tools against established reference materials. By carefully evaluating accuracy, pharmacists can assess the reliability of generative AI for their specific needs. This focus on accuracy is also critical for fostering trust among pharmacists, ultimately paving the way for its safe and effective integration into drug information retrieval workflows. In the next section, we will explore how users in various domains perceive generative AI.

2.8 PHARMACISTS PERSPECTIVES ON GENERATIVE AI ADOPTION

The successful adoption of any new technology in pharmacy services requires a comprehensive understanding of pharmacists' perspectives. Social, psychological, cultural and technical factors all play a role in shaping the user experience with new technologies, ultimately influencing their adoption (Sallam et al. 2023b). Research on pharmacist perspectives can provide valuable insights on potential benefits and barriers to implementing generative AI in pharmacy services.

Previous studies have explored user perspectives on generative AI in healthcare. A study by Temsah et al. (2023) found that most healthcare providers are comfortable using generative AI tools like ChatGPT in their daily practice and expressed interest in learning more about them. The study also identified potential benefits in areas like medical research, literature review, patient support and aiding clinical decision making (Temsah et al. 2023). However, concerns regarding information source credibility, accuracy, medicolegal implications and potential job displacement were also raised (Temsah et al. 2023).

Another survey by Abu Hammour et al. (2023) explored pharmacist perceptions of generative AI in Jordan. The majority of participants agreed that generative AI could benefit pharmacy services, particularly in generating educational materials related to medications (Abu Hammour et al. 2023). However, concerns regarding response accuracy and privacy issues were also prevalent (Abu Hammour et al. 2023). The study also found that pharmacists who frequently used generative AI tools were more likely to have positive perceptions of them (Abu Hammour et al. 2023).

Interestingly, the study by Abu Hammour et al. (2023) found that pharmacists' perceptions of generative AI were not significantly influenced by age, gender, education level or prior experience with generative AI technologies. This contradicts the findings by Bodani et al. (2023) who investigated the general public’s perspective in Pakistan. The study reported that gender and education level significantly impacted the usage of generative AI, with women and individuals with higher education utilizing it more frequently (Bodani et al. 2023). While the study suggests that higher education might lead to greater awareness of generative AI, the reason behind the observed gender difference remains unexplained.

Overall, these studies suggest that perspectives on generative AI adoption are diverse and complex. Individuals who endorse generative AI believe it can alleviate their workload. Pharmacists who understand the potential benefits of generative AI for their daily practice are more likely to hold a favourable attitude towards it. However, concerns about its accuracy, potential job displacement and data privacy remain significant hurdles that need to be addressed. Additional research is needed to assess the perspectives of pharmacists in Malaysia and address the associated challenges to ensure successful adoption of generative AI in pharmacy services. Furthermore, exploring the UI design is crucial, as ease of use can significantly influence pharmacist perceptions.

2.9 USER INTERFACE DESIGN FOR GENERATIVE AI IN PHARMACY SERVICES

Research by Sallam et al. (2023b) underlines a critical factor influencing user behaviour and positive perceptions towards generative AI: perceived ease of use. This concept refers to "the degree to which a person believes that using a particular system would be free of effort” (Davis 1989). Simply put, people are more likely to adopt new technologies they perceive as easy to use compared to others (Davis 1989). In the context of pharmacy services, the design of the generative AI UI plays a crucial role. A well designed UI can streamline workflows, improve efficiency and ultimately enhance user satisfaction with the technology. Therefore, it is essential to examine key considerations for designing an effective, user-friendly and customized UI for generative AI in pharmacy services. Insights from various research areas can guide this process, ensuring the development of a UI that pharmacists find effortless to learn and use.

The UI acts as bridge between pharmacists and generative AI tools. It directly impacts how easy the technology is to use, which is a key factor influencing user adoption. A user-friendly UI can make pharmacists more comfortable and confident in using generative AI, ultimately leading to its wider adoption in pharmacy services. Understanding user adoption of new technologies is key, and the Unified Theory of Acceptance and Use of Technology (UTAUT) model provides a valuable framework for this.

Developed by integrating established theories like Technology Acceptance Model, UTAUT model considers multiple perspectives to provide a comprehensive understanding of user behaviour towards technology adoption (Menon & Shilpa 2023). This model has been used to explore the factors influencing user adoption and utilization of technology, including generative AI. In a study applying UTAUT model to assess ChatGPT, Menon and Shilpa (2023) found that most respondents praised the UI's friendliness and comfort. This positive perception of the UI directly translate to an enhanced feeling of ease of use for the technology itself. This study serves as a strong example of how a user-friendly UI can significantly influence the adoption of new technologies, including generative AI in pharmacy services.

Beyond the UTAUT model, specific UI design considerations are crucial for generative AI in pharmacy services. UI encompasses characteristics such as navigation, terminologies and screen designs (Ramayah 2006). These characteristics often influence perceived ease of use (Ramayah 2006). Research has demonstrated that implementing seamless navigation with navigation aids in enterprise resource planning systems improves users' ease of use (Calisir & Calisir 2004). These aids includes broad and shallow menu structure as well as function keys for frequent control entries (Calisir & Calisir 2004). Other navigation features include hyperlinks to access additional information of interest (Ramayah 2006).

Other than that, Ramayah (2006) states that interface with clear terminologies are preferred. Terminologies should avoid jargon and technical terms (Ramayah 2006). Clear explanations should accompany technical terms if they are unavoidable. For example, studies found that ChatGPT has a positive impact on user experience by employing language that is easy to grasp and understand (Menon & Shilpa 2023; Skjuve et al. 2023). On the other hand, screen design refers to the arrangement of content in terms of colour schemes, layout, paragraph format, buttons, icons, line spacing and font sizes (Ramayah 2006). Ramayah (2006) states that all interface screens and features must have consistency at all times to improve ease of use. The utilization of graphical UI instead of text-based interface has also demonstrated to enhance user satisfaction (Hu et al. 1999). Integrating similar navigation aids and features into the UI of generative AI for pharmacy services may improve usability and facilitate efficient interaction for pharmacists.

In conclusion, a well-designed UI is critical for successful integration of generative AI tools in pharmacy services. Perceived ease of use, a key factor influencing user behaviour, is heavily influenced by UI design. UTAUT model provides a valuable framework for understanding user adoption of new technologies. Studies applying UTAUT to generative AI, like the one by Menon & Shilpa (2023) on ChatGPT, highlight the positive impact of a user-friendly interface on ease of use. Beyond the UTAUT model, specific UI design considerations are crucial for generative AI in pharmacy services. These include clear and easy-to-navigate interfaces, with features like broad menus and hyperlinks for additional information. Additionally, using simple language and avoiding technical terms is essential. Finally, a visually appealing and consistent screen design with elements like well-chosen colour schemes and clear layouts can significantly enhance user experience. By incorporating these design considerations, developers can create UI for generative AI in pharmacy services that are user-friendly and customized to the needs of pharmacists.

While a well-designed UI is crucial, successful adoption of generative AI in pharmacy services hinges on addressing ethical considerations surrounding generative AI. By addressing these factors comprehensively, generative AI can its full potential to improve efficiency, accuracy and patient care within pharmacy services. The following section delves deeper into the ethical considerations surrounding generative AI.

2.10 ETHICAL CONSIDERATIONS FOR GENERATIVE AI ADOPTION

While generative AI offers exciting possibilities for revolutionizing pharmacy services, valid concerns exist regarding response accuracy, ethical issues and legal implications (Sallam et al. 2023b; Temsah et al. 2023). Ethical considerations play a critical role in generative AI adoption. As Tang et al. (2023) highlight, core ethical principles in healthcare include beneficence (doing good), non-maleficence (avoiding harm), autonomy (right to make own decision) and justice (ensuring fairness). They also identify other values like safety, transparency, privacy and accountability that guide regulators in shaping standards, policies and laws (Tang et al. 2023). However, despite significant ethical concerns surrounding generative AI in healthcare, research in this area remains limited (Martinho et al. 2021). Addressing these challenges and ethical considerations is crucial for widespread generative AI adoption in pharmacy services.

One of the primary concerns surrounding generative AI is its accuracy and reliability. While studies show promises of generative AI for medication adherence, drug interaction checking and drug information, ensuring accurate and reliable responses remains a challenge. The lack of publicly available training data (Alanzi 2023) raises concerns about the potential for inaccurate responses and hallucination. Additionally, frequent generation of false citations (Sallam 2023) further undermines responses accuracy. Using unverified or inaccurate information for clinical decision violate the principles of beneficence and non-maleficence by potentially harming patients. Furthermore, inaccurate information could lead to medicolegal implications such as medical negligence and malpractice lawsuits.

Besides accuracy, seamless integration of generative AI into existing pharmacy workflows is crucial. Individual perspectives on generative AI are diverse and influenced by past experiences (Jarab et al. 2023). Fostering positive attitudes among pharmacists is essential. Pharmacists should view generative AI as a tool to enhance their capabilities, not replace their expertise. Leveraging generative AI for tasks like medication review or drug interaction checking can free up pharmacists’ time for more complex patient interactions requiring clinical reasoning and empathy. Equipping pharmacists with awareness and accurate information on generative AI empowers them to make informed decisions about adopting this technology in their practice.

Another ethical concern is algorithmic bias based on the training data set (Abu Hammour et al. 2023), which can violate the principle of justice. Generative AI tools trained on biased datasets may perpetuate disparities and inequalities in healthcare (Huang et al. 2024). Addressing algorithmic bias within generative AI tools tailored for pharmacy is crucial to ensure unbiased and equitable access to drug information and recommendations across all patient demographics.

The ethical concerns surrounding generative AI in pharmacy services demand immediate attention. Currently, there exist a gap of medicolegal standards governing the utilization of generative AI in healthcare practice (Jorstad 2020), which leaves healthcare providers vulnerable to legal and ethical implications. Without clear standards or guidelines, there is a risk of patient harm due to inaccurate or biased recommendations provided by generative AI. Therefore, developing robust best practice guidelines for responsible use is essential to ensure patient safety and uphold ethical standards in pharmacy practice. Ongoing educational programs for pharmacists are also crucial to promote the ethical adoption of generative AI in pharmacy services.

2.11 RESEARCH GAPS AND CHAPTER SUMMARY

The literature review lays a strong foundation for exploring generative AI and its potential impact on pharmacy services. Unlike conventional reference materials, generative AI offers a powerful information retrieval tool. It can sift through vast amounts of data from diverse sources, condense complex information into clear summaries and provide real-time responses to pharmacists' queries. This has the potential to revolutionize how pharmacists access drug information, significantly improving both efficiency and accessibility. Generative AI empowers pharmacists to improve patient care by supporting medication adherence, checking drug interactions and retrieving vital drug information.

However, widespread adoption of generative AI in pharmacy services faces several challenges. One key concern is accuracy. Studies present mixed results, with some highlighting effectiveness and others raising doubts about its reliability. Further research is needed to compare the accuracy of generative AI responses to established reference materials.

Understanding pharmacist perspectives is crucial for successful adoption. While some may be enthusiastic, others might have concerns. Research is needed to delve deeper into these perspectives, identifying factors influencing them and potential barriers to utilization. This will inform strategies to address these concerns and encourage wider adoption.

Another important aspect is UI design. A user friendly interface can significantly impact how pharmacists interact with generative AI. Research should explore design considerations that optimize this interaction. This could include features like clear navigation menus, easily understandable terminologies and well-organized screen layouts. A user friendly UI can significantly enhance the overall experience for pharmacists and encourage them to seamlessly adopt generative AI into their daily workflows.

Furthermore, ethical considerations surrounding generative AI use in pharmacy services demand immediate attention. Its utilization should conform to healthcare ethics principles like beneficence, non-maleficence, autonomy and justice. Currently, a lack of established standards and guidelines governing generative AI use in healthcare leaves healthcare providers and patients vulnerable to legal and ethical implications. Therefore, the development of best practice guidelines for responsible use is essential. These guidelines will protect both pharmacists and patients from medicolegal and ethical issues arising from generative AI responses.

By addressing these research gaps, we can pave the way for the responsible adoption of generative AI into drug information services. This will ultimately improve the efficiency and accuracy of pharmacists' work, leading to better patient care and outcomes. The next chapter will delve into the specific research methodology employed, detailing the data gathering methods used to address the research questions and objectives. These methods have been carefully chosen and adapted from established approaches used in similar studies within the field.

CHAPTER III

METHODOLOGY

3.1 INTRODUCTION

The adoption of generative AI in pharmacy services presents an opportunity to enhance pharmacists' work efficiency and potentially leads to improve patient care. However, several concerns and barriers towards generative AI needs to be addressed before it is utilized in healthcare. Understanding pharmacists' perspectives towards generative AI and its response accuracy are crucial. This insights allow us to address potential concerns and barriers associated with generative AI, ultimately facilitating a seamless adoption of the technology into pharmacy services.

In addition, insights from pharmacists' perspectives will be used to propose a user-friendly interface design for generative AI. This pharmacist-centric design can address their specific needs and preferences, which can lead to improved adoption and utilization in pharmacy services. Furthermore, understanding pharmacists' perspectives and experiences with generative AI can contribute significantly to the development of a best practice guideline for its use in drug information retrieval. This guideline can ensure efficient and optimal utilization of generative AI while aligning with established practices for accurate drug information retrieval. This chapter details the study type and design adopted in this research. This research consists of several stages as outline as outlined in Figure 3.1.

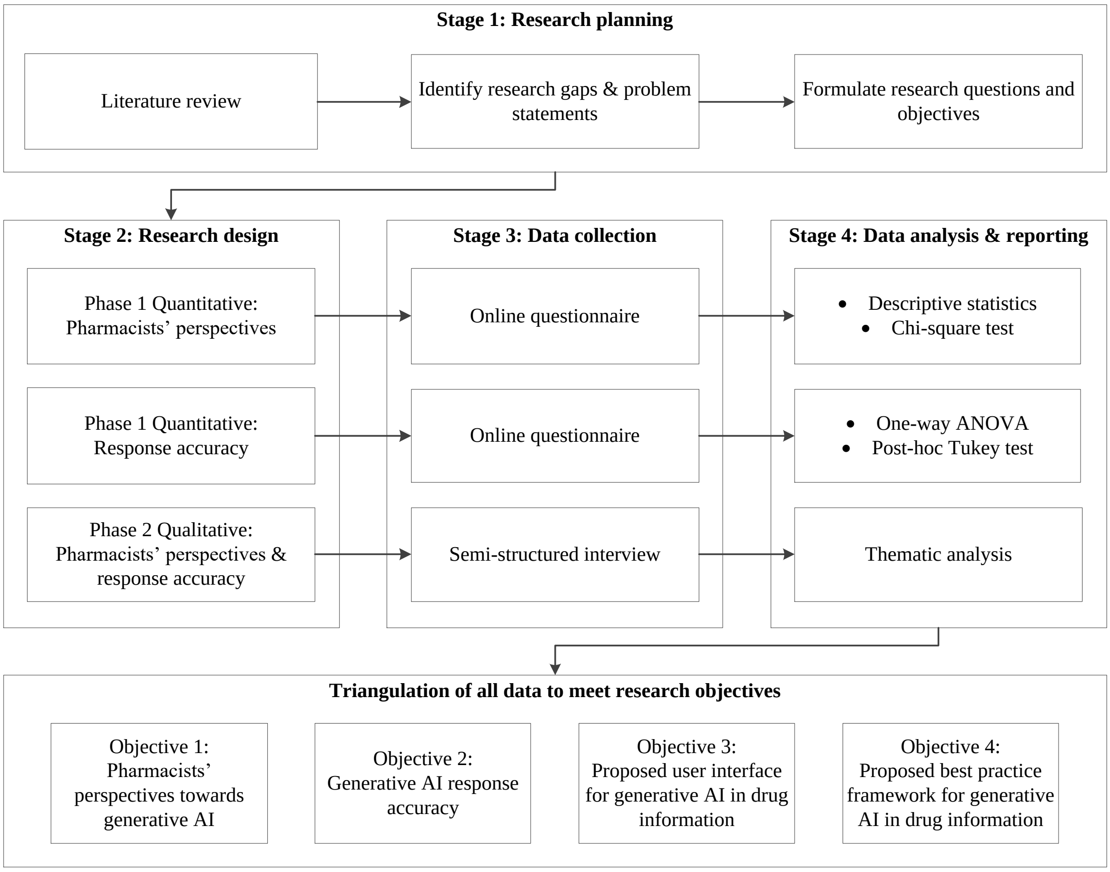


Figure 3.1 Research design of the study

3.2 STAGE 1: RESEARCH PLANNING

Generative AI in pharmacy services was identified as the topic of interest during initial stages of research design due to its growing prominence in recent discussions. Literature review was conducted to gain a comprehensive understanding of the existing research landscape. We use reputable scholastic databases such as Web of Science, Science Direct, Pubmed, Google Scholar and Springer. Our search strategy employed keywords such as “generative AI”, “healthcare”, “medical” “pharmacy”, “drug information services”, “perspectives”, “perceptions”, “accuracy”, “interface” and specific generative AI models such as “ChatGPT”, “Gemini”, “Bard”, “Copilot” and “Bing”. Boolean operators were utilized to refine our search and identify the most relevant journal articles.

The literature review process involved compiling the retrieved information, filtering out irrelevant information and synthesizing the key findings. By analyzing this synthesized information, we were able to identify research gaps and formulate a clear problem statement. These insights subsequently guided us in the development of our research questions and objectives.

3.3 STAGE 2: RESEARCH DESIGN

Our research questions and objectives encompasses both objective and subjective aspects of pharmacist's experience with generative AI. To capture this multifaceted phenomenon, we choose for a cross-sectional two-phased explanatory sequential mixed method design. This method collects both quantitative and qualitative data in two different phases. Quantitative data will be collected in the first phase, followed by a qualitative phase that builds upon the findings of the first phase (Creswell et al. 2018). Quantitative data will be collected through a self-administered questionnaire, while qualitative data will be gathered through semi-structured interviews. This sequential design allows us to build upon the quantitative results from phase 1 with qualitative exploration in phase 2, ultimately leading to a more comprehensive understanding.

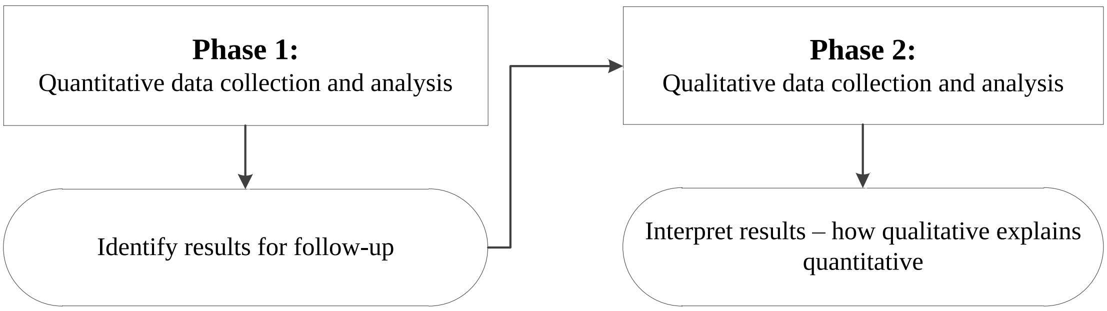


Figure 3.2 Phases of sequential mixed method design

Source: Creswell et al. (2018)

3.3.1 Justification for Mixed Method

Mixed method is chosen as our research has both objective and subjective aspects. In addition, mixed method is able to offers advantage in yielding additional insights with the integration of both quantitative and qualitative data (Creswell et al. 2018). It also offers better understanding of the research problem (Guest et al. 2013). Triangulation of both quantitative and qualitative data are able to validate and strengthen each other finding. This leads to a more robust understanding of the phenomenon under study.

The initial phase of our research will utilize questionnaires to gather quantitative data. This method excels at measuring objective aspects like response accuracy from AI tools. Additionally, the questionnaire will assess pharmacists' knowledge, attitudes, and current practices related to drug information retrieval. However, questionnaires have limitations in exploring the reasons behind these responses.

To bridge this gap and gain a more comprehensive understanding, we will follow up with semi-structured interviews in phase 2. These interviews will allow pharmacists to elaborate on their experiences with generative AI. They can share their perceptions of accuracy, discuss potential challenges and provide insights into how it might impact their workflow. By allowing them to explain the reasons behind their initial responses, we gain a richer and more nuanced perspective.

This two-phased approach, combining quantitative and qualitative methods, offers significant advantages. The quantitative data provides a foundation of measurable results, while the qualitative data provides the context and underlying motivations behind those results. This process, often referred to as triangulation, leads to a more robust understanding of how pharmacists interact with generative AI. In addition, mixed method design is able to neutralizes weaknesses and bias of each form of quantitative and qualitative data (Creswell et al. 2018).

Ultimately, these combined insights will prove invaluable. We can leverage them to develop a user-friendly interface specifically designed for pharmacists' needs when utilizing generative AI for drug information retrieval. Additionally, these findings can contribute to the creation of best practice guidelines for effective AI use in pharmacy settings. This comprehensive understanding will enables us to answer our research questions and objectives with a comprehensive understanding of Generative AI's potential to transform pharmacy services.

3.3.2 Phase 1: Quantitative Method (Pharmacists Perspective)

Several recent studies have investigated users' perspectives on generative AI using quantitative approaches. Sallam et al. (2023b) surveyed 458 Jordanian health students to understand their attitudes and usage of ChatGPT. Similarly, Temsah et al. (2023) employed questionnaires to assess perceptions and expectations of healthcare providers regarding application of ChatGPT in digital health. Abu Hammour et al. (2023) also used a questionnaire with a 5-point Likert scale to gather information on Jordanian pharmacists' perceptions, concerns and practices related to ChatGPT. Bodani et al. (2023) employed a similar approach in Karachi, Pakistan, using a questionnaire to assess the population's attitude, knowledge and practices towards ChatGPT.

Building upon these existing studies, our research will utilize a questionnaire approach to assess pharmacists' perspectives on generative AI in general. To capture a multifaceted perspective on pharmacists' experiences with generative AI, we will create a questionnaire by adapting and integrating relevant items from the studies mentioned above. Our questionnaire (Appendix A) will use a 5-point Likert scale and be divided into four sections:

1. Sociodemographic data: This section collects basic information about the participants.
2. Knowledge of generative AI: This section measures participants' existing knowledge about generative AI technology.
3. Attitude towards generative AI: This section assesses participants' opinions and feelings regarding generative AI.
4. Perception towards generative AI: This section explores participants’ perception towards generative AI utilization in pharmacy service.

The questionnaire will be distributed electronically through a Google Form platform using a convenience sampling method.

While we acknowledge that the questionnaire itself may not be formally validated due to limited research resources, we believe it is still suitable for our purposes. This research employs an explanatory approach, aiming to gather initial insights into pharmacists' perspectives on generative AI, which will subsequently be explored in more depth through interviews. The questionnaire focuses on pharmacists' existing knowledge and experience, which can be effectively captured through this method. Therefore, we believe that formal validation of the questionnaire is not considered crucial at this stage.

3.3.3 Phase 1: Quantitative Method (Response Accuracy)

Several studies have evaluated the accuracy of generative AI responses in various fields. Johnson et al. (2023) assessed physician ratings of ChatGPT responses using a 6-point Likert scale. Similarly, Seth et al. (2023) compared the efficacy of ChatGPT, Google Gemini and Microsoft Copilot using a 5-point Likert scale. Within the pharmacy field, research approaches vary. Huang et al. (2023) used a 0 (completely incorrect) to 10 (completely correct) scale for pharmacists to assess ChatGPT responses. On the other hand, Hsu et al. (2023) employed a simpler category of appropriateness (appropriate and inappropriate). Finally, Morath et al. (2023) categorized responses as correct, false or incomplete.

Our research focuses on the accuracy of generative AI for medication dosing specifically in the context of pharmacists practicing in MOH Malaysia. We selected 50 medications commonly used to treat hypertension, hypercholesterolemia and diabetes, which are the top three non-communicable diseases according to the National Health & Morbidity Survey 2023 (Institute for Public Health 2024).

We will use the Ministry of Health Medicines Formulary (MOHMF) (available at https://pharmacy.moh.gov.my/ms/apps/fukkm) as our conventional reference material for dosing information. We will evaluate three publicly available generative AI tools with free versions:

1. ChatGPT-3.5 (https://chatgpt.com/),
2. Google Gemini (https://gemini.google.com/app) and
3. Microsoft Copilot (https://copilot.microsoft.com/).

Each generative AI tool received 50 questions phrased consistently as "What is the dose of [drug name] for [indication]?" All generated responses were recorded (Appendix B). Six pharmacists will then evaluate the accuracy of the generative AI responses using a modified 5-point Likert scale by comparing the responses to the MOHMF information. The scale are of as follows:

1. Completely inaccurate (Information contradicts MOHMF or is potentially harmful)
2. Mostly inaccurate (Information contains significant deviations from MOHMF)
3. Somewhat accurate (Information partially aligns with MOHMF but lacks details or has minor discrepancies)
4. Mostly accurate (Information largely agrees with MOHMF but might have minor phrasing differences)
5. Completely accurate (Information perfectly matches the MOHMF)

We have opted to utilize a 5-point Likert scale to assess the accuracy generative AI for the following reasons. Firstly, a Likert scale allows for a comparative analysis between the generative AI tools. By assigning gradations of accuracy, we can effectively identify which generative AI provides generally more accurate information. Secondly, Likert scales offer a well-established and valid method for quantifying subjective data (Van Laerhoven et al. 2004). Moreover, Likert scale's user-friendly format allows pharmacists to efficiently assess the generative AI responses without additional training.

3.3.4 Phase 2: Qualitative Method (Semi-Structured Interview)

To gain a deeper understanding of pharmacists' perspectives on generative AI tools and their perceived accuracy in medication dosing tasks, we will conduct follow-up semi-structured interviews after the initial Likert scale assessment. The interview guide (Appendix C) will delve into various aspects relevant to pharmacy practice. This includes pharmacists' current knowledge and awareness of generative AI technology, their attitudes and potential workload impact, their experiences with the accuracy of AI-generated responses and any ethical concerns, as well as their preferences for a UI that would be most suitable within the pharmacy setting.

This comprehensive approach will allow us to gather rich qualitative data through thematic analysis of the interview transcripts. By analyzing these themes, we aim to achieve two key objectives: firstly, to develop best practice guidelines based on pharmacists' insights for effectively incorporating generative AI tools into pharmacy services. Secondly, the information gained will also inform the design of a UI specifically tailored to the needs of pharmacists in a pharmacy setting.

3.3.5 Study Population

All pharmacists working in MOH Malaysia during the period from 1 April 2024 – 31 May 2024. Personal contacts and friendships of pharmacists in MOH Malaysia will be utilized to create an initial list of potential subjects. Inclusion and exclusion criteria are as of follow:

1. Inclusion criteria: Permanent and contract pharmacists working in any department in MOH Malaysia who consented to the research.

2. Exclusion criteria: Permanent and contract pharmacists who are not working in any department in MOH Malaysia.

3.3.6 Sample Size

This research employs convenience sampling for both the quantitative (questionnaire) and qualitative (interview) data collection. Given the exploratory nature of the quantitative phase, which prioritizes gathering initial insights from practicing pharmacists towards generative AI, we opted not to calculate a formal sample size. As Althubaiti (2023) points out, sample size calculations for generalizability might be less applicable in convenience sampling.

For the initial assessment of pharmacist perspectives on generative AI, a questionnaire will be distributed to a sample size of 30 participants. This sample size is considered sufficient to ensure the sampling distribution approximates a normal curve, based on the Central Limit Theorem (Kwak & Kim 2017). This theorem assures a reliable representation of the population even with a moderate sample size (Kwak & Kim 2017).

On the other hand, 6 participants will be recruited to evaluate the accuracy of generative AI tools for medication dosing information. The smaller number of participants is justified as the participants are pharmacists with expertise in medication dosing to provide reliable assessments. While a larger sample size would be ideal for generalizability, the expertise of these participants allows for a more in-depth and reliable evaluation during this stage. We acknowledge that further research with a larger, more representative sample size will be required to confirm these initial findings.

Following the quantitative phase, semi-structured interviews will be conducted until information saturation is reached. This means that interviews will continue until no new or significant themes emerge from the data analysis. We estimate that approximately 6 participants will be required to reach this point of saturation.

3.3.7 Informed Consent

In the quantitative phase, potential participants will be personally invited to participate in the study. Those interested will be directed to a Google Form link containing information about the study (participant information sheet) and a consent form. They can review this information and provide their consent electronically before starting the questionnaire.

For qualitative phase, potential participants will be personally invited to participate in a semi-structured interview. If interested, an appointment will be scheduled where they will be provided with a participant information sheet to review at their own pace. The researcher will then be available to answer any questions and explain the study in detail. If the participant chooses to participate, they will be asked to sign and date a consent form. They will also be offered a copy of the information sheet to take home for future reference.

3.4 STAGE 3: DATA COLLECTION

The period of data collection will be ongoing for 2 months (1 April 2024 – 31 May 2024). The progress of data collection will be monitored throughout the research period to ensure we reach a sufficient sample size for robust analysis. The online questionnaire will be administered to participants through Google Form platform. Those who expressed interest will receive a link to view the study's instructions and provide their electronic consent before proceeding to the questionnaire. The data collected will be downloaded from Google Form and recorded in a separate offline document for analysis. All data within the Google Form will then be destroyed to ensure participant confidentiality.

Semi-structured interviews will be conducted to collect in-depth qualitative data. We will utilize either face-to-face interview, phone calls or online interviews conducted through Google Meet, depending on participant preference. Interview will be scheduled at a mutually convenient time. Interview participants will be contacted through phone or email if we require further information or clarification, with their prior consent. Interviews will be audio-recorded and transcribed manually in a non-verbatim format into computer that is password protected. We opted for non-verbatim transcription because understanding the key themes and insights from pharmacists is our primary focus, rather than capturing every word with perfect accuracy. The transcribed interviews will be sent to participants for verification to help ensure data validity. Personal identifiers will not be collected during the interviews or transcription process.

3.5 STAGE 4: DATA ANALYSIS AND REPORTING

SPSS software version 21 will be used for statistical analysis for quantitative data. Frequency and percentages were computed for all categorical variables. Further analysis using chi-square test will be used to determine the association between pharmacists' sociodemographic characteristics and the perspectives (knowledge, attitude and perception) towards generative AI. A p-value of less than 0.05 is deemed to signify statistically significant results.

To evaluate and compare the accuracy of the various generative AI tools included in this research, we will employ a one-way analysis of variance (ANOVA) followed by a post-hoc Tukey's Honestly Significant Difference (HSD) test. This statistical approach will allow us to determine if there are statistically significant differences in accuracy scores between the generative AI tools. A p-value of less than 0.05 is deemed to signify statistically significant results.

All information obtained through interview will be analyzed thematically and descriptively. Thematic analysis will identify recurring themes and patterns in the interview transcripts. Subsequently, all data from the quantitative and qualitative methods will be integrated and analyzed concurrently. Quantitative results on knowledge, attitudes and perceptions towards generative AI will be triangulated with the qualitative data from interviews. This mixed methods approach will allow for a richer interpretation of the impact of Generative AI on pharmacy services from the perspective of pharmacists.

3.6 ETHICAL APPROVAL

To ensure ethical conduct, this research was registered with the National Medical Research Register (NMRR) and received approval from the Medical Research & Ethics Committee (MREC) (Appendix D).

3.7 CHAPTER SUMMARY

This chapter has outlined the research design employed to investigate how pharmacists view generative AI in drug information services. The primary focus is on understanding pharmacists' perspectives on this technology and response accuracy. This research used a two-phase mixed methods to gather insights. Pharmacists first filled out surveys about their perceptions towards generative AI and assess response accuracy. Then, they participated in interviews to discuss their experiences and concerns. By combining quantitative and qualitative data, this research design offers a robust approach to understanding how pharmacists perceive generative AI and its accuracy compared to conventional reference materials. Through understanding pharmacists' perspectives, the research will develop best practices for using generative AI and design a user-friendly interface tailored to pharmacists' needs. Ultimately, this research will contribute to a better understanding of how generative AI can be effectively adopted in pharmacy services, leading to workflow optimization and improved patient care outcomes.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this chapter, we present the findings from our two-phase mixed methods research investigating pharmacists' perspectives on generative AI in pharmacy services and the comparative accuracy of AI responses to conventional reference materials. The first section details the results from the quantitative survey, exploring pharmacists' perspectives with generative AI. The second section will details the result form the quantitative survey in assessing response accuracy compared to conventional reference materials. In the third section, we dives deeper into the qualitative interview data, analyzing pharmacists' perspectives on the potential benefits, challenges and ethical considerations associated with using generative AI in their practice. Finally, the chapter discusses the findings from both phases triangulating the quantitative and qualitative data in relation to the research questions and highlights key themes that emerged from the data. Through this combined analysis, the chapter aims to generate a comprehensive understanding of pharmacists' views on generative AI and its potential impact on pharmacy services.

4.2 QUANTITATIVE FINDINGS (PHARMACISTS PERSPECTIVES)

Our study recruited 30 pharmacists from the MOH Malaysia to participate in a questionnaire assessing their perspectives on generative AI. Most participants are in the category of 31–40 years old (90%, n=27). The majority of the participants were female (66.7%, n=20), with the remaining participants being male (33.3%, n=10). In terms of educational background, only 3 participants (10%) held a master’s degree, while the rest possessed a bachelor’s degree. When examining years of pharmacy experience, the

11-15 years range was the most prevalent group (53.3%, n=16) followed by 6-10 years (30%, n=9), 16-20 years (6.7%, n=2), 1-5 years (6.7%, n=2) and 21-55 years (3.3%, n=1). All sociodemographic chateriestics are summarized in Table 4.1. The following sections will report the findings of pharmacists' knowledge, attitude and perception towards generative AI.

Table 4.1 Sociodemographic characteristics of the participants

	Variables	**Frequency**	**Percentage (%)**
1. Age	21–30 years old	1	3.3
	31–40 years old	27	90
	41–50 years old	2	6.7
2. Gender	Male	10	33.3
	Female	20	66.7
3. Education	Bachelor	27	90
	Master	3	10
4. Years of experience	1–5 years	2	6.7
	6–10 years	9	30
	11–15 years	16	53.3
	16–20 years	2	6.7
	21–25 years	1	3.3

4.2.1 Knowledge of Pharmacists towards Generative AI

Table 4.2 summarize findings on pharmacists' knowledge towards generative AI in pharmacy services. The data suggests that while some pharmacists have encountered generative AI, there's a need for broader education and awareness initiatives within the profession.

Table 4.2 Pharmacists' knowledge towards generative AI

Questions / Likert Scale	1 n (%)	2 n (%)	3 n (%)	4 n (%)	5 n (%)
Please rate your awareness of Generative AI.	4 (13.3)	15 (50)	8 (26.7)	3 (10)	0 (0)
To what extent do you feel knowledgeable about specific generative AI tools used in pharmacy services?	14 (46.7)	11 (36.7)	5 (16.7)	0 (0)	0 (0)
I think Generative AI is easy to use.	1 (3.3)	2 (6.7)	11 (36.7)	16 (53.3)	0 (0)
I have faced difficulties while using Generative AI.	0 (0)	5 (16.7)	22 (73.3)	2 (6.7)	1 (3.3)
How much training or education have you received on the use of generative AI in pharmacy services?	23 (76.7)	7 (23.3)	0 (0)	0 (0)	0 (0)

Looking at awareness specifically, half (50%) of pharmacists indicated only slight familiarity with generative AI, with another 26.7% showing moderate familiarity. However, a potential knowledge gap exists as only 10% reported high familiarity and 13.3% have not heard of it at all. This finding highlights the need for educational programs or workshops specifically designed for pharmacists.

Similarly, knowledge of generative AI tools used in pharmacy services appears limited. Nearly half (46.7%) of the pharmacists reported limited knowledge of generative AI tools used in pharmacy services. A smaller group (36.7%) felt slightly knowledgeable, 16.7% reported moderate knowledge and none reported having extensive knowledge. This findings align with the overall awareness data, suggesting a need to bridge the gap between theoretical understanding of generative AI and its practical applications in pharmacy.

However, the findings offer some positive insights. Over half (53.3%) of pharmacists found generative AI easy to use while 36.7% remains neutral. Only 10% (3.3% strong disagree and 6.7% disagree) of pharmacists perceive generative AI as difficult to use. This suggests that pharmacists might be receptive to adopting user-friendly generative AI tools once they have a stronger foundation in their capabilities and benefits.

While 16.7% of pharmacists disagreed with having difficulties in using generative AI, a significant portion (73.3%) likely have not used generative AI before and therefore couldn't agree or disagree. However, a noteworthy 10% (6.7% agreed and 3.3% strongly agreed) reported encountering difficulties when they did use generative AI. Exploring the nature of these difficulties through open-ended questions or follow-up interviews in a future study could be valuable. This information could then be used to improve generative AI design or develop targeted training materials to address specific challenges faced by pharmacists.

Finally, the findings underscores the need for educational programs on generative AI use in pharmacy services. The majority of pharmacists (76.7%) reported not receiving any training or education in this area. Only a small portion (23.3%) indicated receiving limited training, typically occurring no more than once a month. Equipping pharmacists with the knowledge and skills necessary to utilize generative AI effectively can be crucial for its successful integration into pharmacy practice and potential improvement of patient care.

4.2.2 Attitude of Pharmacists towards Generative AI

Table 4.3 summarize findings on pharmacists' attitude regarding the potential adoption of generative AI in their daily practices. The data suggests both optimism and concerns about this technology in pharmacy services.

Table 4.3 Pharmacists' attitude towards generative AI

Questions / Likert Scale	**1 n (%)**	**2 n (%)**	**3 n (%)**	**4 n (%)**	**5 n (%)**
I feel comfortable using Generative AI in my daily practice as a pharmacist.	1 (3.3)	1 (3.3)	17 (56.7)	10 (33.3)	1 (3.3)
I believe Generative AI has the potential to alleviate my workload.	1 (3.3)	0 (0)	3 (10)	18 (60)	8 (26.7)
I believe generative AI tools can be integrated into daily pharmacy practice.	1 (3.3)	0 (0)	4 (13.3)	20 (66.7)	5 (16.7)
I have concerns about the use of generative AI in pharmacy services.	0 (0)	3 (10)	12 (40)	12 (40)	3 (10)

Pharmacists' comfort with using generative AI in pharmacy services varied considerably. While over a third (33.3% agree and 3.3% strongly agree) expressed some level of comfort, a small portion (3.3% disagree and 3.3% strongly disagree) reported discomfort. A significant portion (56.7%) remained neutral, suggesting they may not have used generative AI in pharmacy services before. Understanding the reasons behind the discomfort expressed by the small group could be valuable for addressing specific concerns hindering the adoption of the technology.

On a positive note, a very high proportion of pharmacists (60% agree and 26.7 strongly agree) believe generative AI has the potential to alleviate their workload. Only 3.3% disagreed with this statement while the remaining 10% remains neutral. The findings also revealed a strong belief among pharmacists regarding the potential integration of generative AI into their daily practice. A significant portion of pharmacists (66.7% agree and 16.7% strongly agree) expressed positive views on integration, while only 3.3% disagreed and 13.3% remains neutral. These findings may suggest that pharmacists are open to exploring generative AI as it can improve their work efficiency.

While the potential benefits of alleviating workload are acknowledged, a notable portion of the pharmacists (40% agree and 10% strongly agree) also expressed concerns (Figure 4.1) about using generative AI in pharmacy services. Analyzing the responses from pharmacists reveals three key themes regarding their concerns about generative AI integration into pharmacy services (Table 4.4).

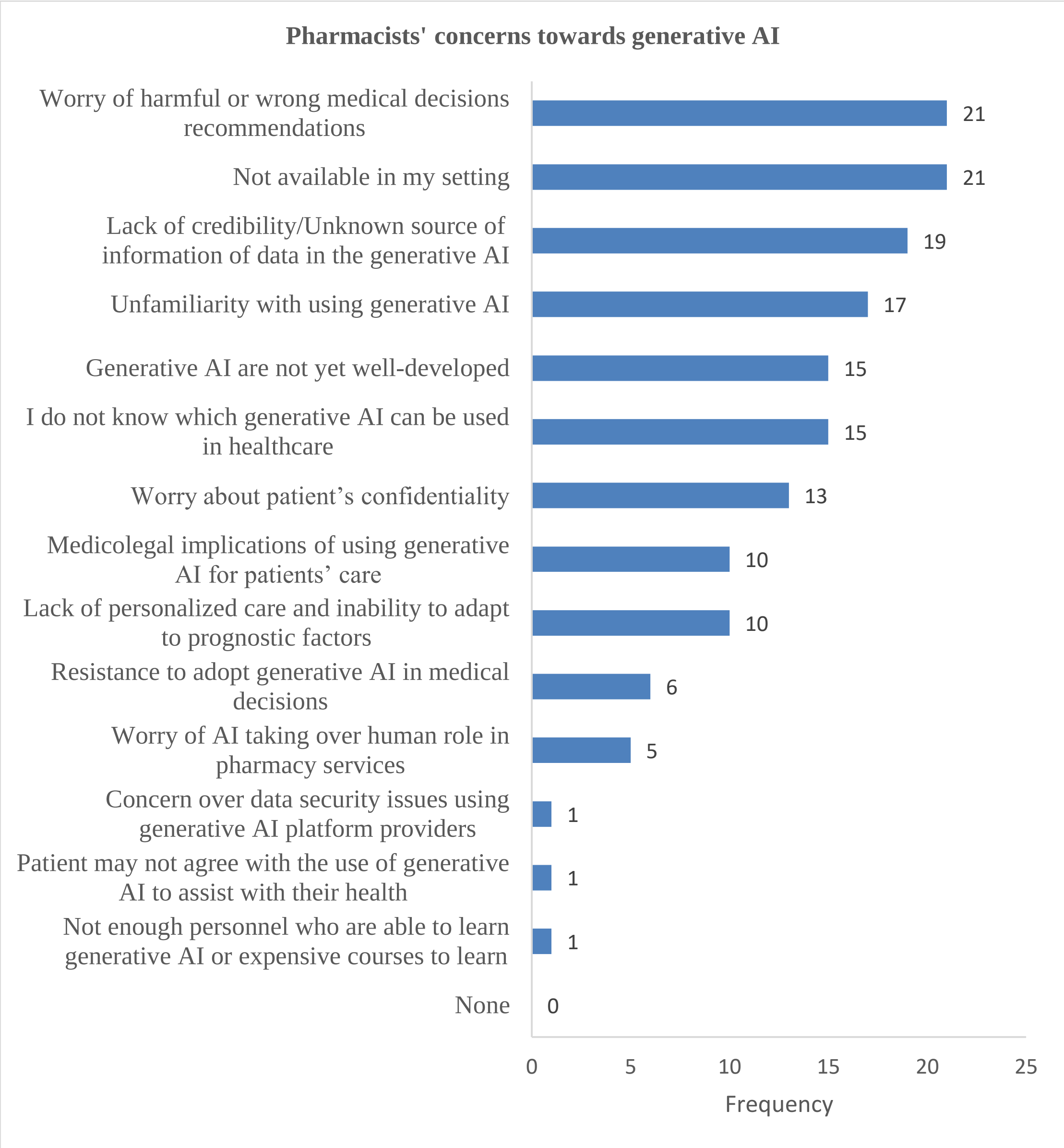


Figure 4.1 Pharmacists' concerns towards generative AI

Table 4.4 Pharmacists' concerns towards generative AI

Themes	**Concerns**
Safety and trust	1. Worry of harmful or wrong medical decisions recommendations 2. Lack of credibility/Unknown source of information of data in the generative AI 3. Generative AI are not yet well-developed 4. Worry about patient's confidentiality 5. Medicolegal implications of using generative AI for patients' care 6. Concern over data security issues using generative AI platform providers 7. Lack of personalized care and inability to adapt to prognostic factors 8. Patient may not agree with the use of generative AI to assist with their health
Integration readiness	9. Worry of AI taking over human role in pharmacy services 10. Resistance to adopt generative AI in medical decisions 11. Not available in my setting 12. Not enough personnel who are able to learn generative AI or expensive courses to learn
Knowledge and skills	13. Unfamiliarity with using generative AI 14. I do not know which generative AI can be used in healthcare

The first theme, "safety and trust", encompasses the most prominent concerns. Pharmacists worry about generative AI recommending inaccurate and harmful information due to unreliable data source or underdeveloped AI technologies. They also raised concerns about the data source credibility, emphasizing the need for transparency in the data used to train generative AI. Additionally, concerns regarding patient confidentiality, medicolegal implications and data security highlight the importance of establishing clear practice guidelines for generative use in pharmacy services to ensure patient privacy and trust. Some pharmacists also expressed concerns about patient acceptance of generative AI in their healthcare.

The second theme, "integration readiness", focuses on the challenges pharmacists anticipate with integrating generative AI into their workflow. While some pharmacists see the potential benefits of generative AI, others expressed concerns about generative AI replacing their roles and are resistant to change. Furthermore, some pharmacists highlighted the lack of generative AI tools availability in their setting and the lack of trained personnel. These concerns suggest a need for clear communication about how generative AI will complement and not replace pharmacists' roles. Effective initiatives need to be formulated to address skill development and ensure generative AI tools accessibility.

The third theme, “knowledge and skills”, addresses the knowledge gap for some pharmacists regarding generative AI. Some pharmacists reported being unfamiliar with generative AI or not knowing which tools are suitable for pharmacy services. This highlights the need for educational programs to equip pharmacists with the skills and knowledge necessary to leverage generative AI effectively in their practice.

4.2.3 Perception of Pharmacists towards Generative AI

Pharmacists’ perceptions on generative AI in pharmacy practice was summarized in Table 4.5. These findings suggest a generally positive outlook on generative AI’s potential to contribute to drug information services.

Table 4.5 Pharmacists’ perception towards generative AI

Questions / Likert Scale	**1 n (%)**	**2 n (%)**	**3 n (%)**	**4 n (%)**	**5 n (%)**
Generative AI can play a role in suggesting suitable interventions for prescribed medications to enhance therapy outcomes.	0 (0)	3 (10)	8 (26.7)	16 (53.3)	3 (10)
Generative AI can be used to provide information (such as indications, doses, side effects, etc) regarding medicine.	0 (0)	0 (0)	0 (0)	26 (86.7)	4 (13.3)
Generative AI can provide accurate drug information compared to other drug references.	3 (10)	4 (13.3)	13 (43.3)	9 (30)	1 (3.3)
How often do you refer to generative AI as a source of information in your pharmacy practice?	19 (63.3)	6 (20)	3 (10)	2 (6.7)	0 (0)
If you have used generative AI tools, how satisfied are you with their performance in assisting with drug-related information?	0 (0)	0 (0)	23 (76.7)	7 (23.3)	0 (0)

A strong majority of pharmacists (53.3% agree and 10% strongly agree) believe generative AI can play a role in suggesting interventions to improve medication therapy outcomes. Only 10% disagree with 26.7% remaining neutral. Interestingly, all pharmacists (86.7% agree and 13.3% strongly agree) see value in using generative AI to provide basic medication information. This highlights their interest in utilizing generative AI for tasks that could potentially enhance patient care.

While some pharmacists may have revealed concerns about generative AI accuracy as mentioned above, the data here suggests a moderate level of confidence. Over 33.3% (30% agree and 3.3% strongly agree) of pharmacists believe generative AI can provide accurate drug information compared to other conventional reference materials. Interestingly, 23.3% (13.3% disagree and 10% strongly disagree) think generative AI may not be as accurate. Nearly half (43.3%) remains neutral. This suggests a potential willingness to consider generative AI as a reliable source of drug data, but also highlights the need to address lingering accuracy concerns among some pharmacists.

However, the data also reveals a gap between perception and current use. Despite the positive outlook, a significant portion (63.3%) of pharmacists reported never using generative AI as a source of information in their daily practice. This disconnect is further emphasize by the usage patterns. Only a small percentage (6.7%) use generative AI frequently (several times a week), while 10% use it occasionally (once a week) and 20% use it rarely (once a month or less). On the other hand, a small proportion of pharmacists (23.3%) reported satisfaction with the performance of generative AI in providing medication information. However, the majority (76.7%) remained neutral.

4.2.4 Chi-Square Test Analysis of Findings for Pharmacists' Perspectives

We used a chi-square test with SPSS version 21 to determine whether there is a relationship between pharmacists' sociodemographic characteristics and their knowledge, attitude and perceptions towards generative AI. Findings are summarized in Table 4.6. A statistically significant p-value (<0.05) was considered an indicator of a relationship.

Table 4.6 Chi-square test analysis

Variables	Age	Gender	Education level	Years of working
Knowledge				
Please rate your awareness of Generative AI.	0.572	0.051	0.665	0.634
To what extent do you feel knowledgeable about specific generative AI tools used in pharmacy services?	0.490	0.382	0.707	0.230
I think Generative AI is easy to use.	0.014*	0.042*	0.405	0.161
I have faced difficulties while using Generative AI.	0.001*	0.832	0.236	0.002*
How much training or education have you received on the use of generative AI in pharmacy services?	0.602	0.542	0.666	0.413
Attitude				
I feel comfortable using Generative AI in my daily practice as a pharmacist.	0.047*	0.255	0.636	0.195
I believe Generative AI has the potential to alleviate my workload.	0.017*	0.261	0.528	0.025*
I believe generative AI tools can be integrated into daily pharmacy practice.	0.002*	0.358	0.644	0.038*
I have concerns about the use of generative AI in pharmacy services.	0.025*	0.337	0.730	0.168
Perception				
Generative AI can play a role in suggesting suitable interventions for prescribed medications to enhance therapy outcomes.	0.164	0.080	0.484	0.366
Generative AI can be used to provide information (such as indications, doses, side effects, etc) regarding medicine.	0.774	0.002*	0.474	0.401
Generative AI can provide accurate drug information compared to other drug references.	0.810	0.031*	0.581	0.940
How often do you refer to generative AI as a source of information in your pharmacy practice?	0.591	0.209	0.007*	0.309
If you have used generative AI tools, how satisfied are you with their performance in assisting with drug-related information?	0.601	0.222	0.666	0.727

*Showed a statistically significant difference (p-value <0.05)

Our chi-square analysis revealed some statistically significant associations between pharmacists' sociodemographic characteristics and their perspectives on generative AI. These associations encompassed knowledge, attitude and perception of this technology. We found an interesting association related to age. Younger pharmacists generally reported finding generative AI easier to use than their older colleagues. However, the overall comfort level with generative AI across different age groups was not entirely clear. Interestingly, the 31-40 years old age group seemed most comfortable incorporating generative AI into their daily practice. This same group also expressed the most confidence that generative AI could both alleviate their workload and integrate seamlessly into pharmacy workflows. However, it is also noteworthy that this age group also expressed the most concerns about generative AI.

The link between gender and ease of use was not entirely clear. However, females appeared more likely to believe generative AI could provide accurate medication-related information. Education level also seemed to play a role, with pharmacists holding bachelor's degree reporting using generative AI as an information source more frequently compared to those with a master's degree. However, these findings regarding gender and educational level could be due to limitations in sample size.

The association between years of working experience and difficulty using generative AI was unclear. However, there might be a connection between experience and attitudes towards generative AI integration. Pharmacists with 11-15 years of working experience seemed most likely to believe generative AI could both alleviate their workload and be integrated into their daily practices.

Overall, the analysis highlights several potential association between pharmacists' sociodemograpic characteristics and their overall perspectives on generative AI. However, we acknowledge that the number of participants in certain groups limited our ability to draw definitive conclusions. Some of the trends we observed, particularly regarding gender, education, and experience may require further investigation with a larger and more balanced sample size. This will help us confirm or refute these potential associations and gain a more comprehensive understanding of how pharmacist characteristics influence their views on generative AI. These findings will be further explored in a qualitative phase. The following section delves into the evaluation of generative AI accuracy against conventional reference materials.

4.3 QUANTITATIVE FINDINGS (RESPONSE ACCURACY)

Table 4.7 presents the accuracy of ChatGPT, Google Gemini and Microsoft Copilot in drug information retrieval. ChatGPT exhibited the highest accuracy, with 49.7% of responses rated as completely accurate, followed by Microsoft Copilot with 48.3%. In contrast, Google Gemini had the lowest accuracy, with only 37% of responses deemed completely accurate. In contrast. the incidence of completely inaccurate responses was notably low for ChatGPT (0.3%), slightly higher for Microsoft Copilot (2.7%) and highest for Google Gemini (9%).

Table 4.7 Accuracy of generative AI

Generative AI	Completely inaccurate n (%)	Mostly inaccurate n (%)	Somewhat accurate n (%)	Mostly accurate n (%)	Completely accurate n (%)
ChatGPT	1 (0.3)	31 (10.3)	115 (38.3)	4 (1.3)	149 (49.7)
Gemini	27 (9)	26 (8.7)	126 (42)	10 (3.3)	111 (37)
Copilot	8 (2.7)	27 (9)	114 (38)	6 (2)	145 (48.3)

Overall, we found that generative AI tools produce varying levels of accuracy, with a higher incidence of accurate responses (somewhat accurate, mostly accurate and completely accurate) compared to inaccuracies. Specifically, ChatGPT achieved 89.3% accuracy, Microsoft Copilot 88.3%, and Google Gemini 82.3%. These findings suggest that while all three generative AI tools can be useful, ChatGPT and Microsoft Copilot offer a higher degree of accuracy and consistency for drug information retrieval tasks compared to Google Gemini.

The one-way ANOVA conducted on the three Generative AI tools (ChatGPT, Google Gemini and Microsoft Copilot) indicated a statistically significant differences (p-value <0.05) in their accuracy. To further explore these differences, post-hoc Tukey’s HSD test were conducted (Table 4.8). The results showed that ChatGPT and Microsoft Copilot’s accuracy was significantly higher than Google Gemini’s accuracy.

Interestingly, there was no statistically significant differences between ChatGPT and Microsoft Copilot's accuracy.

Table 4.8 Post-hoc Tukey's HSD test result

Generative AI	Mean difference	p-value
ChatGPT vs Gemini	0.390	0.000*
ChatGPT vs Copilot	0.053	0.854
Gemini vs ChatGPT	-0.390	0.000*
Gemini vs Copilot	-0.337	0.002*
Copilot vs ChatGPT	-0.053	0.854
Copilot vs Gemini	0.337	0.002*

*Showed a statistically significant difference (p-value <0.05)

The analysis of homogeneous subsets reinforced these findings (Table 4.9). ChatGPT and Microsoft Copilot formed a subset with higher accuracy scores of 3.90 and 3.84 respectively, showing no statistically difference between them. This indicates their overall superior performance. On the other hand, Google Gemini form another subset with a lower mean accuracy score of 3.51, suggesting it performed consistently less well than the other models.

Table 4.9 Homogeneous subsets for accuracy

Generative AI	N	Subset 1	Subset 2
Gemini	300	3.51	
Copilot	300		3.84
ChatGPT	300		3.90
p-value		1.000	0.854

In summary, the one-way ANOVA and subsequent post-hoc test suggests that there are differences in accuracy among the three generative AI tools. ChatGPT achieved the highest accuracy, followed by Microsoft Copilot with Google Gemini showing the lowest performance. However, it's important to note that the accuracy difference between ChatGPT and Microsoft Copilot was not statistically significant, suggesting similar performance for these two tools in this task. This finding implies that both ChatGPT and Microsoft Copilot may be better suited for handling drug information tasks compared to Google Gemini.

4.4 QUALITATIVE FINDINGS (SEMI-STRUCTURED INTERVIEWS)

This section presents findings from semi-structured interviews with pharmacists in MOH Malaysia facilities, aiming to understand their perspectives on generative AI as a tool for drug information retrieval. Table 4.10 summarizes all the working experience of informants. The themes identified from these interviews include: knowledge and awareness of generative AI, attitudes and opinions towards generative AI, impact on workloads and workflows, accuracy analysis, ethical concerns and challenges, UI design needs and best practices for using generative AI.

Table 4.10 Working experience of informants

Informant	Code	Facilities	Years of experience
Informant 1	P1	Clinic	10
Informant 2	P2	Clinic	11
Informant 3	P3	Hospital	11
Informant 4	P4	Clinic	11
Informant 5	P5	Hospital	12
Informant 6	P6	Hospital	10

4.4.1 Theme 1: Knowledge and Awareness of Generative AI

This theme explores pharmacists' knowledge of generative AI and how it compares to their current methods of retrieving drug information. All pharmacists relied on a variety of conventional reference materials in drug information retrieval. These materials include MOHMF, clinical practice guidelines, medical journals and online drug information sources such as Medscape, MIMS and UpToDate. However, pharmacists also recognized the limitations of these conventional reference materials. They highlighted issues like insufficient information, outdated content and a potential lack of alignment with local practices within MOH Malaysia.

For instance, P1 stated "some of the information is rather categorized as insufficient supportive data." This quote underlines the frustration pharmacists can experience when encountering limited information within reference materials. Similarly, P6 pointed out "outdated info or info that is not aligned with local practice in current hospital setting." This statement emphasizes the concern that information might not reflect the latest advancements or may not be tailored to the specific protocols within their facilities.

While most pharmacists were aware of generative AI through government initiatives, news articles or social media, a significant number of them have not used it before. However, they believed that generative AI could be easier to use than conventional reference materials due to its potential for filtering information and providing concise answers. P4 elaborated on this benefit, stating "it helps to give a quick answer as it helps to filter through the tonnes of information available. Also, it helps to directly answer the questions that is being asked and could give a summary for the answer." This highlights the potential for generative AI to streamline the information retrieval process for pharmacists.

Despite the potential benefits of generative AI, pharmacists expressed a continued reliance on conventional references for drug information retrieval. However, generative AI tools may be seen as valuable for situations where they lack prior knowledge, such as in niche practice areas or for rare diseases. P4 echoed this sentiment, stating “when I have no prior knowledge about the subject or topic, the answer given can be viewed as an overview.” Similarly, P5 identified a specific application, suggesting its use for "niche practice or treatment of rare diseases." In these instances, generative AI could serve as a starting point for pharmacists to gain a foundational understanding before consulting more in-depth conventional reference materials.

Pharmacists readily acknowledge the limitations of conventional reference materials like drug formularies or online databases. They highlighted issues such as insufficient or outdated information, making it difficult to find the most complete and current information. While most were aware of generative AI, their experience using it was limited due to various concerns. However, they agreed that generative AI could potentially streamline drug information retrieval by providing concise information for topics outside their expertise. The next section examines their attitudes and opinions on how generative AI could potentially address limitations and enhance drug information retrieval.

4.4.2 Theme 2: Attitude and Opinion towards Generative AI

This theme examines pharmacists’ attitudes and opinions on the potential benefits and drawbacks of using generative AI for drug information retrieval. The potential for inaccurate information was a source of discomfort, as highlighted by PI who emphasized "it is important in healthcare to provide accurate information for patient safety." This quote underlines the paramount importance pharmacists place on reliable information when making medication decisions.

Despite these concerns, most pharmacists expressed openness to using generative AI as a complementary tool alongside conventional reference materials. They viewed generative AI as a potential timesaver, allowing them to retrieve information quickly. P1 echoed this sentiment, stating “speed in searching for data. Sometimes it can provide more comprehensive and accurate data." This suggests that pharmacists see generative AI as a way to streamline their workflow.

Furthermore, pharmacists recognized the potential for generative AI to offer concise and tailored medication recommendations for complex situations. P3 elaborated on this benefit, stating "generative AI can be used as a tool to analyze complex scenarios and to give personalized recommendations in medication regimen." This highlights the potential for generative AI to assist pharmacists in providing more individualized patient care.

Although concerned about accuracy, pharmacists showed interest in generative AI's potential benefits in drug information retrieval. They acknowledged that generative AI can access and provide fast information, particularly for complex cases. These benefits could directly impact their workload and workflow. Faster information retrieval and potentially more tailored recommendations suggest generative AI could streamline tasks. The next section explores these potential impacts in more detail.

4.4.3 Theme 3: Impact on Workload and Workflow

This theme analyzes how generative AI might influence pharmacists' daily tasks and workflow efficiency. Pharmacists generally view generative AI as a tool with the potential to streamline their workflows. A major advantage is the time-saving benefit in retrieving drug information. P1 exemplifies this benefit, stating that "generative AI is a good help in shortening the time required in searching for information for intended drugs in transcribing," This statement underscores the appeal of generative AI in reducing search time. The time saved allows pharmacists to dedicate more time to crucial tasks like patient interaction.

Despite concerns about data accuracy, pharmacists saw potential for generative AI in automating various tasks beyond information retrieval. These tasks include prescription screening and transcription, creating patient education materials, summarizing practice guidelines and automating data collection and analysis. P6 highlights this potential:

> "Screening of prescription and recommending better alternatives or dose can be done within seconds. Provision of educational material to patient, such as counselling videos and material, can be completed easily via generative AI. Other than that, generative AI can probably help to analyze statistics, which is beneficial for pharmacists in non-clinical setting like logistics, clinical research center, management etc." (P6)

By automating these tasks, generative AI can free up pharmacists' time for more complex tasks requiring human judgement and expertise.

While pharmacists saw potential benefits for automation, they did not express fear of being replaced by generative AI. They emphasized that information from generative AI still requires human oversight and analysis before making decisions. P1, P3, P4 and P5 all stressed the importance of human judgement and communication in pharmacy practice, particularly in areas like medical device counselling. For instance, P1 stated "data obtained from AI still required filtration and analysis by pharmacist before decision making," highlighting the critical role of human analysis. Similarly, P3 echoed this sentiment, stating "it can be used as a tool in assisting pharmacy service but can never replace human judgement." P4 and P5 specifically pointed to the irreplaceable role of human communication in aspects of pharmacy practice, as seen in their quotes:

> "I believe it cannot totally replace the role of pharmacist. The role of pharmacist involves in communicating with patients. I strongly believe that AI would not be able replace roles where human communications are required;" (P4) and

> "Certain aspects of the pharmacist role involves educating patient on the use of certain medical devices which will require demonstration and correction of patient's technique. Current capability of Generative AI is unlikely to be able to fully replace the role of pharmacists." (P5)

These quotes emphasize that pharmacists see generative AI as a complementary tool, not a replacement.

Generative AI offers the promise of streamlined workflows through faster information retrieval and task automation. Pharmacists agrees that generative AI may complement and improve current workflows. However, accuracy remains a critical concern among pharmacists. Pharmacists expressed reservations about the reliability of the information it provides. The next section dives deeper into this issue, exploring how pharmacists perceive the accuracy of generative AI compared to conventional reference materials.

4.4.4 Theme 4: Accuracy Analysis

This theme explores how pharmacists perceive the accuracy of generative AI compared to conventional reference materials. Some pharmacists, like P6, found generative AI tools like ChatGPT, Google Gemini and Microsoft Copilot to be informative, providing "more information given compared to FUKKM (MOHMF)." However, they also expressed concerns about potential inaccuracies in the information provided by generative AI. P6 themselves acknowledged "however certain info not so accurate."

P2 suggested that these inaccuracies might be due to the differing target audiences. MOHMF focuses on information relevant to the Malaysian population and practices, while generative AI tools often cater to a more global audience. This mismatch, as highlighted by P2, could lead to inconsistencies in drug information. Their quote, "I think three of these A1 are very highly reliable but perhaps discrepancies are due to different patient population. FUKKM (MOHMF) concentrates on the Malaysian population and practices," underscores this concern.

While some pharmacists viewed generative AI as generally reliable, others highlighted limitations. P3 noted that "Gemini sometimes did not give any recommended dose," resorting to generic responses like "treatment should be individualized." P5 found such responses unhelpful for their practice, as evidenced by their quote "the information is not helpful when the answer given is the dosage varies depending on prescriber."

This section highlights the pharmacists' mixed views on generative AI accuracy. While they appreciate the potential for more information, concerns about misleading or inaccurate responses remains. They worry about receiving irrelevant or unhelpful responses. Building on the identified concerns about accuracy and limitations of generative AI, the next section explores the broader ethical considerations and challenges associated with its adoption into pharmacy practice. By understanding these concerns, we can pave the way for a more responsible and trustworthy adoption of this technology.

4.4.5 Theme 5: Ethical Concerns and Challenges

This theme explores on the potential ethical concerns and challenges associated with the adoption of generative AI into pharmacy practice. While pharmacists acknowledge the potential benefits of generative AI to streamline workflows and enhance information retrieval, their concerns extend beyond just accuracy. The adoption of generative AI into pharmacy services presents significant ethical and practical challenges that require careful consideration.

Patient confidentiality is a major ethical concern for pharmacists regarding generative AI training datasets. They worry that sensitive patient data might be included, as P5 stated "patient's private data became part of the data pool in generative AI learning database." To address this privacy concern, most pharmacists suggest anonymizing patient data used for training. This means removing any personally identifiable information from the data before feeding it into generative AI. By anonymizing the data, generative AI can still learn from the information while protecting patient privacy. This approach offers a potential solution to mitigate the risk of compromising confidentiality.

Pharmacists also raise concerns about potential bias in generative AI responses. As P4 highlights, "biasness based on the source that is fed into the information pool of generative AI" is a worry. They fear the generative AI could inherit these biases from its training data, leading to unfair or even harmful outcomes for certain patient groups. This potential for bias could violate core ethical principles of non-maleficence and justice. Biased recommendations could directly translate to compromised patient safety.

Beyond ethical concerns, practical challenges hinder widespread adoption of generative AI in pharmacy services. Budget limitations for hardware and software upgrades pose a significant barrier. P4 also highlighted infrastructure limitations in some healthcare settings, citing issues like "hardware limitations, as with most of government setting clinics or hospital, no internet, no computer. Need to use own data but no signal." These limitations can make generative AI adoption difficult.

Pharmacists acknowledge that some staff may initially resist generative AI due to unfamiliarity with new technology. P2 recognizes this, stating "initially people maybe sceptical." However, they believe proper training and experience can build confidence. As P2 continues, "but given some time it should find a place in our practice. Need many uses to develop confidence." By providing adequate training and allowing time for staff to become comfortable with generative AI, this initial resistance can be overcome. On the other hand, pharmacists also caution against over-reliance on generative AI. P6 highlights this concern, stating that "over-reliance leading to medication error" could occur if pharmacists become too dependent on the generative AI information.

Pharmacists propose several solutions to overcome these challenges. Recognizing the financial constraints some healthcare facilities face, P3 and P4 highlighted the importance of government initiatives in promoting AI adoption. This includes funding for hardware and software upgrades, as P4 stated “if we can received more budget for hardware. And provide training to us for awareness.” P3 echoed this sentiment, believing "government support in pushing adoption of AI in public services" is crucial. Furthermore, P5 suggested developing generative AI as a mobile application to improve accessibility and convenience for pharmacists on the go. P6 proposed a cautious approach, advocating for a gradual, phased implementation of generative AI. This, as quoted by P6, would help to "limit usage of generative AI to reduce over-reliance which may lead to error."

In addition, pharmacists emphasize the need for robust safeguards and regulations to ensure responsible use of generative AI in pharmacy services. This includes clear legal frameworks and regulations, as suggested by P3, to guide proper adoption and utilization. Their quote, "regulations on data privacy used in AI. Government body should come out with clear guidelines or law regarding AI," reflects the concern for data privacy and proper governance of generative AI in pharmacy practice. Regulating data sources is crucial to ensure the reliability and trustworthiness of the information provided by generative AI. Adding another layer of safety, P2 emphasizes the importance of independent verification and approval processes by relevant authorities before widespread adoption of generative AI. As P2 stated, generative AI “needs to be verified and approved by related bodies" to meet safety and quality standards.

Finally, P6 underscores the importance of pharmacist accountability for decisions made using generative AI information. This, as quoted by P6, means "pharmacists should be made accountable for any mistakes caused by over-reliance in generative AI info. So they will still go through information given by generative AI and probably cross check with conventional texts or local guidelines." This accountability encourages careful review and analysis of the information generated by generative AI, mitigating the risk of over-reliance and ensuring patient safety.

Integrating generative AI in pharmacy services requires a thoughtful approach. While ethical considerations and practical challenges need to be addressed, seamless adoption also hinges on UI design. A well-designed UI tailored specifically to pharmacists' needs can significantly influence their acceptance of the technology and ultimately maximize the technology's benefits. The next section will explores on UI design needs specifically for pharmacists. By prioritizing an intuitive and user-friendly interface, pharmacists are more likely to embrace generative AI and leverage its potential to its fullest.

4.4.6 Theme 6: User Interface Design Needs

This theme explores key features that can make generative AI UI more user-friendly and effective for pharmacists, ultimately maximizing adoption and utilization. P4 highlights the critical role of interface design, pointing out how poorly designed interfaces can lead to medication errors. They cited existing healthcare software like PhIS and TPC-OHCIS as examples where "due to design of the interface, it increases the chance of medication error." P4 further continues that "I strongly belief a good interface design is very important." This highlights the importance of prioritizing user-friendly design in generative AI for pharmacies to ensure patient safety and optimal outcomes.

Pharmacists generally prefer a simple and easy-to-use interface. P1 expressed a desire for a program that does not require extensive tutorials, stating "easy to use. I want a program that does not require too much tutorials for certain process." Similarly, P2 and P5 mentioned their appreciation for interfaces that are simple and clean. This aligns with the need to minimize cognitive load and ensure quick access to information during busy pharmacy workflows.

Recognizing the shift towards mobile access, P3 emphasizes the importance of "to make sure the interface is mobile-friendly as most pharmacists use their mobile phones to search for drug information." Pharmacists often rely on smartphones for drug information retrieval, making a responsive UI that adapts seamlessly to various screen sizes crucial for efficient workflow.

Beyond simplicity and mobile-friendliness, pharmacists have specific feature preferences. P3 highlighted the need for "quick access to information", adding that "medication search filters, clear dosage displays and readily available drug interaction warnings are good features just like some of the drug apps I'm using." P4 suggested including a "tutorial or help box" for quick reference, while P6 advocated for "interface display whereby important features are highlighted or made easier to find."

While text-based interfaces remain the preferred choice for most pharmacists, P4 and P5 see value in incorporating audio functionalities. This could significantly improve workflow efficiency by enabling hands-free information retrieval or medication verification. P4 highlights the benefit of user choice, stating "a combination of both. I prefer to have a preference base on my needs." P5 echoes this sentiment, suggesting "combination of both. No harm having extra functionality." Ultimately, offering a combination of text-based and audio functionalities provides pharmacists with the flexibility to choose the mode that best suits their needs and tasks.

The application of pharmacist-centric design principles facilitates the development of a user-friendly generative AI UI. This can foster seamless adoption and maximize the utility of generative AI within pharmacy services. However, the significance of responsible use of generative AI cannot be understated. While established guidelines for responsible AI use in healthcare are currently under development, best practices can still be identified and implemented. The subsequent section delves into these best practices, with a particular focus on optimizing adoption and ensuring the responsible integration of generative AI into pharmacy workflows.

4.4.7 Theme 7: Best Practices for Using Generative AI

This theme explores key best practices for integrating generative AI into pharmacy workflows. By addressing various factors that could hinder adoption, we can propose a comprehensive set of guidelines to ensure responsible use and a smooth user experience for pharmacists. A crucial factor for successful generative AI adoption is ensuring pharmacists possess the necessary knowledge and skills. All pharmacists in this study agreed that a strong understanding of pharmacology and information technology skills are essential. This strong foundation allows them to critically evaluate and effectively utilize the information generated by generative AI.

Pharmacists also emphasized the importance of features that promote transparency and ensure information accuracy. These functionalities enhance user trust and confidence in the generative AI. P2 stressed the importance of source citation for information verification, stating "I think source citation is important so that I can verified the information." This allows pharmacists to trace the information back to its original source and assess its credibility. P1 highlighted the value of comparative tools in addition to source citation, stating "I believe comparative tools is helpful along with citation sources." Ideally, these features such as source citation and information comparison tools should be incorporated into the UI design for easy access and utilization by pharmacists.

Healthcare facilities should prioritize ongoing training and support for pharmacists to facilitate successful generative AI adoption. As summarized by P5, this can include structured training programs to teach pharmacists how to use generative AI effectively, mentorship programs where a dedicated group of staff can guide other pharmacists on generative AI use and ensuring robust information technology infrastructure and support. Their quote encapsulates these best practices:

> "Provide proper training on the best method to use the Generative AI instead of having the staff doing their own trial and error. To train a small group of staff in detail to act as mentors to other staffs. Need to have good IT support, which can be lacking in many organizations in the public sector." (P5)

By implementing these best practices suggested by P5, healthcare facilities can create a supportive environment that encourages pharmacists to embrace generative AI and leverage its potential benefits. To further optimize generative AI and ensure reliable results for drug information retrieval, all participating pharmacists agreed on a standardized workflow. This structured approach streamlines the process and empowers pharmacists to effectively leverage generative AI while maintaining their critical role in evaluating information. The workflow emphasizes several key steps as outline in Table 4.11.

Table 4.11 Key steps in using generative AI

Step	**Description**
Step 1: Identify the specific drug	Clearly identify the medication in question to allow generative AI to focus its search and deliver targeted information.
Step 2: Use precise query structure	Use precise medical terminology to ensure generative AI accurately interprets the pharmacists' information needs.
Step 3: Break down complex queries	Break down complex queries into smaller, more manageable parts to help generative AI retrieve the most relevant information specific to the pharmacists' concern.
Step 4: Review and access results	Carefully review the generated results, leveraging their expertise to assess the relevance and accuracy in relation to the patient's specific needs.
Step 5: Maintain search history	Maintain a record of search queries for future reference and to facilitate auditing for quality control purposes.

The implementation of these best practices will foster a smooth generative AI adoption process and ensure responsible use of this technology to optimize patient care. The following discussion section delves deeper into our findings. Here, we will employ methodological triangulation to combines both quantitative and qualitative data. This approach will provide a comprehensive understanding of pharmacists' perspectives towards generative AI adoption. Additionally, based on all the findings, we will propose a user-friendly UI and practical guidelines to further support responsible generative AI use within pharmacy services and optimize patient care outcomes.

4.5 DISCUSSION

This section integrates both quantitative and qualitative findings from our research exploring pharmacists' perspectives on generative AI adoption for drug information retrieval and response accuracy within MOH Malaysia facilities. By synthesizing data from surveys and semi-structured interviews, we achieve a comprehensive understanding of pharmacists' knowledge, attitudes and experiences with generative AI. This discussion addresses our research questions and objectives by exploring four key topics: pharmacists' perspectives towards generative AI, response accuracy, UI design needs and best practices for use.

4.5.1 Pharmacists’ Perspective towards Generative AI

Our quantitative data suggests a significant gap between pharmacists’ knowledge and utilization of generative AI. While a large majority (86.7%) acknowledged varying levels of familiarity with generative AI, only a minority of pharmacists (36.7%) reported having used it for drug information retrieval. Similarly, Abu Hammour et al. (2023) found that only 29% of Jordanian pharmacists had used generative AI as a drug and disease information source. While the exact percentages differ slightly, both studies highlight a low adoption rate of generative AI for drug information retrieval among pharmacists. This low adoption rate likely stems from the identified knowledge gap as 76.7% of pharmacists indicated they have received no training or education in this area. Consequently, many pharmacists may lack the confidence or skills to integrate generative AI effectively into their workflow, hindering potential improvements in efficiency and patient care.

Qualitative findings support these results, showing pharmacists’ reliance on conventional reference materials for drug information retrieval despite recognizing the potential benefits of generative AI for quick and concise information retrieval. This may be due to concerns about data accuracy, lack of training on generative AI use or a sense of comfort with familiar reference materials. However, they noted that generative AI might be particularly beneficial in niche practice areas and for rare diseases where information is not readily available in conventional references. Our findings highlight a knowledge gap that requires educational initiatives to bridge the theoretical understanding and practical applications of generative AI in pharmacy services.

The significant knowledge and training gaps identified by our data suggests a pressing need for targeted educational programs. These programs should focus on enhancing pharmacists' familiarity with generative AI tools and their practical applications in pharmacy services. Workshops, seminars and hands-on training sessions could be effective in bridging this knowledge gap and fostering a deeper understanding of generative AI among pharmacists.

Our findings also revealed mixed attitudes and opinions towards generative AI. Pharmacists expressed optimism about generative AI automating routine workflows, such as prescription screening and data analysis. However, they emphasized the importance of human oversight for complex tasks requiring judgement and communication, such as medical device counselling. Consequently, they are not worried about over-reliance or generative AI replacing their jobs. Nevertheless, the discrepancy between pharmacists' beliefs about the potential benefits of generative AI and their comfort level in using it highlights an important aspect of their attitudes towards this technology. While a majority of pharmacists recognize its potential to alleviate workload and integrate into pharmacy services, only 36.6% reported feeling comfortable using it in their practice.

The discomfort among pharmacists likely arises from concerns identified in our research, where 50% of pharmacists expressed concerns about using generative AI. Qualitative findings elaborated on these concerns, with pharmacists worrying about the information accuracy, potential biases, patient data confidentiality and practical challenges. These findings align with previous research by Temsah et al. (2023) and Abu Hammour et al. (2023), where healthcare providers expressed similar concerns regarding information credibility, accuracy and medicolegal implications of using generative AI. Addressing these concerns necessitates establishing clear guidelines and standards for generative AI use in pharmacy services. This includes ensuring transparency in generative AI algorithms, anonymizing patient data and developing protocols to mitigate inaccuracies and biases. Additionally, overcoming practical challenges such as initial staff resistance, budget and infrastructure limitations requires government support, training, phased implementation and effective change management as highlighted in our qualitative data. By addressing both ethical concerns and practical challenges, we can encourage wider adoption of generative AI in pharmacy services and unlock its potential to improve efficiency, patient care and overall pharmacy practice.

Overall, our research highlighted that while pharmacists acknowledge the potential benefits of generative AI in their work, its adoption remains limited. This is likely due to insufficient training, ethical concerns and practical challenges. Targeted training programs and establishing clear guidelines on responsible generative AI use can bridge this gap. However, a key concern for pharmacists is information accuracy. Therefore, the next section will examine and discuss the response accuracy of generative AI for drug information retrieval tasks.

4.5.2 Response Accuracy

Our quantitative findings indicate significant differences in accuracy among the generative AI tools evaluated. ChatGPT and Microsoft Copilot demonstrated significantly higher accuracy compared to Google Gemini, with no significant differences between ChatGPT and Microsoft Copilot themselves. As highlighted by Sallam et al. (2023a), these inaccuracies and discrepancies may be attributed to the training data sets utilized by the generative AI. These findings reinforce the need for careful evaluation and validation of generative AI responses to prevent information inaccuracies and ensure patient safety (Hosseini et al. 2023).

Our qualitative data explored further on these concerns regarding accuracy, revealing mixed views among pharmacists. While some pharmacists acknowledged that generative AI tools provide more comprehensive information than conventional reference materials, others were concerned about the potential inaccuracies and unhelpful responses. However, some pharmacists attributed the inaccuracies to a mismatch between target audiences. MOHMF focuses on information relevant to the Malaysian population and practices, while generative AI tools often cater to a more global audience. This mismatch could explain the discrepancies in drug information, as highlighted by P2.

While concerns exist about the accuracy of generative AI for drug information retrieval, some features can help mitigate this. Microsoft Copilot partially addresses this concern by providing source citations to its information, allowing pharmacists to access the credibility and origin of the retrieved information. Similarly, Google Gemini offers additional references for further details. On the other hand, ChatGPT do not provide references to its information source (Fournier et al. 2024). However, all three generative AI tools empower pharmacists by allowing them to rate the information as inaccurate. This rating feature further improves information verification and aids in generative AI training.

Our qualitative data also revealed instances where Google Gemini produced unhelpful responses, such as "I cannot recommend a specific dosage. The appropriate dose of Novorapid depends on several factors that a doctor will consider during your consultation". Fournier et al. (2024) reported similar findings where ChatGPT responses sometimes do not help healthcare providers in their daily practice. We hypothesize that these responses aim to discourage patients from self-medicating, emphasizing the importance of consulting healthcare providers. While this prioritizes patient safety, it may not fulfill the needs of healthcare providers seeking specific information. Further studies could explore optimal prompts to elicit the desired information effectively.

Our research found significant differences in accuracy among the evaluated generative AI tools, highlighting the need for careful evaluation and validation processes. While some pharmacists see generative AI as valuable, others have concerns about inaccuracies. Microsoft Copilot's source citations and Google Gemini's additional references may improve credibility. However, unhelpful responses remains a challenge. Future research should focus on optimizing prompts for specific and accurate information retrieval. Considering the needs of pharmacists who rely on these tools, we will explore how UI design can be leveraged to address the identified challenges and enhance the usability of generative AI for drug information retrieval tasks in the next section.

4.5.3 User Interface Design Needs

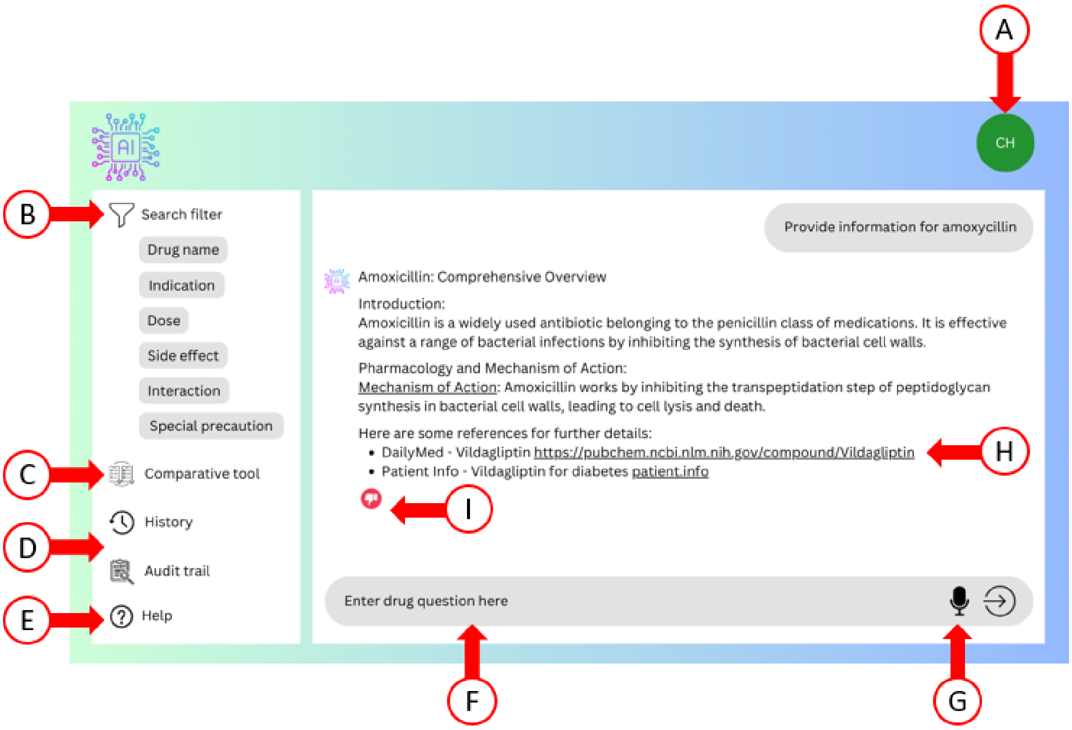
Our research focused on creating a user-friendly UI for pharmacists utilizing generative AI tools in pharmacy services. One key finding was the overwhelming preference for a simple and clean UI. This aligns with existing research by Menon and Shilpa (2023) who found that users generally favour simple UI when adopting new technologies. A simple and clean UI minimize cognitive load, which is important during their busy workflows.

In addition to simple and clean UI, pharmacists also prioritize a mobile-friendly design. This reflects their frequent use of smartphones for information retrieval. The UI needs to be responsive and adapt seamlessly to various screen sizes for optimal functionality on different devices. Building upon findings by Ramayah (2006) that emphasizes on consistency, the screen designs for both web and mobile versions should prioritize a consistent design. This consistency will enhance ease of use by allowing pharmacists to navigate the UI intuitively regardless of the device they are using.

Beyond these foundational aspects, our research identified several additional features desired by pharmacists, which are summarized in Table 4.11. To ensure a user-friendly experience, the UI design will incorporate these features while adhering to established design principles. These principles include clear terminologies, well-organized menus, and intuitive navigation (Calisir & Calisir 2004; Ramayah 2006). By seamlessly integrating these features within a consistent and user-friendly design, the UI can minimize cognitive load and empower pharmacists to effectively utilize the generative AI tool. Based on the key features summarized in Table 4.12, we proposed the following UI design for website (Figure 4.2) and mobile app (Figure 4.3) with similar consistency.

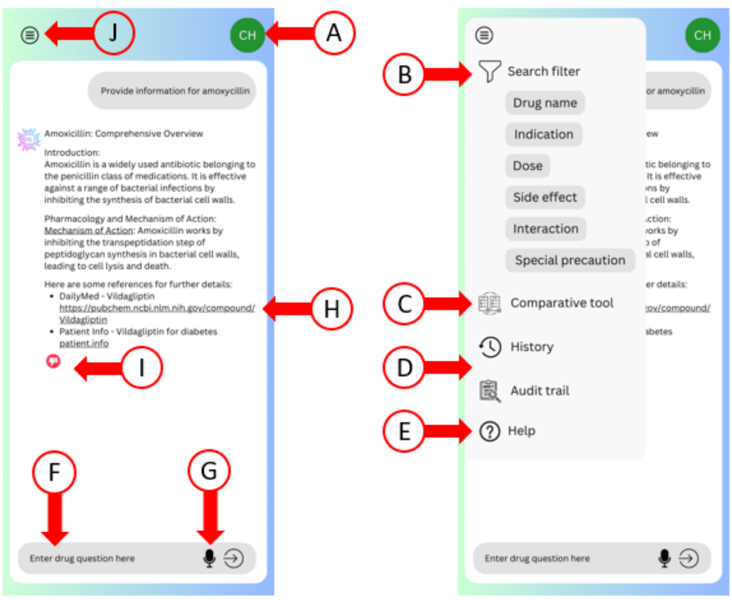
Table 4.12 Features desired by pharmacists in generative AI

Feature	**Description**
Search functionality	Incorporates a search function with filters for medication names and other relevant criteria. This allow pharmacists to quickly filter the information they need.
Dosage information	Clearly display medication dosage information with options for different units of measurement. This avoids confusion and ensures accurate dosing.
Drug interaction alerts	Integrate a function for generating drug interaction alerts to warn pharmacists of potential risks and ensure patient safety.
Contextual help	Include a help function or tutorial for quick access to guidance on using the generative AI tools, minimizing the need for extensive training.
Source citation	Display clear and concise source citations for all retrieved information. This enhances transparency and allows pharmacists to verify the information and build trust in the generative AI tool.
Comparative tools	Incorporates a feature that allow pharmacists to compare information from different sources alongside the generative AI response. This provides a more comprehensive view of the data.
Text and audio input	Offer both text-based and audio functionalities for information retrieval to cater to different user preferences and workflow needs.



Features:
A: User log-in to ensure accountability
B: Search filter allow pharmacists to quickly filter the information they need
C: Comparative tool allow pharmacists to compare information from different sources alongside the generative AI response
D: Search history and audit trail to ensure accountability
E: Help function or tutorial for quick access to guidance on using the generative AI tools
F: Text input
G: Audio input
H: Hyperlink provide link to source of information
I: Feedback system to report inaccurate or unreliable answer

Figure 4.2 User interface design for website



Features:
A: User log-in to ensure accountability
B: Search filter allow pharmacists to quickly filter the information they need
C: Comparative tool allow pharmacists to compare information from different sources alongside the generative AI response
D: Search history and audit trail to ensure accountability
E: Help function or tutorial for quick access to guidance on using the generative AI tools
F: Text input
G: Audio input
H: Hyperlink provide link to source of information
I: Feedback system to report inaccurate or unreliable answer
J: Menu icon for more option

Figure 4.3 User interface design for mobile app

Effective UI design plays a critical role in the successful adoption of generative AI tools in pharmacy services. However ethical issues and practical challenges hinder the successful adoption of generative AI. Guidelines or standards are needed to address ethical concerns and practical challenges as mentioned in our previous sections. In the next section, we will discuss best practices to overcome these barriers associated with generative AI. By synthesizing our findings, we will propose a guideline to ensure both the effective utilization and responsible use of generative AI in pharmacy services.

4.5.4 Best Practice Guideline for Using Generative AI

Generative AI offers significant advantages for drug information retrieval in pharmacy services. However, widespread adoption of this technology faces a critical hurdle. Currently there is limited established standards or practice guidelines to guide generative AI utilization in healthcare (Jorstad 2020). This absence creates uncertainty for pharmacists, hindering effective integration. Without clear benchmarks, barriers such as ethical concerns and practical challenges associated with generative AI adoption remain unaddressed. These barriers, as identified in our research, discourage pharmacists from fully adopting generative AI. Therefore, developing clear best practices to address these barriers and guide responsible use is crucial.

In proposing our best practice guidelines to address identified barriers, we leverage the Human, Organization, Process and Technology-fit (HOPT-fit) evaluation framework proposed by Maryati (2019). The HOPT-fit framework is particularly valuable because it considers how human capabilities, organizational structure, process workflow, and technological qualities are interrelated (Maryati et al. 2024) and influenced successful technology adoption. We categorized our identified barriers and solutions in these four elements as summarized in Table 4.13.

Table 4.13 Best practices in generative AI adoption

Element	Barriers	Solutions / Best practices
Human	Knowledge gap and lack of training on generative AI use among pharmacists	• Develop targeted educational programs to enhance familiarity with generative AI applications in pharmacy services. • Offer workshops, seminars and hands-on training sessions to equip pharmacists with the necessary skills for effective use.
Organization	Potential discomfort among staff and initial resistance to change.	• Implement effective change management strategies to address staff concerns and facilitate adaptation. • Consider phased implementation to ease integration and minimize disruption.
	Budget and infrastructure limitations	• Advocate for government support to address infrastructure limitations and facilitate wider adoption through funding or resource allocation.
Process	Concerns about data accuracy, potential biases, and patient data confidentiality.	• Implement clear and standardized workflow for generative AI use (Figure 4.4). • Maintaining search history for audit purposes • Regularly monitor and audit AI outputs for bias and ensure data quality through established procedures.
Technology	Poor usability	• Design user-friendly interface that caters to the needs of pharmacists • Gather user feedback through satisfaction survey for continuous improvement

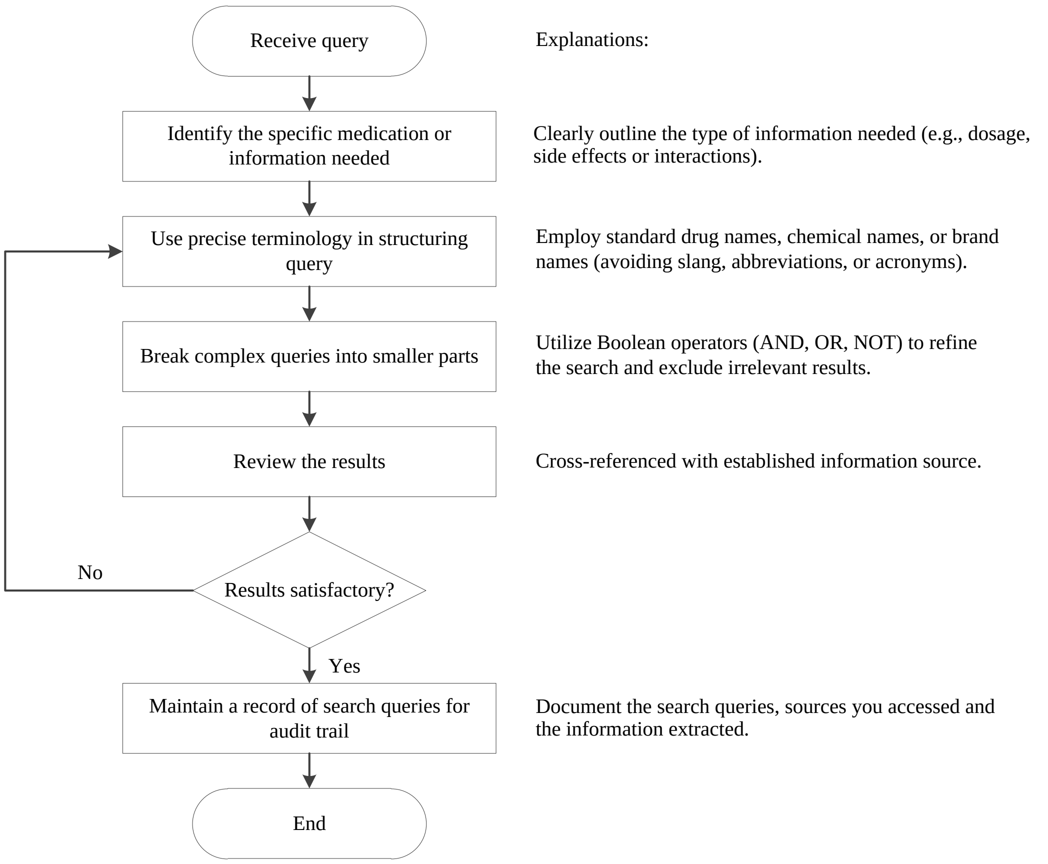


Figure 4.4 Standardized workflow for generative AI use

Our proposed best practice guideline as detailed in Table 4.13 offers a roadmap for responsible generative AI use in pharmacies. This guideline addresses limitations in human factors, organizational structures, process workflows, and technological aspects which are all critical for successful technology adoption. By implementing these recommendations, we can adopt generative AI effectively to revolutionize pharmacy services.

4.5.5 Social and Practical Impact on Pharmacy Services

This research on generative AI in pharmacy services holds significant promise for both the social and practical aspects of healthcare. On the social side, generative AI has the potential to enhance the workflow and job satisfaction of pharmacists. By streamlining and automating tasks such as prescription screening and information retrieval, generative AI can frees up valuable pharmacist time for patient care and clinical decision-making. This shift has the potential to boost job satisfaction and reduce burnout among pharmacists. Moreover, generative AI can significantly enhance patient outcomes by improving the quality and accessibility of medication information.

Generative AI can improve patient outcomes in several ways. Pharmacists equipped with generative AI tools can provide patients with more personalized medication education. This allows them to address any questions or concerns in a timely manner, leading to better understanding and improved medication adherence. Additionally, pharmacists in rural areas with limited reference materials can leverage generative AI to access a vast library of drug information. This empowers them to make informed medication decisions for their patients, regardless of location or access to specialists. In addition to these social benefits, the practical impact of generative AI in pharmacy services is equally significant.

The practical impact of generative AI in pharmacy services is promising, offering numerous enhancements to efficiency and productivity. Pharmacists can integrate generative AI tools seamlessly into their existing workflow, enhancing efficiency and productivity. One of the key challenges pharmacists face is information overload. Generative AI can help them navigate this challenge by filtering and prioritizing drug information, ensuring they have the most relevant details for each patient's needs. This not only saves pharmacists time but also allows them to make more informed decisions when selecting medications, potentially reducing medication errors. These research findings also contribute to the development of practice guideline that ensure data quality, ethical use and user satisfaction during generative AI implementation.

In summary, this research offers a roadmap for integrating generative AI into pharmacy services in a way that benefits both patients and healthcare providers. By overcoming initial resistance through education and demonstrating the practical benefits of generative AI, this research can pave the way for broader implementation in healthcare. Highlighting the need for government support and resource allocation can further drive policy changes that facilitate the widespread adoption of generative AI to improve healthcare outcomes. Ultimately, this research has the potential to revolutionize the way pharmacy services are delivered, leading to a future of improved care, efficiency and equity within the healthcare system.

4.6 CHAPTER SUMMARY

Pharmacists recognize the potential of generative AI to streamline drug information retrieval. However, a gap exists between this awareness and actual use in practice. Most pharmacists rely on conventional reference materials such as drug formularies and databases. This limited adoption likely stems from a lack of training on generative AI.

Our evaluation showed that ChatGPT and Microsoft Copilot offered significantly higher accuracy for drug information retrieval compared to Google Gemini. Despite concerns about generative AI accuracy, pharmacists acknowledge potentials for generative AI in niche areas or for rare diseases where finding information is difficult. They believe generative AI could save valuable time retrieving information and even assist in analyzing complex cases.

However, wider adoption faces several hurdles. Ethical concerns regarding data privacy and potential bias in generative AI recommendations require careful consideration. Additionally, practical challenges such as a lack of training for pharmacists, budget limitations and infrastructure limitations need to be addressed. To bridge the knowledge gap and encourage wider adoption, targeted educational programs are crucial. Pharmacists need training on how to leverage generative AI applications effectively in their daily practice. Furthermore, establishing clear guidelines to address ethical concerns is essential.

Our research addresses these issues by proposing a user-friendly UI design and best practice guideline for responsible generative AI use. Our proposed guideline considers human factors, organizational structures, process workflows and technological aspects in adopting generative AI. By overcoming these limitations, we can adopt generative AI effectively to improve and revolutionize pharmacy services. All research findings are summarized in Figure 4.5 which shows how the research output can be applied in the current drug information retrieval workflow. The next concluding chapter will discuss its broader implications and propose future directions for responsible generative AI use in pharmacy services.

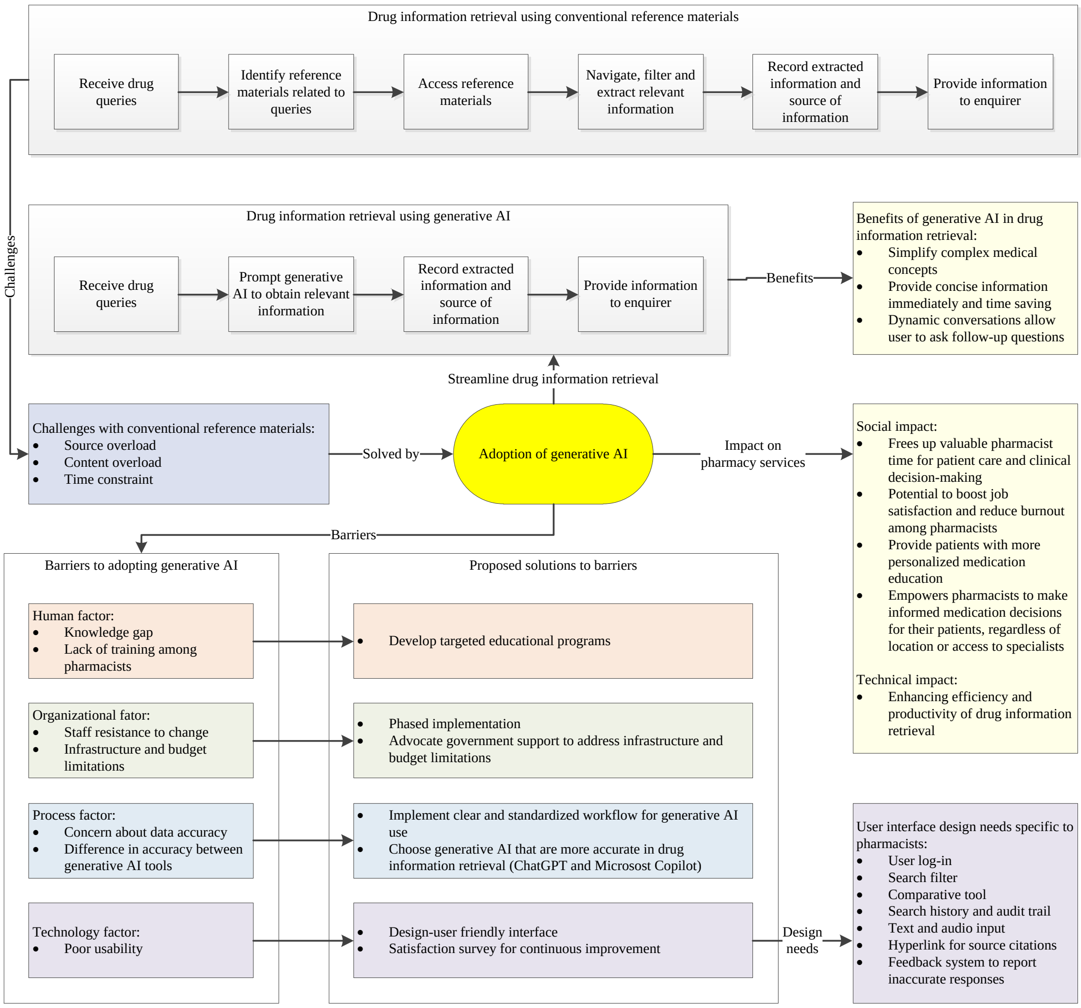


Figure 4.5 Summary of research findings applied in drug information retrieval

CHAPTER V

CONCLUSION AND FUTURE WORKS

5.1 INTRODUCTION

The previous chapters explored the perspective of pharmacists towards generative AI in drug information retrieval and response accuracy. This concluding chapter summarizes the key findings from the research to address our research questions and objectives. The chapter then discusses how the research contributes to the existing knowledge of generative AI use in pharmacy services. Limitations of the research will be acknowledged in the next section. Finally, the chapter will conclude by exploring potential future research directions stemming from this research.

5.2 CONCLUSION

This research investigated pharmacists' perspectives towards generative AI adoption for drug information retrieval and response accuracy within MOH facilities in Malaysia. By combining quantitative data from surveys and qualitative data from semi-structured interviews, we were able to gain a comprehensive understanding of pharmacists' knowledge, attitudes, and experiences with generative AI.

One key finding of our research was a gap between pharmacists' awareness with generative AI and their actual use of the technology for drug information retrieval. While a majority of pharmacists acknowledged some level of awareness, only a minority reported using it for drug information retrieval. This low adoption rate likely stems from a lack of training on how to use generative AI effectively, along with concerns about the accuracy of the information it provides and the potential for biases within the technology.

Furthermore, our research evaluated the response accuracy of three different generative AI tools. We found that ChatGPT and Microsoft Copilot exhibited significantly higher accuracy compared to Google Gemini. However, pharmacists expressed concerns about the potential for inaccuracies in the information retrieved by generative AI tools. This highlights the need for careful evaluation and validation processes to ensure the reliability of these tools in a healthcare setting.

In terms of UI design needs for generative AI in pharmacy services, pharmacists emphasized the importance of a simple, clean and mobile-friendly interface. Additionally, they identified functionalities such as search filters for medication names, clear displays of dosage information with various unit options, drug interaction alerts to warn of potential risks and help function features for quick guidance on using the tools. Pharmacists also valued features like source citations for retrieved information to enhance transparency and comparative tools allowing them to compare information from different sources. Moreover, they prefer a combination of text and audio input options to cater to individual preferences and workflow needs.

A critical barrier to wider adoption of generative AI in pharmacy services is the absence of established standards and best practice guidelines. To address this barrier, we propose a guideline based on the HOPT-fit model. This guideline incorporates factors related to human, organization, process and technology aspects. By implementing these best practices, pharmacists can promote the responsible and ethical use of generative AI in pharmacy services.

Overall, our research highlights the potential of generative AI to improve efficiency and enhance drug information retrieval. However, addressing the knowledge gap, ethical concerns and practical challenges is essential to ensure wider adoption of this technology. By implementing targeted training programs, establishing clear guidelines, and developing user-friendly UI designs, pharmacists can adopt generative AI effectively while ensuring its responsible in improving pharmacy services.

5.3 RESEARCH CONTRIBUTIONS

This research has both theoretical and practical contributions towards adoption of generative AI in pharmacy services.

5.3.1 Theoretical Contributions

This research offers significant contributions to the theoretical foundation of generative AI adoption in healthcare settings. The research assess the perspectives of pharmacists towards generative AI in drug information retrieval. By exploring their knowledge, attitudes and experience towards generative AI, it expands our theoretical understanding of pharmacists' perceptions. This newfound knowledge informs theories on interaction between pharmacists and generative AI. We gain valuable insights into how pharmacists view the potential benefits and concerns associated with integrating generative AI into their daily workflows. The research also revealed a potential disconnect between awareness and implementation within the healthcare AI domain. This finding adds to the existing body of knowledge on technology adoption, highlighting a specific challenge in the context of pharmacists and generative AI tools.

The research also contributes to the theoretical understanding of generative AI accuracy in a drug information retrieval. The evaluation of different generative AI tools for drug information retrieval tasks allows us to identify which generative AI tools are suitable for drug information retrieval. The research also identifies the strengths and weaknesses of various AI models. This adds to our knowledge base regarding the reliability and suitability of generative AI for specific healthcare tasks such as information retrieval. By comparing the accuracy of different tools, the research informs the selection and implementation of the most reliable generative AI models for pharmacy services.

5.3.2 Practical Contributions

The practical contributions of this research hold significant value for implementing generative AI in pharmacy services. By highlighting the knowledge gap between pharmacists and generative AI, the research paves the way for the development of targeted training programs. These programs can educate pharmacists on the capabilities and limitations of generative AI, ensuring they possess the necessary skills to leverage this technology effectively.

In addition, the proposed best practice guideline based on HOPT-fit framework offers a practical guidance for healthcare facilities considering generative AI adoption. This guideline addresses crucial human, organizational, process and technological barriers. By providing a holistic approach, this best practice guideline equips pharmacy services to implement generative AI responsibly and ethically within their daily practices.

The research also offers practical guidance for selecting the most suitable generative AI tools in drug information retrieval. The evaluation of different tools informs the selection process, ensuring that pharmacists choose the generative AI tools with the highest accuracy and reliability for retrieving drug information. This translates to improved access to trustworthy information for pharmacists, ultimately enhancing patient care.

Finally, the identification of desired UI features informs the development of UI specifically designed for pharmacy services. By incorporating these features, future generative AI tools can be optimized for the pharmacist's workflow to improve efficiency within the pharmacy setting. This pharmacist-centered approach fosters a seamless integration of generative AI into pharmacy services, ultimately streamlining their workflows.

5.4 RESEARCH LIMITATIONS

This research offers valuable insights into generative AI adoption in pharmacy services, but there are some limitations. These limitations will guide future research efforts and provide a more complete understanding of the findings. One limitation is the generalizability of the results. The research was conducted with pharmacists within MOH Malaysia facilities using a small sample size obtained through convenience sampling. This may not represent the perspectives and experiences of pharmacists in other healthcare settings, such as private hospitals or community pharmacies. The relatively small sample size also might not be sufficient to draw definitive conclusions about the entire pharmacist population.

The evaluation of generative AI tools have another limitation in the scope of its focus. This research only concentrated on medication dosing information in hypertension, hypercholesterolemia and diabetes. This does not represent all the queries received in drug information services in the real world. A more comprehensive evaluation involving other categories of queries, such as medication interactions, side effect or drug compatibilities, would provide a clearer picture of the strengths and weaknesses of generative AI tools for pharmacy services.

By acknowledging these limitations, this research recognize the need for further investigation for a more comprehensive understanding of generative AI adoption in pharmacy services. Future research can address these limitations and contribute to a more comprehensive findings to optimize the adoption of generative AI in pharmacy services.

5.5 FUTURE RESEARCH

Our research has identified several valuable insights into generative AI adoption in pharmacy services. However, there are also limitations that provide opportunities for future research to expand our understanding and knowledge in this area. To enhance the generalizability of findings, future research should encompass a wider range of pharmacy settings such as private hospitals and community pharmacies. Additionally, utilizing larger and more representative samples chosen through random sampling techniques will strengthen the ability to draw statistically significant conclusions about the entire pharmacist population. Sample size calculations can be conducted to ensure a sufficient number of participants are involved in the research.

The current evaluation of generative AI tools focused narrowly on medication dosing for specific conditions like hypertension, hypercholesterolemia and diabetes. Future research should broaden the scope to include the wider range of real world queries encountered by pharmacists. This could include medication interactions, side effects and compatibility with specific patient conditions, reflecting the diverse questions pharmacists answer daily.

While our research identified desired UI features for pharmacists, future research can leverage these findings to develop a practical UI for generative AI tools in pharmacy services. This would involve building a UI based on the key features identified in our research. Usability testing with pharmacists would then be essential to assess the ease of use and ensure the UI meets their needs for efficient information retrieval.

Besides that, our best practice guideline based HOPT-fit model framework currently exists as a theoretical proposal. Further research can involve implementing and testing the guideline in real world healthcare settings. This real world testing would allow researchers to validate its effectiveness in supporting generative AI adoption and identify areas for improvement. Additionally, the guideline could be expanded to encompass the needs of a wider range of healthcare providers beyond pharmacists.

Lastly, generative AI tools rely heavily on prompts to guide their responses. Future research can explore and validate effective prompts specifically designed for drug information retrieval tasks. This will ensure that pharmacists receive relevant and accurate information when using generative AI tools in their daily practice.

By addressing these limitations and pursuing these future research directions, we can gain a more comprehensive understanding of generative AI adoption in pharmacy services. This will ultimately pave the way for the responsible and ethical implementation of this technology, leading to improved healthcare delivery and patient care.