Experiences of Undergraduate Medical Students in the Use of Smartphones, iPads, and Tablets for Learning during their Preclinical and Clinical Years of Training: A Qualitative Systematic Literature Review

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Abstract

The use of mobile devices has become increasingly common among medical students. While quantitative systematic reviews and meta-analyses show that these tools enhance knowledge acquisition and clinical skills development, qualitative syntheses explaining how and why mobile devices support students' learning across preclinical and clinical education are limited.

This study addresses this gap by synthesising qualitative evidence on undergraduate medical students' experiences using mobile devices for educational purposes. A qualitative systematic literature review was conducted, including 30 qualitative and mixed-methods studies published between 2012 and 2022. Thematic synthesis was used to identify key themes, which were interpreted using relevant educational theories and technology acceptance models.

Findings show that although students reported substantial pedagogical benefits, they also encountered certain challenges, particularly in clinical settings. In response, they adopted various mitigation strategies. The analysis yielded six descriptive themes: device usability, perceived benefits, challenges encountered, mitigation strategies, and external and personal factors influencing mobile device use. These descriptive themes are integrated into three analytical themes: (1) enablers of and barriers to device adoption, (2) the relationship between device usability and perceived educational benefits, and (3) challenges and strategies adopted to address them.

This study makes three contributions. First, it proposes two conceptual models: one illustrating students' mobile learning journeys and the other extending existing technology acceptance models with medical education-specific factors. Second, it introduces a structured, theory-informed qualitative evidence synthesis approach. Third, it deepens our understanding of how and why mobile devices enhance students' learning, thus addressing existing research gaps.

These findings have practical implications. Clear institutional policies legitimising mobile device use in academic and clinical settings, combined with awareness-raising among educators and patients about the educational

benefits of these tools, can help to mitigate these challenges, especially in clinical environments. Future research should investigate mobile device use in workplace settings and explore the long-term effects of mobile learning on professional development.

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Declaration

This thesis is submitted in partial fulfilment of the requirements for the Doctor of Philosophy degree from the Department of Educational Research, Lancaster University.

I hereby declare that I am the sole author of this thesis, that I have conducted the research recorded herein, and that it has not been previously submitted for a higher degree.

I also declare that the word length of the thesis is 48,663, excluding the title page, table of contents, abstract, list of figures, list of tables, acknowledgement, declaration, list of references, and appendices, and does not exceed the permitted maximum of 50,000 words.

Signature ....

Chapter 1: Introduction

The pedagogical benefits of using smartphones and other handheld mobile devices have been well-recognised in medical education (Master et al., 2016), and meta-analyses have shown their effectiveness in the acquisition of knowledge and the development of clinical skills among medical and health professional students (Dunleavy et al., 2019; Kyaw et al.,2019). However, such analyses in educational research may not fully reflect real academic contexts as students' reactions may vary while participating in experimental conditions (Wong et al., 2012), and focusing on quantitative numbers may overlook the areas hidden behind the observable layer of interventions (Pawson, 2006).

This study aims to synthesise evidence beyond a simple evaluation of "what works" by exploring how mobile devices influence learning processes and pedagogical outcomes among medical students in both preclinical and clinical training.

This chapter introduces the study by first discussing the background and context, followed by the research problem, the research aims and objectives, the significance and finally, an overview of the structure of the thesis.

1.1 Background Information on the Study

This section provides background information on the study, including personal motivation and rationale for conducting the study, definitions of mobile learning, classifications of mobile devices, and their affordances. Defining mobile learning and classifying mobile devices help to clarify the scope of the study, and examining their affordances highlights their educational impact on the learning experiences of medical students.

1.1.1 Personal Motivation and Rationale for Conducting the Study

First, I briefly explain my motivation for conducting this study. My interest in this topic originates from my personal experience as a health professional educator teaching medical, nursing, and allied health students. Observing my students using smartphones and other mobile devices in the classroom sparked my curiosity about how they use these devices to acquire knowledge, develop clinical skills, and build a professional attitude, as well as what factors support or hinder their learning outcomes. Understanding students' learning experiences with mobile devices can help educators to design their teaching strategies to meet students' learning needs and expectations better. As I integrated mobile devices into my teaching practice, my own passion for educational technology, coupled with motivation from observing students’ use of these devices, fuelled my desire to explore mobile learning in medical education practice.

Second, I explain the rationale for conducting a systematic literature review. If I carried out an empirical study within a single institution, the findings would be limited to that specific context and might not offer broader insights. As I aim for a more holistic understanding of the topic, along with reliable evidence, conducting a systematic literature review is the most appropriate research methodology for my study. This approach is particularly suitable for exploring how and why mobile devices facilitate student learning, as it allows the synthesis of findings from multiple studies, thus providing a broader overview, offering insights into reliable evidence across various settings, and enhancing the generalisability of the findings.

After presenting my motivation and rationale for conducting the study, the next section provides some useful definitions of mobile learning and classifications of mobile devices that are used in relevant chapters of the thesis.

1.1.2 Definitions of Mobile Learning

Mobile learning, often abbreviated as m-learning or M-learning, can be defined in different ways. Early definitions of mobile learning primarily focused on the technology involved; for instance, Traxler (2005) defined it as any educational provision delivered through handheld or palmtop computers. Ellaway and Masters (2008) provided a similar definition for medical education, describing it as learning through the use of mobile, handheld electronic devices.

Over time, however, the concept has evolved to involve people using technology in various contexts and their interactions with technology. For instance, Sharples et al. (2007), as cited in Crompton (2013a), defined mobile learning as “The process of coming to know through conversations across multiple contexts amongst people and personal interactive technologies" (p.4). This definition encompassed four essential concepts that underpin mobile learning: pedagogy, context, electronic devices, and social interaction. However, this definition resulted in confusion and ambiguities due to the use of the word 'conversation', suggesting mobile learning was focused only on verbal communication.

A more contemporary definition from Crompton (2013a) modified this definition to "learning across multiple contexts, through social and context interactions, using personal electronic devices" (p.4), thus retaining the four central constructs defined by Sharples et al. (2007). The 'context', specifically in mobile learning, is influenced by various factors, including the role of the teacher, the learners' experiences, the physical setting, and their interactions. Crompton (2013a) further expanded this definition by incorporating the concept of mobility, defining mobile learning as any learning that occurs when the learner is not in a fixed, pre-determined location and takes advantage of the learning opportunities offered by mobile technologies.

A more recent definition from Kearney et al. (2020a) maintains the concepts of Sharples et al. (2007) and Crompton (2013a). It describes mobile learning as any learning facilitated through the use of mobile devices, emphasising their key characteristic of being usable anywhere.

1.1.3 Classification of Mobile Devices

Deciding which devices should be included in mobile learning is a topic of debate among scholars because mobile learning is dynamic, and technologies are constantly being invented or redesigned. Crompton (2013b) suggests that mobile devices in mobile learning should be considered as electronic devices that are easily transported and can be used at anytime, anywhere.

However, some scholars have specific classifications for mobile devices in mobile learning. For instance, in the earlier era of medical practice, mobile devices included Personal Digital Assistants (PDAs) and cellular or mobile phones (Ellaway & Masters, 2008). With the advancement of technology, the definition of a mobile device has expanded. Today, it encompasses any digital device characterised by portability, the capability to be used in various locations, and regular usability by an individual. These devices are typically equipped with advanced functionalities such as Internet/ Wi-Fi access, a camera, and video capabilities. Under this definition, mobile devices include smartphones, tablets, iPads, and laptops (Kearney et al., 2020a; Maudsley et al., 2019). When referring to mobile devices, we refer to the physical structure of the devices and their functionalities, and the term mobile technologies encompasses the software elements, such as applications or apps, operating systems, the underlying infrastructure and technical protocols that support the operation of mobile devices (Masters et al., 2016).

After these definitions of mobile learning and the classification of mobile devices, the next section transitions to mobile devices' affordances.

1.1.4 Affordances of Mobile Devices

The affordances of mobile devices refer to the capabilities and functionalities that these devices provide to users across various contexts (Margaret, 2018). By understanding these affordances, we can better comprehend how and why students respond to these devices, leading to specific learning outcomes occurring within certain educational contexts.

Five essential types of technological affordances for mobile devices were identified by adapting the works of several scholars, including Bower (2008), Concole and Dyke (2004), Margaret (2018), and McQuiggan et al. (2015). These affordances include connectivity, accessibility, portability, mobility, and multifunctionality, and they are explained in detail below.

Connectivity is a fundamental functionality of mobile devices, referring to the capability of a device to connect to the Internet, various networks and other devices. This connectivity feature allows users to access web-based services, retrieve information, and communicate in real time (Margaret, 2018; McQuiggan et al., 2015).

Accessibility of information and learning resources at any time, from anywhere, via mobile devices is a crucial affordance for facilitating students' learning (Conole & Dyke, 2004).

The portability of mobile devices refers to their physical characteristics, such as weight and size, which allow users to carry them from one place to another easily (Margaret, 2018; McQuiggan et al., 2015). This portability feature of devices enables users to use them in various settings without being tethered to a single location.

Mobility includes not only the physical characteristics of portability but also a device's ability to maintain the functionality of connectivity and accessibility to resources in different environments and conditions (Bower, 2008; McQuiggan et al., 2015).

The multifunctionality of mobile devices allows them to serve various roles, such as camera (still or video), voice recorder, calendar, and note-taker. This feature allows users to customise their devices to suit their preferences, needs and interests (McQuiggan et al., 2015).

After providing background information for the study, the focus now shifts to identifying research gaps in the existing literature on mobile learning from the perspective of medical education.

1.2 Identification of Research Gaps

The personal motivation and rationale outlined in Section 1.1.1 serve as the study's starting point. They lead to searching the literature for the current state of research on the topic and identifying research gaps.

Scoping searches on primary studies and systematic reviews were conducted to get an overview of existing research on mobile learning in medical education. While the details of these searches are provided in Chapter 2, this section discusses key research gaps and how they inform the formulation of review questions for this study.

A scoping review of 42 primary studies and nine systematic reviews on the use of mobile devices among medical and health professional education students identified five knowledge gaps, two population gaps, one methodological gap and one theoretical gap (Figure 1.1). These gaps are classified according to the taxonomy proposed by Miles (2017), with definitions available in Appendix A. These gaps were identified through a synthesis of study findings from scoping searches, and the reader can refer to Section 2.2

for further details of the search results. The following sections provide a brief discussion of these research gaps.

Figure 1.1 Research Gaps Identified from the Scoping Searches

1.2.1 Knowledge Gaps

The scoping searches identified five types of knowledge gaps. While existing research discusses the types, purposes, pedagogical benefits, and challenges of mobile device use among health professionals, it lacks an in-depth examination of factors influencing students' use of devices for learning purposes. A deeper understanding of these factors remains absent, highlighting the first knowledge gap in the literature.

The second knowledge gap stems from insufficient knowledge in prior research regarding how mobile devices facilitate individual students' learning experiences and assist them in achieving their learning goals.

The third and fourth knowledge gaps concern the challenges of mobile learning and mitigating strategies to address them. While previous research has addressed these challenges, strategies for overcoming them have not been explored in depth. Additionally, ethical and privacy concerns related to mobile device use in clinical settings have received limited attention.

The final knowledge gap is that most studies have focused on the immediate impacts of mobile learning, with little investigation into its long-term effects after students graduate. Therefore, there is a need for research to examine the sustained influence of mobile learning beyond formal education.

1.2.2 Population Gaps

The scoping searches of systematic reviews identified two types of population gaps. The first population gap is the lack of focus on the specific group of health professional students as the study population. The systematic reviews identified in the scoping review encompass a wide range of health professionals, grouping both students and practitioners from fields such as medicine, dentistry, nursing, and allied health. However, these reviews do not distinguish between these groups. Given the unique roles and responsibilities of each profession, summarising their experiences with mobile devices collectively may obscure the specific challenges and benefits faced by each group. This lack of specificity highlights the need for studies focusing on particular subgroups within health professionals. A focus solely on medical students can provide targeted insights unique to this group of health professionals.

The second population gap concerns the limited research on mobile learning practices in low- and middle-income countries. Previous studies have predominantly focused on high-income Western countries, such as the United States of America (USA), the United Kingdom (UK), Australia and Canada, while research in resource-limited settings remains unexplored.

1.2.3 Methodological Gap

Previous research on mobile learning implementation in health professional education reveals a methodological gap. Scoping searches of 42 primary studies and nine systematic reviews revealed that only 14% and 1%, respectively, employed a qualitative approach to examine the use of mobile devices in medical and health professional education. These findings indicate a general underutilisation of qualitative research designs in the field.

1.2.4 Theoretical Gap

An apparent theoretical gap exists in the previous research regarding the use of educational theories and pedagogical frameworks in the design and implementation of mobile learning.

While nine research gaps have been identified through scoping literature searches, this study addresses seven of them. The next section presents the scope of the research gaps covered in this study.

1.3 Setting the Scope of the Study

While mobile learning is increasingly integrated into medical education, not all the research gaps identified in Section 1.2 can be addressed within a single study. Therefore, this study focuses on seven research gaps via a qualitative systematic literature review.

Specifically, it aims to address knowledge gaps related to the factors influencing students' use of mobile devices, an in-depth understanding of how mobile devices facilitate individual students’ learning experiences, and strategies adopted to overcome mobile learning challenges. Additionally, it covers a population gap by capturing the unique learning needs of medical students, a methodological gap in the underutilisation of qualitative research, and a theoretical gap in applying educational theories and pedagogical frameworks in mobile learning research. However, this study did not address mobile learning practices in low- and middle-income countries or the long-term effects of mobile learning beyond formal education.

The next section presents the research aim and objectives to address the above-mentioned research gaps.

1.4 Research Aims and Objectives

This study aims to synthesise the findings from primary qualitative and mixed-methods research studies on the experiences of undergraduate medical students using mobile devices for their learning.

With the overarching purpose of the study established, the following research objectives are formulated to achieve the research aims.

1. To identify the enablers and barriers to mobile device usage among medical students.
2. To describe the usability features of mobile devices in medical education.
3. To explore the benefits students gain from using mobile devices in their learning.
4. To identify the relationships between the usability features of mobile devices and mobile-enabled students' learning behaviours.
5. To explore the challenges students encounter in their learning when using mobile devices.
6. To identify the strategies students adopt to mitigate the challenges they face in their mobile learning practices.

The objectives outlined above aim to address the research gaps identified in Section 1.2. The first objective seeks to fill the gap in our understanding of the factors influencing students' use of mobile devices. The second, third, and fourth objectives focus on bridging the gap in knowledge regarding the mechanisms through which these devices support students' learning. The fifth and sixth objectives address the gaps related to the challenges students face in using devices and the strategies they adopt to overcome these challenges.

Focusing this study on medical students addresses the population gap resulting from the limited attention given to specific groups of health professional students. Using a qualitative methodology helps to fill the gap arising from the underutilisation of this approach in research on mobile learning implementation within medical education.

After addressing the research aim and objectives of the study, the next section highlights their significance in medical education.

1.5 Significance of the Study

This study offers valuable insights for medical educators, curriculum developers, institutions, and researchers who seek to understand and support the integration of mobile devices into students' learning processes.

From a practical perspective, the findings highlight the real-world challenges students face when using mobile devices – particularly in clinical settings – and the strategies they adopt to overcome them. These insights can help educators and institutions develop supportive learning environments by legitimising device use, offering training to educators, raising awareness among patients, and creating clear institutional policies.

The study also has theoretical relevance, as it applies and extends existing educational- and technology-related theories to explain how students engage with mobile learning in authentic contexts. Two conceptual models are proposed to deepen our understanding of mobile learning in undergraduate medical education. The first model captures students' mobile learning journeys, and the second extends existing technology acceptance frameworks by incorporating factors specific to medicine, such as patient perceptions, professionalism concerns, and institutional support.

Methodologically, the study offers a structured and transparent approach to conducting a qualitative systematic literature review. This approach can serve as a model for future researchers wishing to conduct rigorous evidence syntheses in medical education.

Finally, the study has research significance by identifying future directions for investigation, such as exploring mobile learning in workplace-based settings, testing the proposed conceptual models, and examining the long-term impacts of mobile learning in the medical education context.

The chapter concludes by describing the organisational structure of the thesis in the next section.

1.6 Organisation of the Thesis

This thesis is organised into six chapters. Chapter 1 (Introduction) provides an overview of mobile learning in medical education, outlines the research problem, presents the aims, and discusses the significance of the study. Chapter 2 (Literature Review) examines existing research on mobile learning in health professional education, educational theories and technology acceptance models. Chapter 3 (Methodology) details the process of conducting a qualitative systematic literature review. Chapter 4 (Results) presents the themes and sub-themes developed from data synthesis. Chapter 5 (Discussion) discusses the results of the study with reference to previous studies and its implications and contributions. Chapter 6 (Conclusion) summarises the main findings and discusses personal reflections.

The thesis follows the American Psychological Association (APA) 7th edition guidelines for citations, referencing, tables and figures (American Psychological Association, 2023). The formatting of the thesis follows the Lancaster University Doctoral Programme thesis template February 2025 version.

1.7 Chapter Summary

This introduction chapter has introduced the topic, identified research gaps, established the research aims and objectives, and outlined the significance of the study. The next chapter, Literature Review, examines the theoretical underpinnings, existing literature on primary studies, and systematic reviews relevant to mobile learning in medical education.

Chapter 2: Literature Review

This chapter conducts a comprehensive review of existing literature related to mobile learning in medical education. It comprises three sections – theoretical literature, empirical studies, and systematic reviews. The synthesis of findings from these previous empirical studies and systematic reviews leads to the formulation of the research questions and the selection of a research methodology. A concept map illustrating these areas of the literature review is presented in Figure 2.1.

2.1 Theoretical Literature Review

This section discusses theories, frameworks, and models of mobile learning. The rationale for reviewing these theories, frameworks, and models is to provide a comprehensive understanding of how and why students learn by using mobile devices.

Crompton (2013b), in the Handbook of Mobile Learning, notes that proposing theories for mobile learning is a challenging task. A two-step approach was applied to undertake this endeavour. First, the term "mobile learning" was deconstructed into two components: "mobile devices" and "learning". Next, through extensive literature reading listed in Appendix B, theories related to students' learning processes and those concerning mobile devices or technologies were explored.

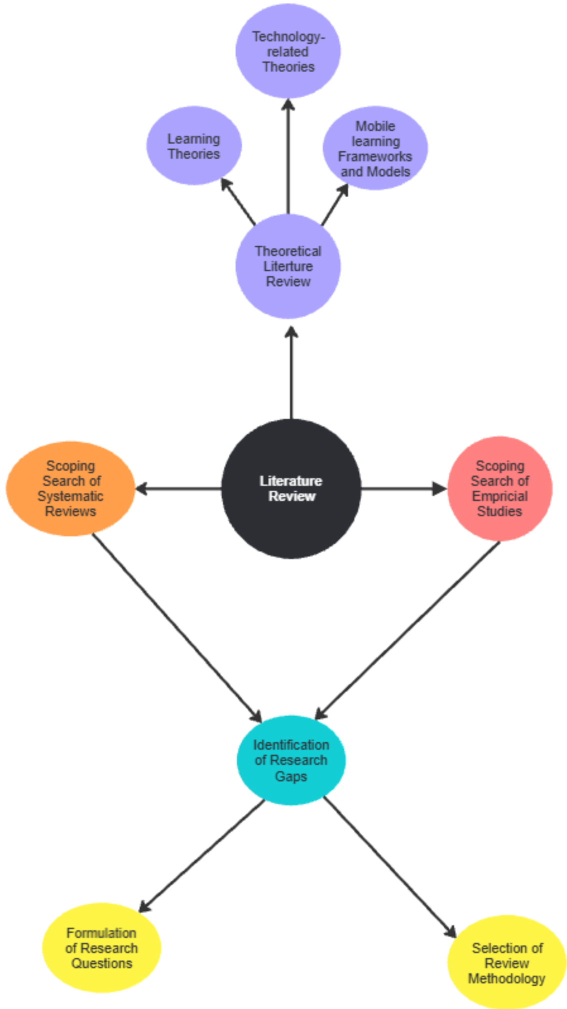

Figure 2.1 A Literature Review Concept Map of the Study

Using this approach, theories of mobile learning were categorised into two main groups: learning theories and technology-related theories. Based on the researcher's experience as an educator in the field of medical and health professional education, along with the extensive review of the literature listed in Appendix B, eight learning theories and four technology-related theories and models were selected to be discussed in this chapter. Their theoretical constructs are used to interpret and explain themes and sub-themes that emerged from the thematic synthesis. The reader can refer to Section 5.3 for the applications of theories and models described in Section 2.1.

The next section presents eight learning theories relevant to mobile learning implementation.

2.1.1 Learning Theories Relevant to Mobile Learning

Two teams of researchers have sought to link mobile learning with various learning theories. Naismith et al. (2004) identified six categories of learning theories relevant to mobile learning. These theories include behaviourism, constructivism, situated learning, collaborative learning, informal learning, and learning and teaching support. Another team, Keskin and Metcalf (2011), connected mobile learning with a broader set of 15 theories: behaviourism, cognitivism, constructivism, situated learning, problem-based learning, context-awareness learning, sociocultural theory, collaborative learning, conversational learning, lifelong learning, informal learning, activity theory, connectivism, navigationalism, and location-based learning. There is some overlap in the theories identified by these two teams of researchers, indicating common theoretical foundations in the study of mobile learning.

From these long lists, eight learning theories (Figure 2.2) were selected based on the researcher's experience and a thorough review of the literature. Each theory is explored in three areas: brief descriptions, critical analysis, and example studies of relevance to this research. This structured approach provides a framework for understanding how these theories support and explain the mechanisms of mobile learning among students.

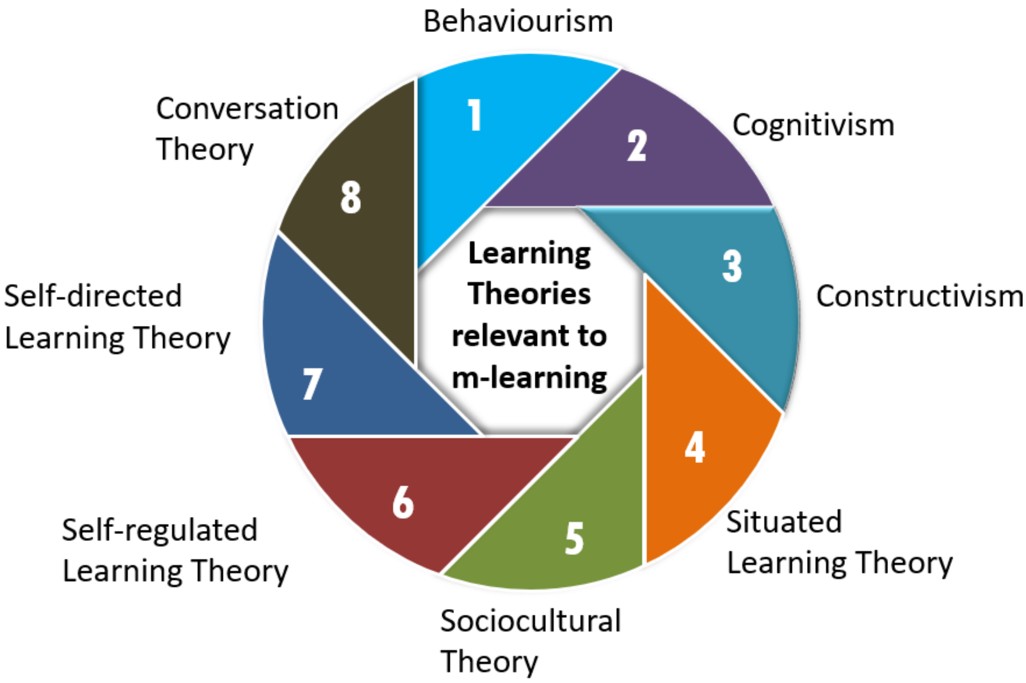

Figure 2.2 Learning Theories Relevant to Mobile Learning

2.1.1.1 Behaviourism

Behaviourist learning involves activities that promote observable changes in behaviour, aligning with Skinner's principles of operant conditioning, which build on Pavlov's classical conditioning (Bates, 2015a; Driscoll & van Barneveld, 2015; McQiggan et al., 2015a; Naismith et al., 2004). In this paradigm, learning is enhanced by reinforcing the association between specific stimuli and responses. While behaviourist teaching approaches are suitable for rote learning and the memorisation of factual information, they do not account for the role of cognition in learning. Students are treated as passive agents who receive information transmitted from the teacher, and their minds are viewed as blank canvases (Goldhawk, 2023b).

In mobile learning for medical education, behaviourism is particularly relevant for explaining self-directed learning behaviour. For example, Harmon (2015) applied interactive quizzes via mobile apps during anatomy lectures for medical students, where students received immediate feedback on their responses. This approach aligns with behaviourist principles by reinforcing correct answers through positive feedback, thereby improving students' academic performance through repetition and conditioning.

2.1.1.2 Cognitivism

This theory centres on how learners receive, organise, store, and retrieve information. In this model, sensory inputs such as sight and sound are processed and initially stored in short-term memory. Due to limited capacity, information stored in short-term memory is discarded, used immediately, or transferred to long-term memory for retention. Cognitivism addresses the mental processes of learning, emphasising structuring information to facilitate knowledge transfer from short- to long-term memory (Bates, 2015c; Driscoll & van Barneveld, 2015; McQiggan et al., 2015a). However, it can be overly mechanistic, treating learners like information processors and often ignoring the social and emotional dimensions of learning (Goldhawk, 2023b).

Cognitivism offers a useful lens for understanding how medical students engage in self-directed learning through mobile technologies. Mobile learning applications that use multimedia elements or interactive interfaces, such as three-dimensional (3D) anatomical models, benefit from cognitivism by enhancing memory retention and comprehension through well-structured content. For example, Küçük et al. (2016) used a mobile augmented reality (mAR) application (app) to teach a neuroanatomy topic. The app features interactive, high-quality images of the spinal cord, requiring students to identify and type answers for the labelled structures displayed. By combining visual inputs (images) with kinesthetic interaction (touch-based navigation), the app leverages dual-channel processing to facilitate the transfer of knowledge from short-term to long-term memory. These design features demonstrate how the app supports structured learning processes aligned with cognitive learning theory.

2.1.1.3 Constructivism

Constructivism focuses on creating a learning environment in which learners take centre stage in constructing the meaning of what they are learning and socially negotiating that meaning with others. In constructivist theory, activities in which learners actively construct new ideas or concepts based on their previous and current knowledge and learning are designed to be authentic, relevant, immersive, and contextual (Driscoll & van Barneveld, 2015; Naismith et al., 2004). Constructivist learning can be difficult to implement in a structured curriculum due to its open-ended nature. It may also require significant guidance to ensure that students construct an accurate understanding (Goldhawk, 2023b).

Mobile learning tools that allow students to engage in problem-based learning (PBL) or case-based learning (CBL) align with constructivist principles, such as virtual patient scenarios, to enhance diagnostic reasoning skills. For instance, Grover et al. (2020) used the Whatapp messenger for a CBL approach to pathology teaching. In this study, students engaged in a case scenario of a patient presenting with anaemia, simulating real-world medical practice. This experiential approach allows learners to construct their understanding of clinical processes by actively participating in realistic scenarios, aligning with constructivism's principle that knowledge is built through hands-on, meaningful activities.

2.1.1.4 Situated Learning Theory

Socially situated learning theory posits that learning is a social and collaborative process. It introduces the concept of "legitimate peripheral participation", whereby learners begin as apprentices at the periphery of a community and gradually acquire competence through interaction with experienced members. This "community of practice", as Wenger described it, is characterised by the shared interests and activities of its members (Aubrey & Riley, 2019b; Bradley & Postlethwaite, 2003; Loke, 2015).

Central to this theory is the importance of presenting knowledge in authentic contexts, where learners engage directly with real-world scenarios to develop practical skills (Bates, 2015b; Naismith et al., 2004). The theory has faced substantial criticism for the challenges in its application to modern, complex, and highly technological environments. Critics question its relevance to contemporary workplaces and educational settings, highlighting issues such as power dynamics, hierarchical structures, and conflicts among members, which can hinder collaboration and learning (Aubrey & Riley, 2019b).

The portability of mobile technologies allows the learning environment to be expanded beyond the classroom into authentic and appropriate contexts of use. In medical education practice, mobile devices enable situated learning through context-aware applications, such as tools for real-time patient data access during clinical rounds. For example, an iPad-based interactive app aligns with the principles of situated learning (Nuss et al., 2014). This application uses electronic health records (EHR), such as X-ray images, electrocardiograms, lab reports, and physician notes, and creates realistic patient cases. By navigating these cases and answering questions based on the timeline of medical events, students engage in decision-making processes that reflect actual clinical workflows. This immersion in patient care provides learners with meaningful, context-rich experience that fosters the development of their diagnostic and decision-making skills.

2.1.1.5 Sociocultural Theory (Social Constructivism)

This theory focuses on the role of social interaction and cultural context in cognitive development. Vygotsky argues that learning is not just an individual process; in fact, it is shaped by cultural tools, social interaction and language. He introduced the concept of the “zone of proximal development (ZPD)”, which identifies the gap between what a learner can do independently and what they can achieve with guidance from more knowledgeable others, such as peers or teachers. This concept is closely associated with scaffolding, where support is provided to learners to help them advance through their ZPD. Consequently, sociocultural theory underscores the importance of collaborative learning environments (Aubrey & Riley, 2019a; Bradley & Postlethwaite, 2003; Goldhawk, 2023b; Yardley et al., 2012). However, by placing too much emphasis on the role of community and culture in the learning process, the theory may underestimate the role of individual agency and self-regulation (Bates, 2015c).

Mobile learning apps such as discussion forums and group problem-solving activities align well with sociocultural principles and facilitate peer-to-peer collaboration. For example, O'Donovan and Maruthappu (2015) demonstrated how implementing a video-conferencing app called Skype for teaching clinical examinations to students from Malaysia and the UK reflects the core principles of social constructivism and collaborative learning. These videoconferencing apps enable social interaction, shared knowledge construction, interactive discussions, the collaborative creation of study resources, and team-based learning activities. These features foster a socially rich learning environment in which students and facilitators co-create knowledge and engage in collective problem-solving, highlighting the collaborative essence of sociocultural theory.

2.1.1.6 Self-directed Learning Theory

Self-directed learning (SDL), a concept derived from Knowles' theory of andragogy, is a learning process in which individuals take the initiative in their educational processes. These processes include diagnosing their own learning needs, formulating learning goals, identifying learning resources, selecting and implementing appropriate learning strategies, and evaluating their performance (Saks & Leijen, 2014; Taylor & Hamdy, 2013). SDL can be challenging for students who lack intrinsic motivation or the ability to self-regulate their learning effectively.

In the context of mobile learning, the unique affordances of mobile devices, such as portability, connectivity, accessibility, and flexibility, support SDL. These features empower students to take ownership of their learning, facilitating a more personalised learning experience. The role of SDL principles in anatomy education is highlighted in a study by Mansouri et al. (2020). In this context, self-assessment mobile apps enhanced SDL by encouraging students' active participation, fostering metacognition, and improving factual recall.

2.1.1.7 Self-regulated Learning Theory

Another learning theory linked to taking ownership of learning is Self-regulated Learning (SRL). Although it is a self-controlled learning process, instructors usually set learning goals, and the scope of the learning process is narrower than that of SDL. When applied to medical education, SRL describes the cyclical control of academic and clinical performance through several key processes, which include goal-directed behaviour, the use of specific strategies to achieve goals, and the adaptation and modification of behaviours or strategies to optimise learning and performance (Sandars & Cleary, 2011). Zimmerman's SRL process, described in Sandars and Cleary (2011), includes three phases – planning (goal-setting), performance (self-monitoring), and reflection (evaluating outcomes). In the context of mobile learning in medical education, Alegría et al. (2014) demonstrated how students used tablets for their self-regulated learning activities during their clerkship training programmes.

2.1.1.8 Conversation Theory

Conversation theory, developed by Pask, explores how knowledge is constructed through dialogue (Pask, 1976). According to the theory, knowledge is formed and agreed upon through conversational exchanges (Crompton, 2013b). Effective learning occurs when learners engage in conversation that allows them to interrogate and share their perceptions, leading to mutual understanding. Learning is seen as an ongoing dialogue with the external world, its artefacts, oneself, and with other learners and educators (Naismith et al., 2004). Building on this foundation, Laurillard (2007) developed the conversational framework to evaluate and leverage new technologies in support of the learning process. While conversation is a fundamental component of all learning forms, mobile learning activities provide opportunities for students to take ownership and control of their learning. This is achieved through digitally facilitated, location-specific activities (Crompton, 2013b). However, such dialogue can be difficult to implement in asynchronous mobile learning environments, where immediate interaction is not possible.

Mobile learning platforms such as discussion boards or synchronous chat tools foster conversational learning, allowing students to construct knowledge collaboratively. For example, a study using WhatsApp-based discussion groups aligns with conversation theory (Grover et al., 2020). In this study, learning occurred through meaningful dialogue and interaction between participants via a WhatsApp-based platform for collaborative learning and active engagement between students and faculty, facilitating the exchange of ideas and clarifications. The study exemplifies how conversational frameworks encourage learners to question, respond, and refine their thinking through interactions with peers and faculty.

The strengths, weaknesses, and relevance of the above-mentioned eight learning theories to mobile learning in medical education are summarised in Appendix C.

After analysing eight earning theories and their linkage to mobile learning, the next section discusses three technology-related theories relevant to mobile learning.

2.1.2 Technology-related Theories Relevant to Mobile Learning

The extensive literature review has identified three technology-related theories relevant to mobile learning: activity theory, technology acceptance models (TAMs), and the unified theory of acceptance and use of technology (UTAUT) (Figure 2.3). Each of them is discussed in three areas – brief descriptions, critical analysis, and example studies of relevance to this research.

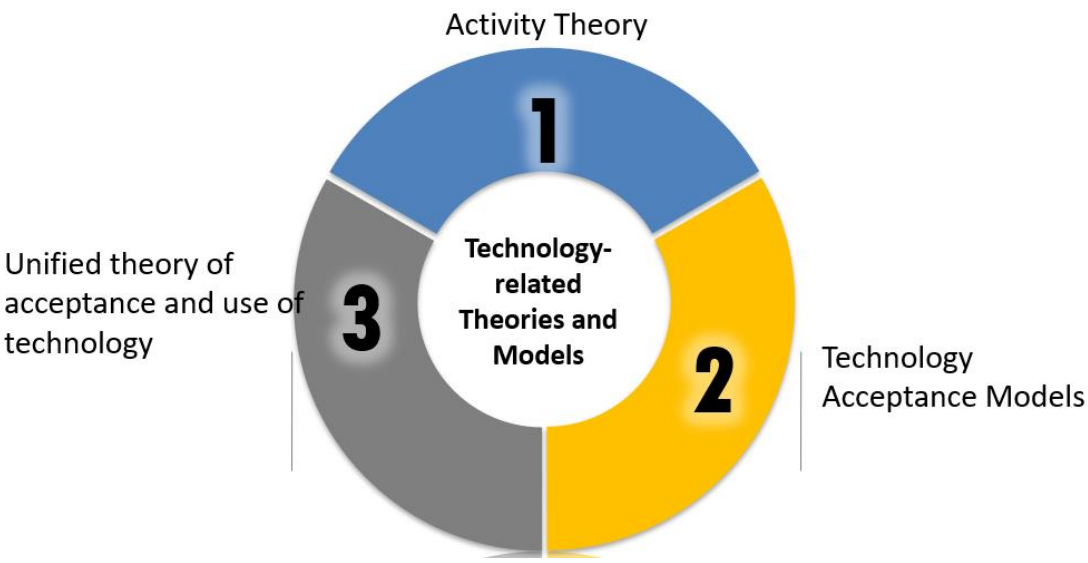

Figure 2.3 Technology-related Theories and Models

2.1.2.1 Activity Theory

Activity Theory (AT) is built on the work of Vygotsky (Isssroff & Scanlon, 2002), and a basic AT model consists of a subject (a learner or a group of learners), an object (a task or an activity), and artefacts (tools used by the subject). The activity transforms the object into a tangible or intangible outcome. However, as this basic model does not explain the relationship between a subject and its environment, Engeström (2014) introduces another component, the community, leading to the formation of three relationships: subject-object, subject-community, and object-community (Figure 2.4). Tools (artefacts) mediate the relationship between subject and object. Rules, norms, regulations, and etiquette mediate the interaction between subject and community, whereas the division of labour is a mediator between object and community. Contradictions and tensions may exist in AT theory when external influences change elements of activities and cause imbalances between them (Issa et al., 2014). The complexity of its framework can make it challenging to apply in practice. It may also be less intuitive for educators unfamiliar with its constructs.

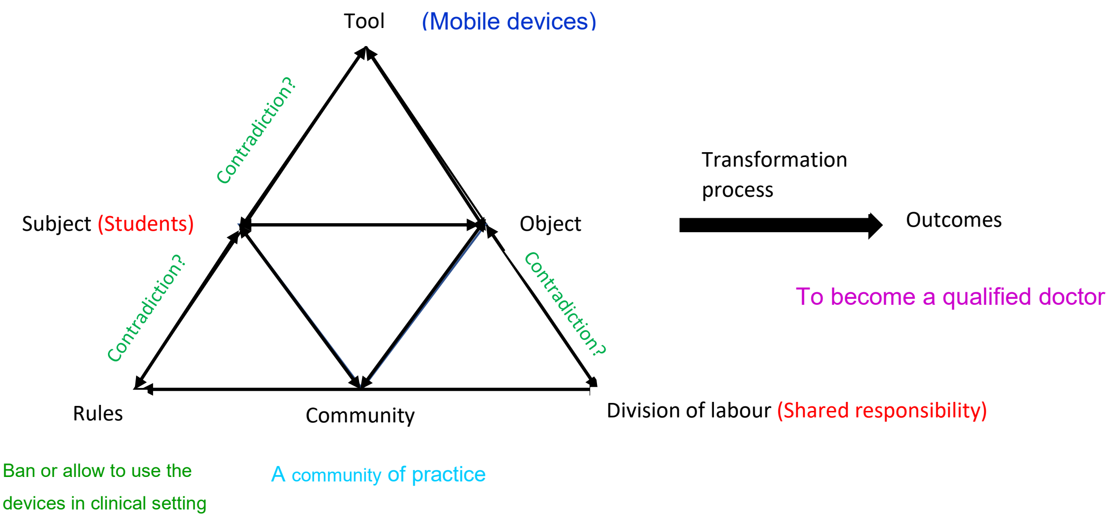

Figure 2.4 Components of an Activity Theory for Mobile Learning in Clinical Settings

In the context of mobile learning, AT provides a framework to analyse how mobile devices, as mediating tools, are integrated into educational practices and transform these practices. Pimmer et al. (2013) utilised AT to examine the impact of technology on medical education in resource-constrained countries. The study revealed that students adopted mobile technologies as cultural tools for informal learning, enabling them to facilitate situated learning by immediately accessing information sources relevant to their experience and engaging with educational content in social networking communities. Additionally, the study showed that tensions and confrontations emerged between learners and educators due to the implicit guidelines and hidden mobile curriculum, underscoring the complex interplay between technology, educational norms, and learning environments.

2.1.2.2 Technology-acceptance Models (TAMs)

TAM is a widely recognised framework used to understand and predict how people accept and use technology (Davis, 1989). The model suggests two determinants that influence an individual's decision to use a new technology:

1. Perceived Usefulness (PU): This refers to the degree to which a person believes that using a particular technology will enhance their job performance or productivity. If users perceive the technology as beneficial, they are more likely to adopt it.
2. Perceived Ease of Use (PEOU): This is the degree to which a person believes that using the technology will be free from effort. The easier a technology is to use, the more likely it will be adopted.

TAM was further extended to form TAM 2 (Venkatesh & Davis, 2000) and TAM 3 (Venkatesh & Bala, 2008) by adding additional variables. TAM 2 added two determinants: social influence and cognitive infrastructure processes. Subjective norms (the influence of others) and image (perception of enhancing one's status) represent a social influence process, while cognitive instrumental processes like job relevance, output quality, and result demonstrability make the usefulness of technology more apparent. In TAM 2, experience and voluntary use of technology are added as moderators.

TAM 3, six additional variables are added, and models of the determinants of PU and PEOU are developed. PU is determined by PEOU, subjective norm, image, job relevance, output quality, and result demonstrability. PEOU is determined by computer self-efficacy, perception of external control, computer anxiety, computer playfulness, perceived enjoyment, and objective usability. These last six variables are proposed as new relationships in TAM 3. Figure 2.5 illustrates the determinants of TAMs.

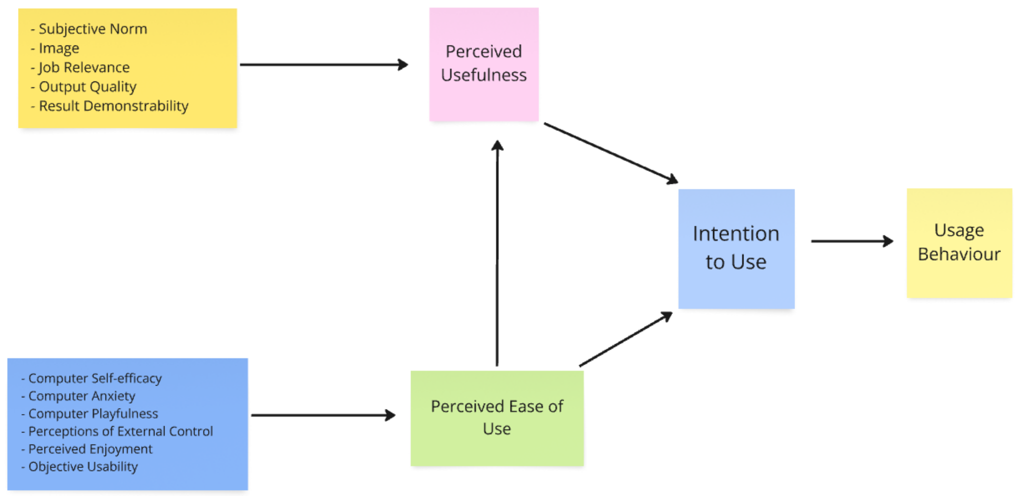

Figure 2.5 Determinants of Technology Acceptance Models

TAMs provide a robust framework for understanding the factors influencing the adoption and sustained use of mobile technology in medical education. In a study by Do et al. (2022), online surveys based on the TAM framework were conducted to identify factors affecting the use of iPads among preclinical medical students. The study revealed key drivers of mobile technology usage, including PU, PEOU, satisfaction, knowledge acquisition, and anticipation. Notably, most of these factors align well with the constructs of the framework, underscoring its applicability to guiding the integration of mobile technologies in educational contexts.

Although TAMs provide a robust framework to understand user acceptance of technology, there are certain limitations. First, TAMs are not specifically tailored to educational or clinical contexts, potentially limiting their applicability to scenarios like medical education. Second, the models do not account for dynamic or evolving user behaviours over time, such as changes in acceptance as users become more familiar with the technology. Last, TAMs do not adequately address social or organisational influences that are critical in collaborative settings like medical education.

2.1.2.3 Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT), proposed by Venkatesh et al. (2003), explains factors that influence a user's intention to use a technology. The model includes four main constructs: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions (Figure 2.6).

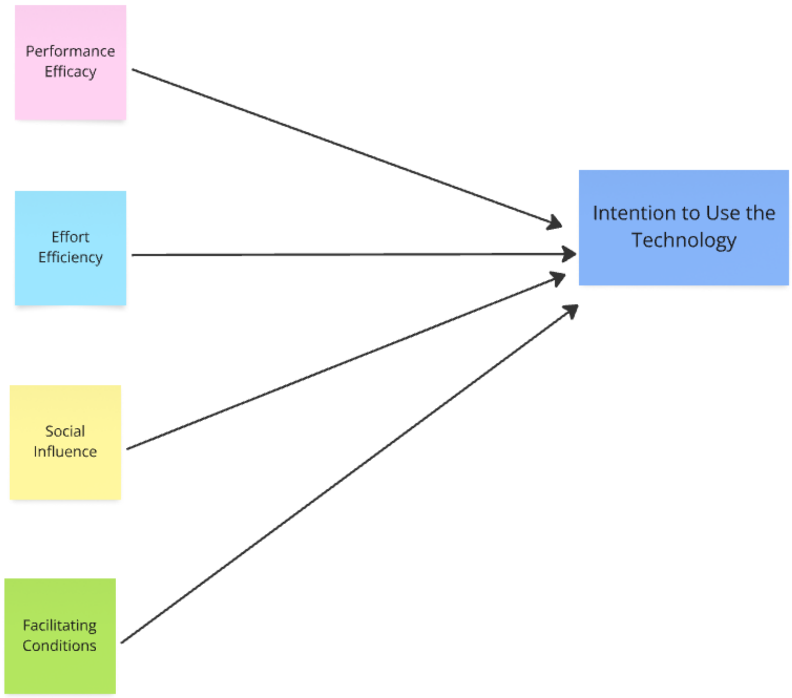

Figure 2.6 Four Main Constructs of the UTAUT Model

Performance Expectancy refers to people's belief that using a given technology will improve their work performance, and it equates with the PU construct from TAM (Davis, 1989). Effort Expectancy refers to people's belief that using the system is free of effort, and it is related to PEOU from TAM (Davis, 1989). Social Influence occurs when a user's decision to adopt a new system is influenced by their perception of what peers and faculty think about it.

Facilitating conditions are the perceived availability of organisational and technical infrastructure support for the system. These constructs are moderated by four variables: gender, age, experience, and voluntariness to use. UTAUT is valuable in understanding mobile technology adoption as it examines how social, organisational, and technical infrastructure contexts, along with perceptions of usefulness and ease of use, influence technology adoption.

The UTAUT model does have some limitations. The inclusion of multiple constructs and moderators makes the model more complex to apply and interpret compared to TAM. UTAUT is a general technology acceptance model and does not specifically address educational settings or learning processes. While comprehensive, UTAUT may not adequately address variations in technology use across diverse clinical and educational settings.

Although having certain weaknesses, UTAUT is well-suited to understand the broader institutional and social factors influencing mobile learning adoption in medical education. For example, Garavand et al. (2019) conducted a survey using the UTAUT model to identify factors influencing mobile learning adoption in medical education. The study revealed that effort expectancy, facilitating conditions, and behavioural intention had both direct and indirect effects on students' adoption of mobile technology. The study also highlighted demographic mediators, noting that gender and education level influenced adoption. This study demonstrates the model's potential to provide valuable insights into the adoption of mobile technology in medical education while accommodating diverse influencing factors.

While the TAMs and UTAUT are primarily developed for any technology-related applications in general, the next section presents a framework specifically designed for implementing mobile learning.

2.1.3 Frameworks and Models of Mobile Learning

This section examines one prominent mobile learning framework: the FRAME model. The model is composed of distinct components and dimensions, offering valuable insights to educators and other stakeholders on integrating mobile technologies into educational settings.

The FRAME model, an acronym for the Framework for the Rational Analysis of Mobile Education, was developed by Koole and is a comprehensive framework for analysing mobile learning (Koole, 2009; Koole et al., 2018). It incorporates three interrelated components: device (D), learner (L), and social aspects (S), along with their key intersections. Central to the framework is mobile learning, which is embedded with an information context. These components and intersections are depicted in Figure 2.7.

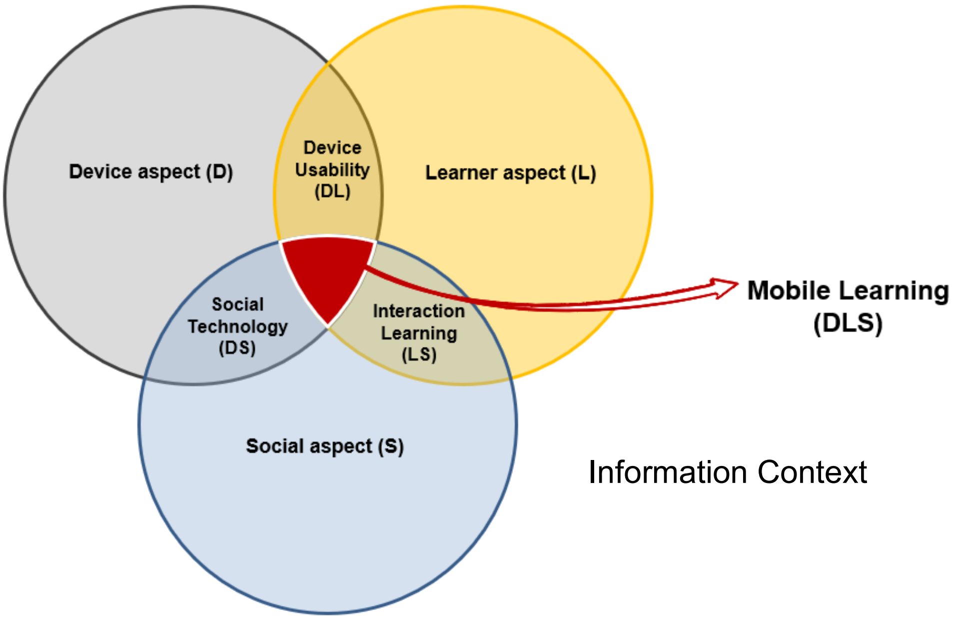

Figure 2.7 The FRAME Model for Mobile Learning Implementation

The device aspect (D) focuses on the physical and technical attributes of mobile devices, including their size, weight, input and output capabilities. The learner aspect (L) considers the characteristics of the learner, such as cognitive ability, prior knowledge, and learning preferences. The social aspect (S) addresses the interactions between learners and their social environment.

These components are represented in a Venn diagram to illustrate their interconnection. Overlapping areas signify the integrated nature of mobile learning, where the device, learner, and social aspects converge to create a holistic learning experience. This intersection is where mobile learning is most effective, leveraging the strengths of each component to enhance educational outcomes.

Device usability (DL), the intersection between device and learner aspects, focuses on user-friendliness and accessibility of mobile devices for learners. It involves evaluating the interface design, ease of navigation, and overall functionality of the device to support an effective learning experience. DL is crucial because it directly influences how learners interact with the technology, potentially facilitating or hindering the learning process.

Social technology (DS), the intersection between the device and social aspects, emphasises the role of technology in enabling social interaction and collaboration among learners. This includes tools and platforms that allow learners to communicate, share information, and collaborate, thereby enhancing the social dimension of learning. This intersection is vital for creating a connected learning environment where learners can engage with peers and teachers.

Interaction learning (LS), the intersection between learner and social aspects, focuses on how learners interact with their peers and the social context to facilitate a collaborative learning environment. It underscores the importance of social interactions in the learning process, whereby learners can share knowledge, discuss ideas, and learn from each other.

These components and intersections depicted in Figure 2.5 illustrate how they come together to create a comprehensive mobile learning experience. The model emphasises that no single aspect is more important than any other; instead, it is the integration of these elements that leads to effective mobile learning.

In the context of mobile learning, Lall et al. (2019) applied the FRAME model to synthesise the findings from qualitative and mixed methods studies on mobile learning implementation in medical and nursing education. The review identified factors impacting on students’ adoption of mobile technology in their learning, including the portability of devices, interaction among learners, and the need for institutional infrastructure and support. However, it also highlighted barriers such as limited Internet connectivity and challenges to professionalism.

With the theories, models, and frameworks of mobile learning implementation established, the next section focuses on previous research on digital technology and mobile devices in medical and health professions education.

2.2 Scoping Literature Search

This section discusses scoping searches on empirical studies and systematic reviews that investigated mobile learning in health professions education. These searches aim to provide an overview of the existing literature on mobile learning in medical education, an estimate of how many studies were likely to be found when the main search was conducted, and an understanding of key issues related to the topic area (Dundar et al., 2023).

A scoping literature search was conducted in two areas, namely, empirical studies and systematic reviews.

2.2.1 Scoping Search of the Literature on Empirical Studies

A scoping review of existing empirical studies on mobile learning in medical education was conducted by applying Arksey and O'Malley's (2005) methodological framework (Arksey & O'Malley, 2005). The research question guiding this scoping review was: "What is known from the existing literature about mobile learning in medical education?". This scoping search is presented under three headings: search strategy, search results, and identification of research gaps.

2.2.1.1 Search Strategy

Two electronic databases – Medical Literature Analysis and Retrieval System (MEDLINE) and Scopus – were used to search for papers, and two strings of keywords were used. The first string of keywords was "mobile learning" OR "m-learning" OR "M-learning" OR "mobile devices" OR "cell phones" OR "tablets" OR "smartphones". The second string of keywords was "medical students" OR "medicine students" OR "students in medicine". These strings were searched using delimiters of title and abstract, with the Boolean operator OR being used to expand the search. The Boolean operator AND is used to combine these two strings of keywords.

Reference lists of studies found through the databases were checked, and relevant studies were included in the scoping review. Three key journals in medical education, Medical Teacher, Medical Education and Clinical Teacher, were identified and searched for relevant articles.

The study population was limited to medical students in clinical placements. Empirical studies from academic journals written in English and published between 2010 and 2019 were included in the review. Relevant data from selected articles were extracted and recorded in a tabular matrix format (Appendix D).

2.2.1.2 Search Results

An initial search identified 520 papers, and after applying inclusion criteria, 42 papers were selected for a final scoping review. Among these 42 empirical studies, 63% were quantitative, 23% were mixed methods, and 14% were qualitative. Notably, the majority of studies employed survey methodologies, with limited use of qualitative or mixed-methods approaches.

Furthermore, 74% of the studies were conducted in developed countries and 26% in developing countries, highlighting a geographical imbalance in research on mobile learning.

The use of mobile devices in medical schools is considered a type of intervention, and it is categorised into two groups: the devices supplied by the school and a Bring Your Own Device (BYOD) scheme. Thirty-one studies (74%) investigated the practice of BYOD, whereas 11 (26%) examined the practice of the use of a mobile device supplied by the schools. Therefore, it can be said that BYOD is a common practice among medical students.

The scoping review categorised its findings into the following three themes.

2.2.1.2.1 Uses, Benefits, and Challenges of Mobile Devices

Mobile devices are widely used for logistical purposes (e.g., scheduling, web browsing), personal use (e.g., social media), learning tools (e.g., note-taking, reading e-texts), and learning content (e.g., accessing clinical guidelines and drugs information) (Ellaway et al., 2014). Key benefits include portability, real time access to information, and enhanced clinical decision-making support (Friederichs, Marschall, & Weissenstein, 2014; Wallace et al., 2012). Challenges include distractions from social media (Maudsley et al., 2019; Robinson et al., 2013), concerns over privacy and confidentiality (Pimmer et al., 2013), and negative perceptions among educators (Quant et al., 2016).

2.2.1.2.2 Use of Mobile Applications in Medical Education

Medical-related apps, particularly those providing drug information and clinical guidelines, are the most commonly used (Jebraeily et al., 2017; Payne et al., 2012). Students often use these apps contextually, such as searching for disease-related information before patient interaction (Joynes & Fuller, 2016).

2.2.1.2.3 Students' Learning Behaviours in Mobile Learning Environments

Mobile learning enables various learning behaviours – contextual learning (Davies et al., 2012), just-in-time learning (Joynes & Fuller, 2016), and opportunistic learning (Rashid-Doubell et al., 2016). However, the review highlights the presence of informal and hidden curricula**,** where the lack of explicit instruction on mobile device use may cause tension between students and educators (Pimmer et al., 2013; Shenouda et al., 2018).

2.2.1.3 Identified Gaps from the Scoping Search of Empirical Studies

While the scoping review provided a broad overview of mobile learning in medical education, it also revealed the following research gaps that require further exploration. A taxonomy of research gaps proposed by Miles (2017) is applied to identify these research gaps. Explanations of the different types of research gaps are given in Appendix A.

1. Knowledge Gap –Unexplored Factors Affecting Mobile Device Usage

The scoping review described mobile learning practices but did not investigate why students use mobile devices in certain ways.

2. Knowledge Gap – Lack of Connection Between the Usability and Benefits of Mobile Devices

While the review described the benefits of mobile learning, it did not link these elements to the usability features of mobile devices. There is a need to explore how mobile learning benefits, including learning behaviours, align with the functional features of mobile devices, such as portability and accessibility of information.

3. Knowledge Gap – Insufficient Exploration of How Mobile Devices Assist Students' Learning

While 80% of studies in the review focused on the advantages of mobile devices, only 20% investigated how these devices facilitate students' learning. There is a need to explore the mechanisms of how devices help students to achieve learning outcomes.

4. Knowledge Gap – Lack of Strategies to Overcome Challenges in Mobile Learning

Although challenges such as privacy concerns, distractions, and impacts on professional behaviour were noted, no studies in the review discussed how students employ strategies to mitigate these challenges.

Following the presentation of the scoping search of empirical studies, the next section examines the literature on previous systematic reviews.

2.2.2 Scoping Search of the Literature on Systematic Reviews

As this review study aimed to synthesise qualitative evidence of the effectiveness of mobile learning in medical education, the scoping search was expanded to identify systematic reviews of mobile learning in health professional education. This scoping search is presented in more detail, covering the search strategy, search results, data extraction, general and methodological characteristics of the included reviews, strengths and limitations of their methodologies, and the identification of research gaps.

2.2.2.1 Search Strategy

For this scoping literature search, MEDLINE Complete Database and Google Scholar were used. Appendix E details the strategy for searching the MEDLINE Complete Database.

The search terms used were “mobile learning OR m learning OR m-learning OR mobile devices”; “medical education OR health professional education OR health professions education OR health professions students”; and “systematic review OR meta-analysis OR qualitative systematic review”. These terms were searched within the Title and Abstract fields. The Title and Abstract were combined with the Boolean operator OR, while three key search terms were combined using the Boolean operator AND.

A supplementary search on Google Scholar was performed using the search terms “mobile learning”, “medical education”, and “systematic review”.

2.2.2.2 Search Results

The search strategy yielded 41 studies. Filters such as English language, academic journals, and subject major headings (e.g., mobile applications, medical education, distance education, cell phone, medical students, anatomy, augmented reality, clinical clerkship, clinical competence, handheld computers, continuing education, graduate medical education, internship and residency, professional practice) were applied. After applying these delimiters, 19 articles remained. Then, the titles of these 19 articles were screened, excluding those that were purely clinical or protocols for systematic reviews. This process resulted in eight relevant articles. Further screening of references of these eight reviews identified an additional four more systematic reviews. Three of these reviews, published in 2006, focused on PDAs. As these PDAs are no longer used in clinical practice, these three reviews were excluded. The remaining review had already been identified through database searches. A supplementary search on Google Scholar identified an additional article. Consequently, the final review included nine systematic review articles.

2.2.2.3 Data Extraction

Data on the nine selected reviews were extracted, capturing details such as author(s), year of publication, type of review, review questions, study population, type of intervention, outcomes, types of included studies, data used, key findings, conclusions, contributions, research gaps, and a critique of each review. The extracted data can be found in Appendices F and G, where Appendix F presents the general characteristics of the studies, and Appendix G specifically focuses on their methodological approaches. After data extraction was completed, data analysis and synthesis followed, which are presented in the next sections.

2.2.2.4 General Characteristics of Previous Systematic Reviews

The findings from nine systematic reviews are synthesised and presented under the subheadings of years of publication, type of review, study aim(s), study population, type of intervention, and outcomes.

2.2.2.4.1 Year of Publications

The reviews were published between 2016 and 2022, and articles included in the reviews were published between 1990 and 2020.

2.2.2.4.2 Types of Review

Among nine reviews, six used quantitative systematic review methods (Bajapai et al., 2019; Brusamento et al., 2019; Chandran et al., 2022; Dunleavy et al., 2019; Koohestani et al., 2018; Kyaw et al., 2019), two applied a mixed-methods systematic review (Maudsley et al., 2019; Mi et al., 2016), and one adopted a qualitative systematic review approach (Lall et al., 2019).

2.2.2.4.3 Aims of the Reviews

These reviews primarily aimed to assess the effectiveness and implementation of digital tools, including mobile technology, in health profession education. While quantitative systematic reviews primarily focused on evaluating the effectiveness of digital tools and mobile learning interventions, qualitative systematic reviews examined the factors that influence the implementation and use of mobile devices. A mixed-methods systematic review sought to identify both effectiveness and the factors influencing the effectiveness of mobile technology.

2.2.2.4.4 Study Population

The study populations in the reviews were mainly undergraduate and postgraduate health profession students, including those in medical, dental, nursing, and allied health fields. However, a review by Brusamento et al. (2019) targeted postgraduate health professionals specialising in paediatrics, and a review by Kyaw et al. (2019) focused exclusively on both undergraduate and postgraduate medical students. Focusing on various groups of students in the health professions could reflect the higher volume of digital education research in these fields.

2.2.2.4.5 Types of Interventions

Regarding types of interventions, mobile learning interventions were a prominent focus in most reviews, including those by Chandran et al. (2022), Dunleavy et al. (2019), Koohestani et al. (2018), Lall et al. (2019), Maudsley et al. (2019) and Mi et al. (2016).

In contrast, studies by Bajpai et al. (2019), Brusamento et al. (2019), and Kyaw et al. (2019) explored a broader range of digital tools in addition to mobile learning interventions. For instance, Bajpai et al. (2019) examined interventions, including online modules and offline modes, such as the use of compact disc read-only memory (CD-ROM) and digital simulation. Similarly, Kyaw et al. (2019) investigated online modules, virtual patient simulation, and video-assisted oral feedback as types of interventions. Brusamento et al. (2019)

specifically included the use of high-fidelity mannequins to assess clinical skills among paediatricians.

Most studies compared digital interventions to traditional learning methods. Some studies, for example, Brusamento et al. (2019), also compared different types of digital interventions, such as high-fidelity vs low-fidelity mannequins. The diversity of digital intervention studies reflects the rapidly evolving landscape of educational technology in health professions education. The predominance of mobile learning interventions may indicate their growing importance, possibly due to their flexibility and accessibility.

2.2.2.4.6 Outcomes of Reviews

The systematic reviews collectively affirm the effectiveness of mobile learning as a complementary or alternative approach to traditional educational methods. However, the scope and focus of outcomes vary among the reviews, and three groups of outcomes emerged: improvement in knowledge, skills, and attitude; identification of benefits and challenges; and use of learning theories in mobile learning and digital education interventions. These three outcomes are discussed in detail in the following sections.

2.2.2.4.6.1 Improving Knowledge, Skills, and Attitudes among Health Professionals

The outcomes of interventions reported in the reviews primarily focus on the effectiveness of digital tools in improving learners' knowledge, skills, and attitudes.

Three reviews reported the positive impact of digital tools on knowledge acquisition. Chandran et al. (2022) reported a substantial pooled effect size of 0.94 (95% CI: 0.57 to 1.31), indicating a positive effect of mobile apps on enhancing knowledge levels among health professional students. Similarly, Dunleavy et al. (2019) found mobile learning to be as effective as, or more effective than, traditional learning methods for improving knowledge, with a pooled effect size of 0.43 (95% CI: 0.05 to 0.80). Koohestani et al. (2018) also observed a significant enhancement in theoretical knowledge acquisition in areas such as medication error awareness and anatomy course performance, further underscoring the cognitive benefits of mobile learning tools.

The effectiveness of digital tools in enhancing skills varied across the reviews. Brusamento et al. (2019) highlighted a significant benefit of using high-fidelity mannequins in paediatric training, reporting an average improvement in post-intervention skill scores of 15%. Dunleavy et al. (2019) also found a positive impact of mobile learning on skills acquisition, with a pooled effect size of 1.12 (95% CI: 0.56 to 1.69). In contrast, Chandran et al. (2022) reported no significant improvement in skills, with a pooled effect size of 0.36 (95% CI: -0.23 to 0.96), suggesting that mobile apps may be less effective for skills development than knowledge acquisition. Kyaw et al. (2019) reported low-quality evidence and small effect sizes in the improvement of communication skills among medical students when comparing digital education to traditional methods. This finding suggests that while some digital tools are effective for general skills acquisition, their efficacy in developing communication skills may require further investigation.

Furthermore, Koohestani et al. (2018) highlighted improvements in students' attitudes and perceptions towards mobile learning, reflecting its benefits across Bloom's Taxonomy, particularly in the affective domain.

The findings collectively indicate that digital education modalities generally show promise in enhancing knowledge and skills. Mobile learning appears to be particularly effective in knowledge dissemination, while advanced simulation technologies, such as high-fidelity mannequins, excel in practical skills development.

2.2.2.4.6.2 Benefits and Challenges of Mobile Learning and Digital Education

In addition to investigating the effectiveness of mobile learning and other digital education interventions, three reviews explored the benefits and challenges of implementing these technologies.

The reviews collectively highlight several benefits of mobile learning and digital education. Lall et al. (2019) synthesised the findings from primary qualitative and mixed-methods studies by applying the FRAME model and identified benefits such as improved patient care and the facilitation of learning. In addition to these benefits, they also underscored the critical role of device usability, the social aspect involved in mobile learning, and a sense of ownership and personalisation. Similarly, Mi et al. (2016) highlighted the advantages of mobile learning in health professions education. Mobile devices enable students to access a wide range of educational resources and tools efficiently, enhancing their learning experience. The study emphasised the role of mobile devices in improving flexibility and convenience for learners, allowing them to engage with learning materials anytime, anywhere. These devices were also found to support personalised learning by catering to individual learning needs and preferences, fostering self-directed and independent learning. These tools also supported students in assessment, communication, clinical decision-making, note-taking, and accessing information, as noted by Maudsley et al. (2019). Across the reviews, mobile devices are recognised as valuable tools for fostering flexible and contextual learning in clinical and academic settings.

Despite these benefits, the reviews also identified several challenges associated with the implementation of mobile learning. Lall et al. (2019) highlighted the need for institutional support, reliable Internet connectivity, and appropriate training to facilitate the effective integration of mobile devices. Maudsley et al. (2019) identified concerns related to informal and hidden curricula, concerns about disapproval from educators and patients, patients' confidentiality, privacy, and security, and potential distractions when using mobile devices in clinical settings. Mi et al. (2016) further noted concerns about how preceptors and patients perceive mobile device use by students. These challenges underscore the importance of addressing social dynamics, providing clear institutional policies, and ensuring positive role modelling to optimise the use of mobile learning technologies.

2.2.2.4.6.3 Use of Learning Theories in Digital Education

Complementing the practical insights from these reviews, Bajpai et al. (2019) delved into the theoretical foundations of digital health education. The review examined the use of learning theories in the design and implementation of various digital education modalities. Analysis revealed that only one-third of the 242 included studies explicitly reported the use of learning theories, with the most commonly cited being problem-based learning, social learning theory, and Mayer's multimedia learning theory. The review also highlighted that many studies failed to integrate appropriate pedagogical frameworks in the planning and implementation of mobile learning and digital education interventions.

The next section presents the methodological characteristics of the nine systematic reviews.

2.2.2.5 Methodological Characteristics of Previous Systematic Reviews

This section focuses on the methodological approaches of nine systematic reviews, including protocol registration, types of databases used, supplementary search strategies, study design, data collection, extraction and analysis methods, quality appraisal tools, and reporting.

2.2.2.5.1 Registration of the Review Protocol

Five of the nine reviews (Brusamento et al., 2019; Chandran et al., 2022; Dunleavy et al., 2019; Kyaw et al., 2019; and Lall et al., 2019) explicitly mentioned protocol registration, with PROSPERO, University of York, Centre for Reviews and Dissemination https://www.crd.york.ac.uk/prospero/, showcasing adherence to methodological rigour. The remaining reviews did not specify protocol registration, which might indicate variability in transparency and methodological planning.

2.2.2.5.2 Types of Databases Used

Most reviews utilised a similar set of databases for literature search, including MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Excerpta Medica Database (EMBASE), PsycINFO, Education Information Resources Centre (ERIC), and Cochrane Central Register for Controlled Trials. This pattern indicates that the researchers applied a standardised approach in their search strategies. Additional databases like Scopus and Web of Science were also frequently used. Google Scholar and ProQuest were used selectively for grey literature searches.

2.2.2.5.3 Supplementary Search Strategies

Most reviews (seven out of nine) explicitly conducted supplementary searches, such as scanning reference lists, grey literature, key journals, and key conference proceedings, ensuring comprehensiveness in their search strategies. However, Lall et al. 2019 solely used a database search strategy, and Bajapi et al. (2019) did not mention supplementary search methods, potentially limiting their comprehensiveness.

2.2.2.5.4 Types of Included Studies

Among nine reviews, six reviews predominately included randomised controlled trials (RCTs) (Bajpai et al., 2019; Brusamento et al., 2019; Chandran et al., 2022; Dunleavy et al., 2019; Koohestani et al., 2018; Kyaw et al., 2019). Two (Maudsley et al., 2019; Mi et al., 2016) included quantitative, qualitative, and mixed methods studies, and one review by Lall et al. (2019) included qualitative and mixed method studies.

Overall, these reviews collectively cover a broad spectrum of methodological approaches, enhancing the robustness and applicability of their findings.

2.2.2.5.5 Study Selection and Use of Inclusion and Exclusion Criteria

All reviews reported clear inclusion criteria, primarily targeting health professional students and focusing on digital or mobile learning interventions.

2.2.2.5.6 Data Extraction

All reviews extracted data from the included studies using standardised data extraction forms. Tools for data extraction, such as pre-piloted forms, were used in reviews like Bajapi et al. (2019) and Maudsley et al. (2019), ensuring consistent and standardised data collection.

2.2.2.5.7 Use of Quality Appraisal Tools

The majority of the reviews conducted quality appraisals of the included studies. Four quantitative reviews (Brusamento et al., 2019; Chandran et al., 2022; Dunleavy et al., 2019; Kyaw et al., 2019) used Cochrane Risk of Bias Tools to assess the risk of bias in the included studies. Lall et al. (2019) adapted quality appraisal tools used in previous studies to evaluate the methodological qualities of the included studies. Koohestani et al. (2018) and Maudsley et al. (2019) adapted quality assessment tools designed for medical education research studies. Two studies (Bajpai et al., 2019; Mi et al., 2016) did not mention the use of quality appraisal tools.

2.2.2.5.8 Data Analysis Methods

As for data analysis methods, quantitative systematic reviews typically follow Cochrane methodology and utilise meta-analysis and pooled effect size to determine the effectiveness of digital tools. Meta-analysis used in these reviews facilitates summarising quantitative synthesis of results across studies, thereby increasing statistical power and providing more precise effect estimates.

On the other hand, qualitative synthesis methods such as framework analysis (Lall et al., 2019) and thematic analysis (Maudsley et al., 2019) enable the exploration of complex, context-dependent factors in the implementation of digital education.

A critical issue that arises from data analysis is evident in some reviews, such as those by Bajpai et al. (2019), Koohestani et al. (2018), and Mi et al. (2016), which included quantitative studies but opted for the development of themes, instead of performing meta-analyses. However, these reviews did not clearly articulate how the findings from quantitative studies, presented as numerical data, were analysed to contribute to qualitative evidence. This lack of transparency in the qualitative analysis process may undermine the reliability and validity of the findings from these reviews.

2.2.2.5.9 Reporting

Most reviews (except Bajpai et al., 2019) adhered to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) guidelines for systematic reviews, ensuring transparency and completeness in reporting.

2.2.2.5.10 Assessment of Overall Quality of the Reviews

Few reviews explicitly assessed the overall quality of their methodology or findings. Brusamento et al. (2019), Dunleavy et al. (2019), and Kyaw et al. (2019) employed the Grading of Recommendations, Assessment, Development, and Evaluations assessment (GRADE) criteria to assess confidence in their findings, while other reviews did not explicitly report similar evaluations.

2.2.2.5.11 Involvement of Review Members in Screening and Data Extraction

Most reviews highlighted multi-reviewer involvement during the screening of papers and data extraction phases to ensure reliability and resolve disagreements between the reviewers. However, Koohestani et al. (2018) lacked any explicit mention of team involvement in these critical steps, which might reduce reliability and increase bias.

2.2.2.6 Strengths and Limitations of Methodologies Used in the Previous Systematic Reviews

The methodological diversity among these systematic reviews reveals both strengths and limitations in the current body of research. Among the strengths, rigorous adherence to systematic review protocols indicates strong methodological planning and ensures transparency and replicability in the findings. Additionally, the use of mixed-methods approaches offers holistic insights by integrating quantitative and qualitative data. Another significant strength is the use of multi-reviewer involvement in screening and data extraction, enhancing reliability and reducing bias in most reviews. Adherence to PRISMA guidelines across most reviews ensures transparency and reproducibility in reporting. The consistent use of the Cochrane Risk Assessment Tool for quality appraisal in quantitative studies further ensures reliability and comparability in assessing evidence within these reviews.

Despite these strengths, certain limitations were identified. The lack of protocol registration in some reviews reduces transparency and replicability of findings. The limited use of qualitative systematic reviews restricted the in-depth exploration of learners' experiences and perspectives. Additionally, while quantitative studies applied standardised appraisal tools, other types of reviews exhibited variability in their quality appraisal methods, which could affect the consistency of evaluating evidence across the broader body of work.

Based on a detailed synthesis of these systematic reviews on mobile learning, the next section identifies research gaps.

2.2.2.7 Gaps Identified from a Scoping Search of Systematic Reviews

In this section, a total of seven research gaps are identified from the synthesis of findings of nine systematic reviews. Miles's (2017) taxonomy of research gaps applied in Section 2.2.1 is used to classify these gaps.

2.2.2.7.1 Knowledge Gap – Lack of evaluation of Long-term Effectiveness of Mobile Learning

The predominance of short-term outcome measures limits our understanding of the long-term effects of digital education interventions. Few studies (Koohestani et al., 2018; Mi et al., 2016) address the lack of evaluating the long-term effects of mobile learning interventions and highlight a critical area for future research to understand the long-term effectiveness and retention of knowledge and skills acquired through digital education.

2.2.2.7.2 Knowledge Gap – Lack of Focus on Ethical and Privacy Concerns

There is a lack of focus on ethical issues, particularly concerning patient privacy and data security in the use of mobile devices in clinical settings (Lall et al., 2019).

2.2.2.7.3 Knowledge Gap – Conceptual Gaps in Understanding Mobile Learning

While existing reviews have described the types, reasons, pedagogical benefits, and challenges of using mobile devices among health professionals, none have effectively conceptualised how these devices contribute to acquiring medical knowledge and developing clinical skills. There is a notable gap in defining a conceptual framework that underpins mobile learning in medical education.

2.2.2.7.4 Population Gap – Limited Research from Middle- and Low-income Countries

There is a recurring mention of the scarcity of studies from low-income countries, indicating a significant gap in understanding how digital education tools work in diverse socioeconomic settings (Brusamento et al., 2019; Chandran et al., 2022; Dunleavy et al., 2019; Kyaw et al., 2019).

2.2.2.7.5 Population Gap – Lack of a Specific Focus on a Study Population

Existing systematic reviews often encompass a broad range of health professionals, including both students and practitioners from various fields such as medical, dental, nursing, and allied health, without distinguishing between them. Given the distinct roles and responsibilities of healthcare professionals, summarising their experiences with mobile devices collectively may not accurately reflect the unique challenges and benefits that each group faces. This lack of specificity in existing research underscores the need for focused studies on particular subgroups within the health professions.

2.2.2.7.6 Methodological Gap – Underutilisation of Qualitative Evidence Synthesis Methods

Despite the inclusion of qualitative studies in some reviews, there is a general underutilisation of qualitative methods to explore deeper insights into the experiences and perceptions of learners and educators regarding the use of mobile devices and other digital technologies in educational settings.

2.2.2.7.7 Theoretical Gap – Lack of Theoretical Underpinnings in Design and Implementation

Four reviews (Bajpai et al., 2019; Dunleavy et al., 2019; Lall et al., 2019; Maudsley et al., 2019) noted a lack of use of learning theories and pedagogical frameworks in the design and implementation of digital education tools. The lack of explicit pedagogical frameworks in these reviews suggests a potential area for improvement in digital education design and implementation.

After presenting the research gaps identified from a scoping search of systematic reviews, the next section summarises the findings of previous systematic reviews.

2.2.2.8 Overall Summary and Leveraging Insights from Previous Systematic Reviews

The synthesis of nine systematic reviews provides a comprehensive overview of the research conducted on mobile learning and digital education within health profession education. These reviews, published between 2016 and 2022, collectively encompass articles from 1990 to 2020. They include six quantitative systematic reviews, two mixed-methods systematic reviews, and one qualitative systematic review, reflecting diverse methodological approaches. The primary focus of these reviews was to evaluate the effectiveness and implementation of digital tools and mobile technologies, with study populations ranging from undergraduate to postgraduate students in medicine, nursing, and allied health. While most interventions concentrated on mobile learning tools, some reviews also investigated broader digital tools, such as high-fidelity mannequins, virtual patient simulations, and online modules.

The findings from the reviews highlight three main outcomes. First, mobile learning interventions were effective in enhancing knowledge acquisition, with pooled effect sizes demonstrating significant improvements. However, the impact on skills development varied, with tools like high-fidelity mannequins excelling in practical training, while mobile apps showed limited effects on skills acquisition. Second, in addition to effectiveness, the reviews explored the benefits and challenges of mobile learning. Benefits included portability, personalised learning, and contextual learning, which fostered evidence-based practice and self-regulated learning. Conversely, challenges such as professionalism concerns, privacy issues, and technical limitations underscored the need for institutional support and clear policies. Last, one review further examined the integration of learning theories into digital education, revealing a gap in the consistent application of pedagogical frameworks. Collectively, these insights provide a nuanced understanding of the potential and limitations of digital education within health professional education.

The synthesis of findings from previous systematic reviews offers crucial insights into shaping the methodology of the study. First, the gaps identified in the preceding sections informed the development of the research questions and the selection of an appropriate methodology for this study. Second, the previous reviews provided a refined list of keywords and search terms tailored for mobile learning in health professions education. By incorporating these proven search terms into the literature search strategy, a comprehensive and focused retrieval of relevant studies can be ensured for the present study. Third, the identification of key databases such as MEDLINE, CINAHL, and EMBASE, which are repositories of high-quality research in health professions education, guides the selection of resources. This targeted approach helps to access the most pertinent studies and enhances the breadth and depth of this literature review. Finally, the use of established and robust quality assessment methods, as outlined in previous systematic reviews, offered a structured framework for evaluating the effectiveness of mobile learning interventions.

After summarising the scoping search of the systematic review, the next section consolidates the research gaps identified in Sections 2.2.1.3 and 2.2.2.7.

2.2.3 Consolidation of Research Gaps Identified from the Scoping Searches

Research gaps identified from the scoping reviews of primary studies (Section 2.2.1.3) and systematic reviews (Section 2.2.2.7) are consolidated and grouped based on the types of gaps (Table 2.1).

Table 2.1 Identified Research Gaps from the Scoping Searches

	Type of Research Gap	Research Gap Identified from Scoping Searches
1.	Knowledge gap	Unexplored factors affecting mobile device usage among students
2.	Knowledge gap	Insufficient exploration of how mobile devices assist students’ learning
3.	Knowledge gap	Lack of strategies to overcome challenges of mobile learning
4.	Knowledge gap	Lack of focus on ethical and privacy concerns in using mobile devices
5.	Knowledge gap	Lack of evaluation of long-term effectiveness of mobile learning
6.	Population gap	Limited research on mobile learning in low- and middle-income countries
7.	Population gap	Lack of focus on a specific study population of health professionals
8.	Theoretical gap	Lack of theoretical underpinning design and implementation of mobile learning
9.	Methodological gap	Underutilisation of primary qualitative and qualitative systematic reviews regarding the use of mobile devices and other digital technologies

After the research gaps have been identified, the next section presents the development of review questions and the selection of a research methodology for the study to address these selected research gaps.

2.3 Development of Review Questions and Selection of the Research Methodology

This section discusses the evolution of the development of the central research question, the formulation of sub-questions, and the selection of a research methodology.

2.3.1 Formulation of a Central Review Question

A preliminary review question was drafted as “What are the experiences of medical students with the use of mobile devices in their training programmes?” taking into account the question formulation used by Joanna Briggs Institute (JBI) Evidence Synthesis (Lockwood et al., 2020). The formulation uses the mnemonic PICo, where P stands for ***p***opulation, I stands for the phenomenon of ***i***nterest, and Co stands for ***co***ntext (Table 2.2).

Table 2.2 Review Question using the PICo Mnemonic

Review Question: What are the experiences of medical students with the use of mobile devices in their training programmes?		
Population	Phenomenon of interest	Context
Medical students	Experiences with the use of mobile devices	Medical training programmes

Recognising that this question was too broad and would pose challenges in conducting focused research, a strategy suggested by Machi and McEvoy (2022) was employed to refine it. By using this strategy, the question is broken down into four main concepts: medical students, experiences, mobile devices, and medical training programmes. This division highlighted that the key concepts were overly broad and lacked specificity, prompting several critical questions: Which phases of medical education are being addressed – undergraduate or postgraduate? Which academic years are included? Are the students in preclinical or clinical years? What constitutes “experiences” in this context? How should “mobile devices” be defined within the scope of this study?

To address these issues and narrow the scope for a more in-depth investigation, several specific revisions were made by referring to a typical undergraduate medical education programme, as illustrated in Figure 2.8.

1. Study Population: the study was focused on medical students, drawing on the researcher’s extensive knowledge of medical training programmes and experience as an educator of both undergraduate and postgraduate medical

students. Another reason for exclusively focusing on medical students is that study populations in previous systematic reviews were a mix of medical and other health professions students. Since the job scopes of different health professionals vary, drawing evidence from a mixed group of study populations may not be generalisable to medical students. By concentrating on medical students, this study aims to provide insights that are directly applicable and relevant to medical students, thereby enhancing the impact and applicability of the findings in medical education.

2. Academic Phase: the academic phase was defined as including both preclinical and clinical years of an undergraduate medical training programme.
3. Definition of Mobile Devices: the term “mobile devices” was limited to smartphones, iPads, and tablets, as these are the devices most commonly used by students.
4. Operational Definitions of Experiences: experiences were defined as students’ perceptions, opinions, and feelings toward the integration and utility of mobile devices in their education, including their perceived benefits, challenges, and impact on learning outcomes.

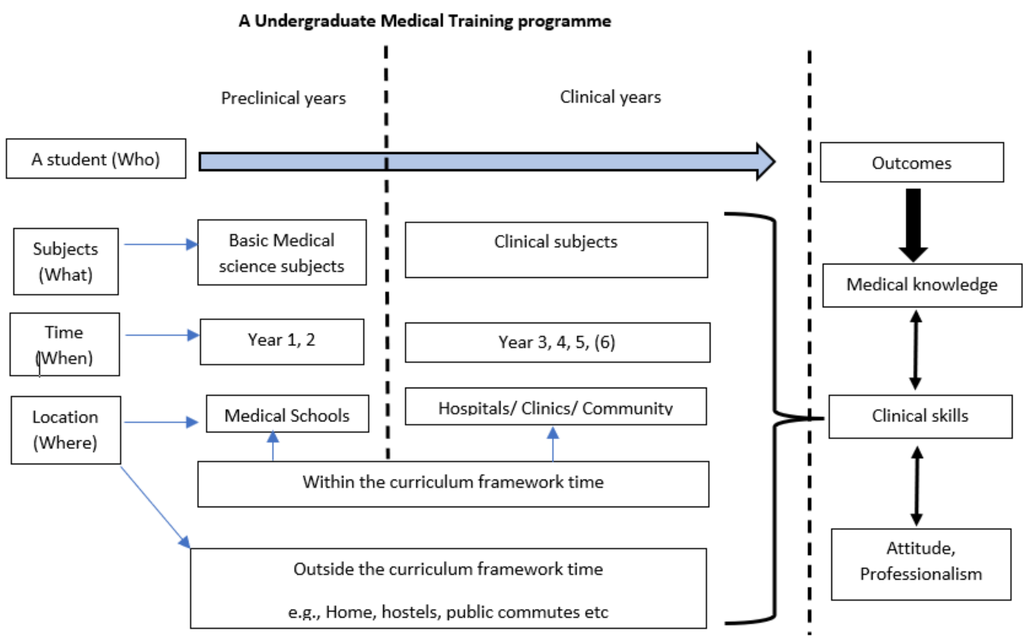

Figure 2.8 The Structure of A Typical Undergraduate Medical Training Programme

5. Phenomenon of Interest: the concept of “experiences” was recognised as broad and requiring further specification. To maintain a focus on the pedagogical aspects of mobile device use, the scope was limited to experiences related to students’ learning processes.

After considering these refinements, the revised review question became, “What are the experiences of undergraduate medical students with using smartphones, iPads, and tablets for learning during their preclinical and clinical years of training?”

In this revised question, the population is undergraduate medical students, and the phenomenon of interest is students’ experiences with the use of smartphones, iPads, and tablets for learning. Context is the preclinical and clinical years of an undergraduate medical training programme (Table 2.3).

Table 2.3 Revised Review Question

Review Question: What are the experiences of undergraduate medical students with using smartphones, iPads, and tablets for learning during their preclinical and clinical years of training?		
Population	Phenomenon of interest	Context
Undergraduate medical students	Experiences with the use of smartphones, iPads, and tablets for learning	Preclinical and clinical years of medical training programmes

2.3.2 Development of Sub-questions

After the central review question was formulated, the research gaps identified in Section 2.2.3 were referred to develop the following sub-questions:

1. What are the enablers and barriers to mobile device usage among medical students?
2. What are the usability features of mobile devices?
3. What benefits do students gain from using mobile devices in their learning?
4. How do the usability features of mobile devices facilitate students’ learning?
5. What challenges do students encounter in their learning when using mobile devices?

6. How do students adapt to mitigate the challenges they face in their mobile learning practices?

The mapping of research gaps (Table 2.1) and related review sub-questions (Section 2.3.2) is illustrated in Table 2.4. Among nine research gaps, six of them, shaded in green, are addressed in this review.

Table 2.4 The Mapping of Research Gaps and Review Questions to Address These Gaps

	Type of Gap	Research Gap Identified from Scoping Searches	Review Questions (RQ)
1.	Knowledge gap	Unexplored factors affecting mobile device usage among students	RQ 1 (Unexplored factors are meant for enablers and barriers)
2.	Knowledge gap	Insufficient exploration of how mobile devices assist students' learning	RQ 2, 3 and 4 (The research gap of how mobile devices facilitate students' learning is addressed by exploring device usability features, pedagogical benefits, and how these features bring about these benefits. These three areas of inquiry are addressed as RQ 2, 3 and 4)
3.	Knowledge gap	Lack of strategies to overcome challenges of mobile learning	RQ 5 and 6 (Although the gap focused on ethical and privacy concerns, the study expanded the gap to include all challenges students face. It is framed as RQ 5 and challenges students adopted as RQ 6)
4.	Knowledge gap	Lack of focus on ethical and privacy concerns in using mobile devices	
5.	Knowledge gap	Lack of evaluation of long-term effectiveness of mobile learning	Not addressed in this review
6.	Population gap	Limited research on mobile learning in low- and middle-income countries	Not addressed in this review
7.	Population gap	Lack of focus on a specific study population of health professionals	The study population is focused on medical students

			(The focus on medical students is explicitly mentioned in RQ 1)
8.	Theoretical gap	Lack of theoretical underpinning in the design and implementation of mobile learning	Not directly addressed in this review. However, educational theories are applied to explain students' learning behaviours.
9.	Methodological gap	Underutilisation of primary qualitative and qualitative systematic reviews regarding the use of mobile devices and other digital technologies	The selection of the review methodology as a qualitative systematic literature review (This research gap does not need to be included in the RQs, as it is one of the reasons for adopting qualitative methodology in this study)

2.3.3 Selection of the Research Methodology

Given the nature of the review questions, which focus on an in-depth exploration of students' experiences, and the identified methodological gap (Table 2.4), this study aims to employ a qualitative systematic literature review approach to synthesise findings from primary qualitative and mixed-methods studies on mobile learning implementation in medical education.

2.4 Chapter Summary

This literature review chapter has thoroughly examined the multifaceted aspects of mobile learning within health professions education, covering its theories, frameworks, and models. Previous research on the use of mobile devices among health professionals and education students has also been synthesised.

As this chapter concludes, it sets the stage for the next chapter on Methodology. The forthcoming chapter will detail the research design and methods employed to address the gaps identified in this review.

Chapter 3: Methodology

This chapter outlines the research approach and methods used in this study. It begins with a discussion of the research's underlying philosophical assumptions, including the ontological and epistemological stance that informs it. Next, an explanation of the chosen methodological approach, a qualitative systematic literature review, is given. The chapter then describes a ten-step process for conducting this review. Finally, ethical considerations are discussed to demonstrate the study's reliability and credibility.

3.1 Philosophical Assumptions of the Study

This study adopts a constructivist ontological stance, recognising that reality is not a fixed, singular entity but rather is shaped by human interactions, interpretations, and meanings (Cohen et al., 2011; Creswell & Creswell, 2017; Egbert & Sanden, 2014b). In the context of medical students' experiences with mobile devices for learning, knowledge is constructed by the diverse perspectives presented in existing primary studies. Instead of seeking an objective truth about the effectiveness of mobile learning, this study acknowledges that multiple realities exist, each influenced by the various contexts in which research is conducted. By synthesising the findings from various qualitative studies, this research aims to construct a deeper understanding of how medical students interact with mobile devices as learning tools rather than uncovering a singular, universal experience.

Given this constructivist ontological stance, knowledge about medical students' mobile learning experiences is not discovered in an objective sense but rather emerges through an inductive approach to interpretation and meaning-making. This study, therefore, aligns with an interpretivist epistemology, which assumes that knowledge is subjective, fluid, and shaped by human experiences and contexts (Cohen et al., 2011; Creswell & Creswell, 2017; Egbert & Sanden, 2014a; Egbert & Sanden, 2014b).

3.2 Methodological Approach to Research

Since this study follows an interpretivist epistemology, it is essential to use a methodology that supports the synthesis of meaning rather than objective measurement. A qualitative systematic literature review with thematic synthesis is well suited to this approach, as it enables the identification and interpretation of patterns across diverse qualitative research findings. This methodological approach ensures that findings are not merely collated but rather analysed in a way that generates new insights by making connections between the findings of empirical studies (Aveyard et al., 2016a).

3.3 Research Methods

The systematic review processes described by Aveyard (2023), Aveyard et al. (2016b), Booth et al. (2016), Dickson et al. (2023), Gough et al. (2013), and Harden and Thomas (2005), as well as the systematic literature searching guide provided by Lancaster University (https://lancaster.libguides.com/health/systematic), were analysed and synthesised to develop a ten-step process (Figure 3.1). This refined process serves as the foundation for the methodology employed in this research study.

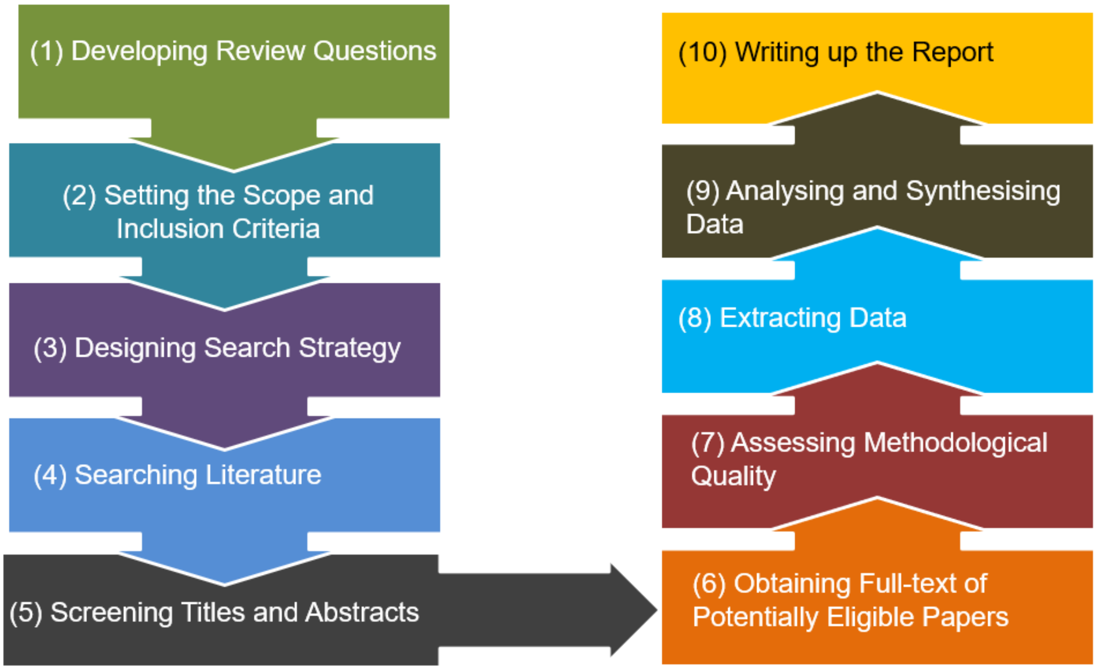

Figure 3.1 Steps for Conducting a Systematic Literature Review

3.3.1 Developing Review Questions

The review questions stated in Section 2.3 are reiterated here to ensure clear linkages between the steps.

The review question is: "What are the experiences of undergraduate medical students with using smartphones, iPads, and tablets for learning during their preclinical and clinical years of training?".

3.3.2 Setting the Scope and Inclusion Criteria

The eligibility criteria for the review were defined to ensure a focused and relevant analysis of mobile learning in medical education. These criteria covered seven key aspects: population, types of intervention, phenomenon of interest, context, types of studies, language, and year of publication.

Starting with the population, the review included studies involving undergraduate medical students enrolled in either public or private medical schools. These students were pursuing an undergraduate medical degree with no restrictions on age or gender (Dunleavy et al., 2019). Studies that involved other medical professionals, such as faculty members, postgraduate medical students, residents, doctors, specialists, and other health professional students (e.g., dental, nursing, pharmacy, physiotherapy, occupational therapy, and radiography students) were included, provided that qualitative data for undergraduate medical students could be extracted separately. However, studies involving these healthcare professionals, either alone or in combination with medical students, were excluded if qualitative data specific to undergraduate medical students could not be isolated. This approach ensured a clear focus on the perspectives of undergraduate medical students.

Regarding types of interventions, the review focused on medical students' use of mobile devices, such as smartphones, iPads, and tablets. This definition aligns with the parameters set in Section 2.3.1, which explicitly excludes other electronic devices, such as desktop computers. This focus helped to isolate the unique contributions of mobile devices to medical education.

For the phenomenon of interest, the review included studies that explored the experiences of undergraduate medical students in using smartphones, iPads, and tablets during their preclinical and clinical years of training. Studies that only focused on unrelated technological aspects or that lacked relevance to students' learning were excluded.

In terms of context, the review included studies conducted in both academic and non-academic settings, as depicted in Figure 2.6 of a typical undergraduate medical programme. Academic settings encompassed educational environments such as medical schools, hospitals, and clinics, irrespective of geographical location. Non-academic settings included any location outside formal teaching environments like homes, hostels, or public commutes, provided they were used for learning purposes. These broad inclusion criteria ensured a comprehensive understanding of where and how mobile learning occurs within the context of medical education.

The types of studies included were those using qualitative research methodologies, such as phenomenology, ethnography, grounded theory, and action research. The review also included the qualitative component of mixed-methods studies if it could be distinctly defined and extracted. Data collection methods included focus group discussions, individual or group interviews, and observation.

Last, concerning language and year of publication, the review was limited to papers written in English and published between 2010 and 2022. The start date of 2010 was selected based on an observation of Klimova (2018), i.e., that mobile learning began to penetrate medical education in that year.

A summary of inclusion and exclusion criteria, serving as a quick reference guide for the reader, is shown in Appendix H.

3.3.3 Designing the Search Strategy

After identifying the scope and establishing inclusion and exclusion criteria, a search strategy was designed to identify relevant literature, adapting key steps suggested by Dundar et al. (2023). This search strategy encompassed three steps, shown in Figure 3.2.

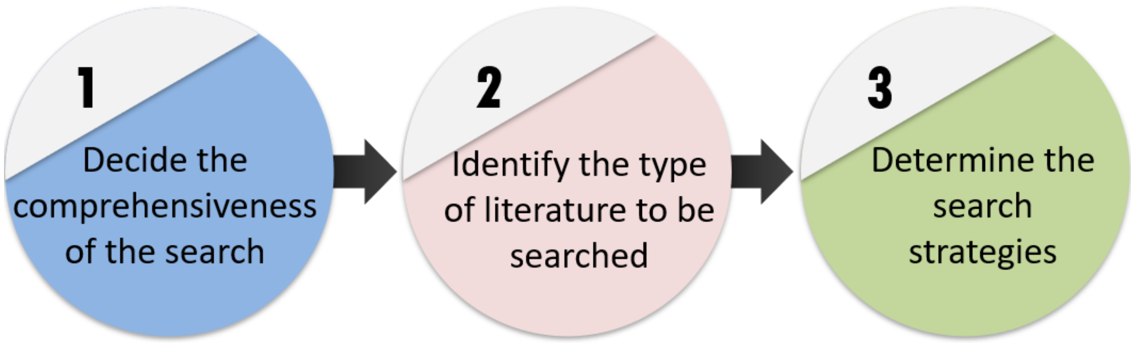

Figure 3.2 Key Steps Undertaken to Design the Search Strategy

First, the comprehensiveness of the search was decided by considering the review question and the topic area. As it was crucial to strike a balance between sensitivity and specificity, it was decided to search the literature as comprehensively as possible. Second, the types of literature to be included were identified. Despite time and resource constraints, the search aimed to identify literature relevant to answering the review question. Therefore, it was planned to search both published and unpublished literature. The published literature included empirical studies employing qualitative and mixed-methods methodologies. Unpublished materials, classified as grey literature, included sources not indexed by commercial publishers, such as theses and dissertations relating to the review question.

Last, transitioning from the planning to the execution phase, six search strategies were employed: (1) electronic searching using computer-held databases, (2) searching reference lists, (3) citation searching, (4) hand-searching of relevant journals specific to medical education, (5) author searching, and (6) locating unpublished grey literature (Aveyard, 2023; Aveyard et al., 2016b; Booth et al., 2022). Electronic database searching served as the primary approach, while the remaining five strategies acted as supplementary methods to complement it. Figure 3.3 illustrates the search strategies used in this research study.

Figure 3.3 Search Strategies Used for the Study

3.3.4 Searching Literature

This section details how the six search strategies mentioned in Section 3.3.3 were implemented.

3.3.4.1 Electronic Database Searching

Electronic database searching was the primary strategy adopted, and it involved four steps (Dundar et al., 2023), as shown in Figure 3.4.

Figure 3.4 Key Steps in Electronic Database Searching

3.3.4.1.1 Identifying Specific Databases

The first step in the search strategy was to identify and locate databases relevant to the research topic. These databases were then categorised into two types: subject-specific and general science databases. Subject-specific databases included those related to medicine and education, such as MEDLINE Complete, CINAHL, EMBASE, the Cochrane Library for Medicine, ERIC, British Education Index, and PsycInfo for education. General science databases included Scopus, Web of Science, and Google Scholar. Of the ten databases identified, eight (MEDLINE Complete, CINAHL, EMBASE, ERIC, British Education Index, PsyInfo, Scopus, and Web of Science) were accessed through Lancaster University, one (Cochrane Library) through the University of Dundee, and one (Google Scholar) via the Google search engine. MEDLINE Complete and CINAHL were accessed through EBSCOHost and EMBASE through OVID platforms.

3.3.4.1.2 Identifying Key Search Terms

The second step was defining keywords. Three key concepts from the research question were identified to define keywords. The first concept was the study population, specifically, the type of student. The second concept was the type of intervention, which in this study involved mobile devices. The third concept was the phenomenon of interest, which is the experience of students in using mobile devices for learning and educational activities. It is important to note that the types of studies, i.e., qualitative and mixed methods methodologies, as the fourth concept, were intentionally not included because combining too many keywords might result in nil or very few results. Another reason was that the study design might not be explicitly included in the titles of the research articles. Therefore, qualitative and mixed-methods studies were searched during the screening phase by scanning both titles and abstracts.

Three approaches were used to generate keywords and synonyms. First, the researcher's medical knowledge was used to identify relevant terms related to the chosen topic. Second, the published systematic reviews discussed in Section 2.2.2 were referred to, and their search filters were adapted to extract relevant keywords. Third, librarians and information specialists from Lancaster and Oxford Universities were consulted. Generating keywords for a literature search involved several iterative steps. The keywords were carefully reviewed and refined in each iteration to ensure alignment with the main concepts of the research topic. After five rounds of revision, a finalised list of keywords was developed to reflect the focus of the study.

3.3.4.1.3 Searching Databases

The third step was to search the databases selected in Step 1. The keywords and their synonyms identified in Step 2 were entered into search boxes in the databases, and search fields were limited to title and abstract. Title searching specifically searched for keywords within the titles of articles, aiming to identify studies that directly addressed the topic of interest. Similarly, Abstract searching targeted the keywords present within the abstracts of papers.

Two Boolean operators were used in combination with the identified keywords to retrieve more relevant articles. Using the “OR” operator, the search was expanded to include articles containing the specified keywords or their relevant synonyms within each concept. This approach captured a more comprehensive range of articles related to the research topic. The “AND” operator narrowed the search results by finding articles with all the specified keywords. Using the “AND” operator ensured that the articles retrieved focused on the intersection of three main concepts of the research topic. This approach helped to identify articles that specifically addressed the relationship between mobile devices, experiences, and medical students.

Additionally, Medical Subject Headings (MeSH) were used for these three concepts in MEDLINE Complete, CINAHL, and EMBASE databases to identify specific keywords. In the search strategy, the “Major Concept” tag in MeSH was applied to focus on articles where the selected MeSH terms were the main subject of the study. This search string was indicated by “MM” in the search results, signifying that the articles retrieved were primarily centred around the major concepts defined in the MeSH terms, ensuring the relevance and specificity of the search results to the research questions. The identified MeSH terms were also combined using the Boolean Operator “OR”. The results from the free text keywords search and those from the MeSH searches were then combined using the Boolean Operator “AND”. The application of both a free-text keyword search and a MeSH search for the three concepts using the MEDLINE Complete database is illustrated in Appendix I.
In the search strategy for this review, three advanced search techniques were employed to enhance the precision and breadth of the search results. These techniques included the use of wildcard and proximity operators, specifically an asterisk (*), a question mark (?), and the adjacent search operator (EBSCOHost., n.d.).

An asterisk (*) used as a wildcard operator allows for the inclusion of multiple variations of a root word. By placing an asterisk at the end of the root of a word, the search engine retrieves records that contain any ending of that root word. For example, using mobile technolog* would search for “mobile technology” and “mobile technologies”.This technique is particularly useful in capturing data that might use different terminologies or derivations of a core concept.

A question mark (?) serves as a single-character wildcard. It replaces one letter and is used when there are variations in spelling. For example, using “behavio?r” can help to find articles that use either the American spelling “behavior” or the British spelling “behaviour”. This wildcard is especially useful for ensuring comprehensive search results that include all possible spellings of a given term.

A proximity search, also known as adjacency searching, looks for two or more terms occurring close to each other within a specified number of words in any order (Booth et al., 2022). Different database platforms use different proximity operators; the EBSCOHost platform’s operator is Near, which has the symbol N. In the database search for this study, Near3 or N3 was selected to find words that are within three words of each other in any order. For instance, searching “medical N3 education” would retrieve documents where “medical” and “education” appear within three words of each other, regardless of which word comes first. This operator is crucial for locating articles where key concepts are discussed in close proximity but not necessarily in a fixed phrase, allowing for a broader retrieval of relevant data. These search operators are integral to refining the search process, enabling a more targeted and comprehensive exploration of the literature.

It is important to note that each database offers distinct interfaces and search functionalities, necessitating tailored search queries for optimal results. The process used free text keywords, and MeSH was applicable to MEDLINE Complete, CINAHAL, and EMBASE. For other databases, their specific instructions to retrieve relevant papers were adhered to. Although the search approach varied across databases, the same three concepts derived from the research questions were consistently applied to all the databases identified in Step 1. The search queries employed for each database are presented in Appendix J, offering detailed insights into the specific search strategies used in this study.

After an initial search of each database, three limiters – type of articles, year of publication, and language – were applied. First, the article type limiter was used to target academic journals. This restriction helps to prioritise scholarly publications, which often undergo a rigorous peer-review process and provide reliable and in-depth research findings. Second, the year limiter was set to include articles published from 2010 to 2022. This time frame was chosen as it aligns with the beginning of mobile learning in medical education and facilitates capturing the most recent developments in the field. Last, the language limiter was set to English to include only articles published in English, ensuring that the results were accessible and understandable. By employing these limiters, the search results were refined to focus on high-quality academic journal articles published in English within the specified time range, thus enhancing the relevance and reliability of the findings.

3.3.4.1.4 Preparing Record-keeping Forms

A record-keeping form for each database, adapted from Rader et al. (2014), was used to maintain a systematic record of the search process, and a summary of all the databases that were searched was prepared. A record-keeping form includes key elements such as the database platform, search date, time frame of the search, search strategy employed, and the number of records retrieved from each database. The forms for each database can be found in Appendix K, providing transparency and facilitating the reproducibility of the search process.

3.3.4.2 Supplementary Search Strategies

In addition to the electronic database searches, supplementary search strategies, described in Section 3.3.3, were used to supplement the electronic database search to ensure a thorough review of relevant literature, minimise publication bias, and provide a broad spectrum of information on the topic (Aveyard et al., 2016b; Booth et al., 2022). These supplementary search strategies are described in the following sections.

3.3.4.2.1 Checking Bibliographies and Reference Lists

Following the electronic database search, the reference lists of included papers were checked for additional relevant papers that were not captured in the initial database search. This strategy helps in uncovering literature that might have been missed due to database indexing limitations or keyword selection.

3.3.4.2.2 Citation Searching

A citation searching approach was used to look for more recent papers citing older key papers that were identified from the electronic database search. Software called Litmaps Pro (https://www.litmaps.com/) was used for citation tracking.

3.3.4.2.3 Hand Searching

Hand searches of specific journals relevant to the topic were also conducted, and these journals included Academic Medicine, BMC Medical Education, Clinical Teacher, Medical Education, Medical Teacher, and Advances in Health Science Education. Although it is termed hand searching, this approach involves electronic searching of e-journals through Lancaster University's Library. Hand searching is particularly useful for finding articles that are very recent or not yet indexed in electronic databases.

3.3.4.2.4 Author Searching

In this approach, key authors like Ellaway and Pimmer, who have contributed significantly to mobile learning in medical education, were identified, and additional relevant papers written by these authors were searched.

3.3.4.2.5 Grey Literature Search

Last, unpublished or grey literature for theses and dissertations was searched using ProQuest from Lancaster University Library.

3.3.5 Screening Titles and Abstracts

After searching the literature, the next step was to screen the articles retrieved by adapting the key steps suggested by Dundar and Fleeman (2023). This stage encompassed four steps, as shown in Figure 3.5.

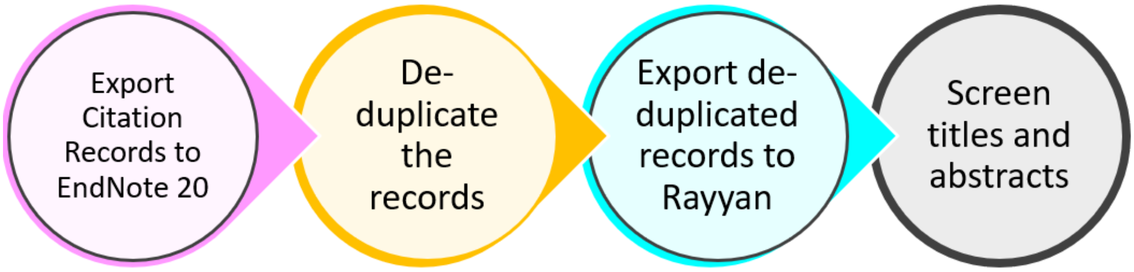

Figure 3.5 Key Steps Undertaken to Screen Titles and Abstracts

First, the citation records from databases and supplementary searches were downloaded and imported into EndNote 20 referencing software. Next, as searching multiple databases resulted in significant duplication of references, a de-duplication procedure in EndNote was performed, as explained by Bramer et al. (2016). This procedure involves seven steps and systematically compares references based on specific fields such as author, year, title, secondary title, pages, volume, and issue. Table 3.1 shows the fields to be compared in each step. Duplicates were promptly identified and removed during the initial steps from 1 to 3. However, for the subsequent steps, starting from step 4, where the number of duplicates decreased, pairs of duplicate papers were manually assessed and decided which duplicates to retain or remove.

Table 3.1 Fields to be compared for a De-Duplication Procedure

Steps	Fields to be compared
1	Author, Year, Title and Secondary Title
2	Author, Year, Title and Pages
3	Title, Volume and Pages
4	Author, Volume and Pages
5	Year, Volume, Issue and Pages
6	Title
7	Author and Year

After this de-duplication process, the citations of the final papers were then exported to Rayyan (https://www.rayyan.ai/) software. Using software like Rayyan can streamline the review process (Booth et al., 2022) as the interface of Rayyan allows for rapid identification of relevant studies by scanning titles and abstracts and providing a clear rationale for the inclusion and exclusion of each study, thereby making the review process transparent and well-documented.

Conducting a review alone may introduce limitations in the review process, such as during the screening, selecting articles, and data extraction stages. However, if a review is undertaken as part of a course or a programme requirement, it is expected to be the individual effort of a student, as the work will be assessed and graded. Therefore, a screening strategy was adopted by following the guidance of Dickson et al. (2017). In this strategy, Eugenie, using a Lancaster University email address, served as a first reviewer. The first reviewer invited a second reviewer under the name of Phyu, with a personal email address. In that case, Eugenie and Phyu were the same person, performing as the first and second reviewers by using different email addresses.

As the first reviewer, Eugenie screened titles and abstracts of identified articles against the inclusion and exclusion criteria set out in Section 3.3.2, categorising each article as either included or excluded. A three-step approach, adapted from Aveyard (2023) and Dundar and Fleeman (2023), was used to determine the eligibility of articles for inclusion in the review. First, the titles of each article were evaluated against predefined inclusion and exclusion criteria. Articles that met the inclusion criteria were marked for inclusion, while those that did not were excluded. Second, if the titles were ambiguous or provided insufficient information to make a decision, abstracts of the articles were read to get more information. Finally, if uncertainty persisted after reviewing the abstracts, the full texts of the articles were accessed and reviewed to make a decision.

The colour-coded Population, Intervention, Control, and Outcomes (PICO) filters in the Rayyan software simplify the screening process. The reasons for exclusion with each decision were documented, ensuring transparency in the process.

After setting aside these results for about one week, the second reviewer, Phyu, replicated the screening process. Finally, the results from both reviewers were compared, and conflicts were resolved, as suggested by Dundar and Fleeman (2017). This strategy is clearly illustrated in Figure 3.6.

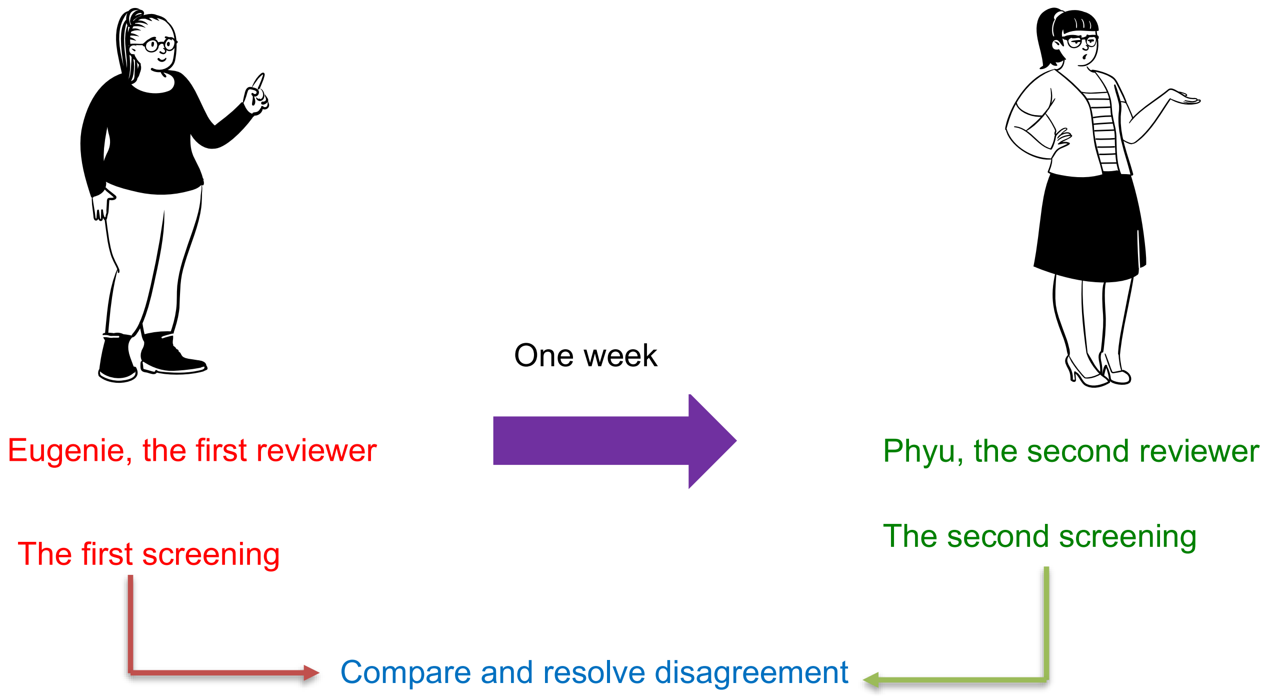

Figure 3.6 An Illustration of A Screening Process by Two Reviewers

Conducting the review independently may represent a limitation, particularly in the context of potential publication. These limitations are addressed in the Discussion chapter.

3.3.6 Obtaining the Full-text Papers of All Potentially Eligible Studies

Once the screening process was finalised, a list of included studies was prepared, and these included records were exported to EndNote 20. Three strategies were utilised (Figure 3.7) to obtain the full texts of these papers.

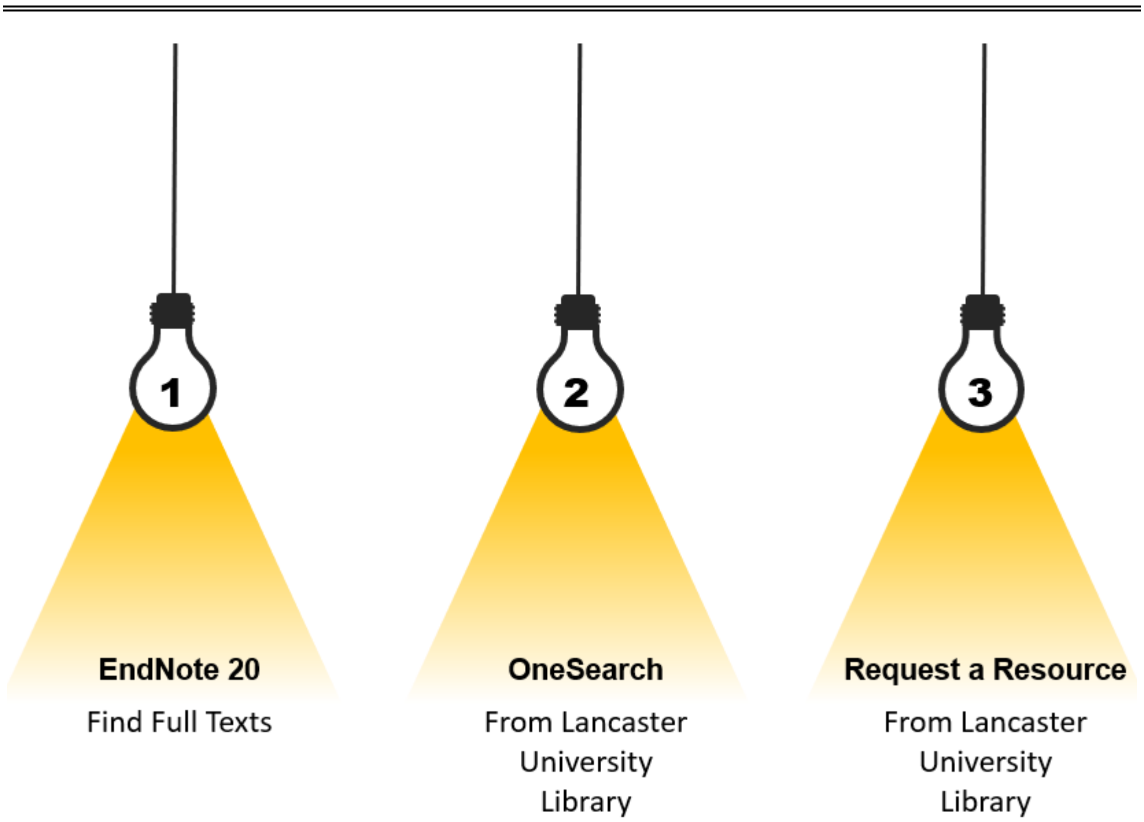

Figure 3.7 Three Strategies to Obtain Full Text of the Included Studies

Since EndNote 20 features a “Find Full Text” function, this tool was utilised to obtain full-text papers in Portable Document Format (PDF) format. As this function was not able to locate the full texts for all included papers, Lancaster University’s OneSearch was used to find full-text papers. When full texts were unavailable via OneSearch, the library’s “Request a Resource” function was requested to find the required texts. The library typically responded within a few days and provided the full-text papers requested. Instead of printing the papers, PDF copies were attached to the corresponding references in EndNote 20, which not only helped in organising the papers but also contributed to saving paper.

3.3.7 Assessing the Methodological Quality of Selected Articles

The steps for assessing the methodological strengths and limitations of the included studies were adapted from Greenhalgh and Brown (2023). This process involves four steps, as shown in Figure 3.8.

Figure 3.8 Key Steps Undertaken to Assess the Methodological Quality of Selected Articles

3.3.7.1 Identifying appropriate quality assessment tools

The methodological quality of the final set of studies was assessed using a tool previously applied in studies by Lall et al. (2019) and Rees et al. (2011). This tool was selected because it is suitable for both qualitative and mixed-methods studies. Utilising the same tool across all study types enhances the comparability of assessment (Noyes et al., 2018). The tool evaluates two dimensions: trustworthiness and usefulness of findings.

The trustworthiness dimension assesses the extent to which methods were employed to ensure rigour by systematically and critically evaluating various study aspects, thereby guaranteeing that the findings are reliable, valid, and applicable to the research questions. This dimension evaluates rigour in sampling, data collection, and analysis. When assessing rigour in sampling, the appropriateness of the sampling strategies to the research questions, the ability to obtain a diverse sample of the population in question, and the representativeness of the sample population's characteristics in the context of the study were considered. The rigour in data collection was assessed in terms of its comprehensiveness to capture a rich description of participants' experiences and perceptions. Regarding rigour in data analysis, it was evaluated whether the methods used were systematic, feedback was obtained from colleagues, and the researcher exercised reflexivity (Lall et al., 2019; Rees et al., 2011).

The usefulness of the findings dimension is assessed based on whether the findings were supported by the data, the breadth and depth of the findings, and the extent to which the data explain the phenomenon of interest. To evaluate whether the data supported the findings, it was checked whether there was sufficient data that the researchers used to reach their conclusions, as well as the inclusion of the frequency of quotations or verbatim extracts. The breadth of findings was considered the extent of descriptions, while depth was defined as the extent of richness and complexity of findings. Finally, the extent to which the data explained the phenomenon of interest was judged by whether the researchers incorporated the perspectives and experiences of all study participants (Lall et al., 2019; Rees et al., 2011).

Each dimension of the quality assessment tool comprises three questions, and the response to each question is rated as either low, medium, or high, based on the operational definitions of the criteria outlined above. If the responses to two or more questions are rated as high, the overall rating for that dimension is classified as "high". If two or more responses are rated as medium, the overall rating is "medium". If two or more responses are rated as low, the overall rating is "low". Criteria used to appraise the study quality are illustrated in Figure 3.9, and explanations for each criterion are shown in Appendix L.

It is acknowledged that these ratings were based on the researcher's subjective judgment. To increase the rigour of this methodological quality assessment, cross-checking was conducted using the process described in Section 3.3.5, in which the researcher acted as both first and second reviewer. The two sets of ratings were compared, and any disagreements were resolved by consulting the full-text papers. A summary table of quality appraisal, presented in Appendix W, reflects the outcomes after all conflicts were resolved.

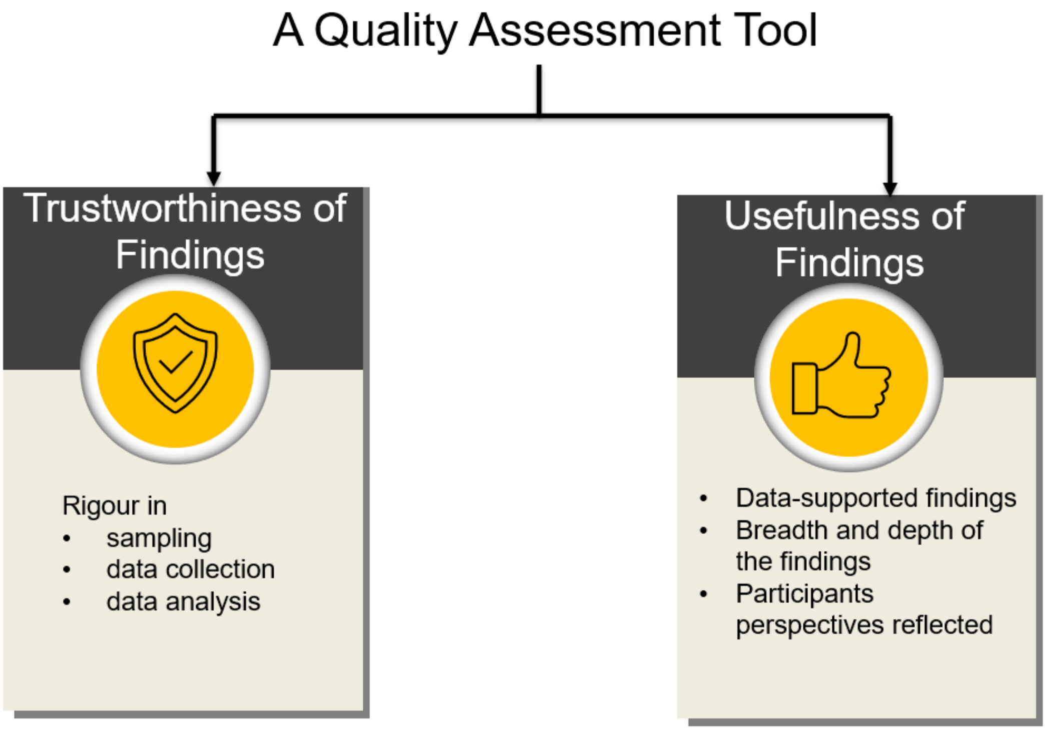

Figure 3.9 Criteria Used to Appraise Quality of the Included Studies

3.3.7.2 Conducting a Quality Assessment using a Chosen Tool

After selecting a quality appraisal tool, a quality assessment for each included paper was conducted. Google Forms were created to capture these ratings, and these Forms are available at https://forms.gle/nyotsSNoYDz3MnYZ8.

3.3.7.3 Tabulating and Summarising the Findings of the Quality Assessment

Upon completing the appraisals, the findings were summarised and tabulated, as presented in Appendix W. Although Noyes et al. (2018) recommend conducting a quality assessment with more than one person to reach a consensus on the strengths and limitations, this task was performed independently, as discussed in Section 3.3.5.

3.3.7.4 Making Decisions on the Inclusion or Exclusion of Studies

After evaluating methodological quality, in line with Hong et al. (2018), studies with low methodological quality were not excluded. The selection process and the number of papers included were documented using the PRISMA flow diagram http://www.prisma-statement.org/, as shown in the Results chapter.

3.3.8 Extracting Data from Selected Studies

The key steps involved in extracting and reporting data from the included studies were adapted from Fleeman and Dundar (2023) and are detailed in Figure 3.10.

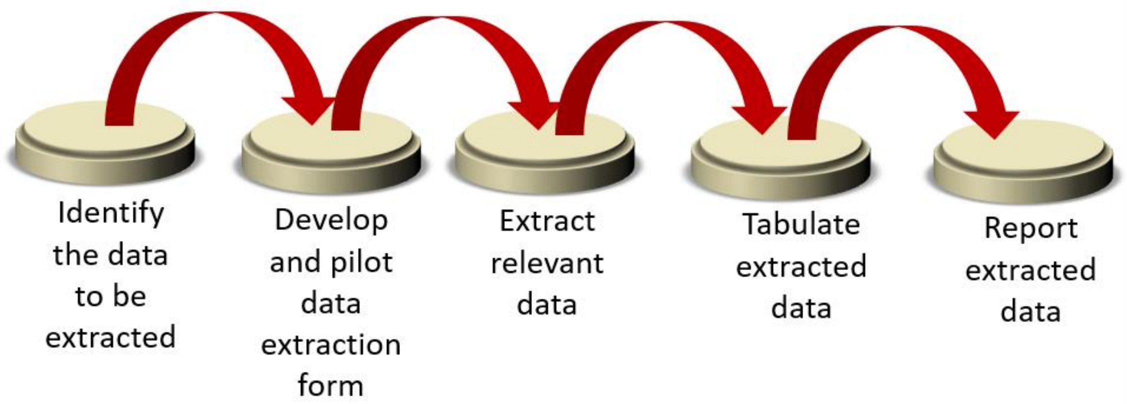

Figure 3.10 Key Steps Undertaken to Extract and Report Data from Included Studies

Following the recommendations of Aveyard et al. (2016c), Fleeman and Dundar (2023), and Noyes et al. (2018), data from the studies were categorised into descriptive and analytical data. Descriptive data primarily consisted of contextual information about each study, including the author(s), year of publication, place of conducting the study, study setting, research questions, study population, sample size, type of intervention, control group (if applicable), study design, data collection and analysis methods. Analytical data encompassed themes and sub-themes that emerged from each study.

After defining the data to be extracted, a data extraction form using Google Forms was developed, piloted with two papers, and revised based on the characteristics of these two papers. The final version of the data extraction form is available at https://forms.gle/4m4LjxFtdq77ASBQ8.

This Google Form was used to extract data from the included studies. As discussed in Sections 3.3.5 and 3.3.7, the data extraction process was carried out independently and followed the advice of Fleeman and Dundar (2023). After the first reviewer finished data extraction, the data table was put aside for one week. Then, the extraction was done again by the second reviewer, and finally, the first reviewer cross-checked both sets of extracted data, identified any inconsistencies, and rectified them.

Upon completing data extraction, the extracted data were downloaded as a Microsoft Excel file, and a data extraction table was prepared. This table was used to report the findings in the Results chapter and can be found in Appendix U.

3.3.9 Analysing and Synthesising the Data

A thematic synthesis approach (Thomas & Harden, 2008) was applied to synthesise the qualitative data extracted in Step 8. This method was chosen because it provides a structured approach, enabling an in-depth analysis of qualitative data. Thematic synthesis is particularly suitable for novice reviewers. It can be applied to studies with both thin data to produce descriptive themes and thicker data to develop more complex analytic themes. However, this approach has limitations in its interpretative power and may risk oversimplification if not applied carefully (Flemming & Noyes, 2021; Noyes et al., 2019; Noyes et al., 2018). MAXQDA software version 24.5.1 was used for thematic synthesis.

The data analysis and synthesis followed the three-stage thematic synthesis approach. These stages were iterative and overlapping rather than distinct or linear. The first stage involved inductive line-by-line coding of the "results" or "findings" sections of the 30 included studies to reveal the underlying meanings and concepts within the data. Each code was reviewed to ensure consistency and refine interpretations. In the second stage, descriptive codes were examined for similarities and differences, grouped into related descriptive themes, and iteratively refined. This process involved renaming, merging, or discarding codes to accurately represent each emerging theme, resulting in a draft narrative summary that closely aligned with the original findings of the primary studies. In the third stage, analytical themes were developed by exploring the implications of the descriptive themes. Conceptually similar themes were grouped through an iterative process of comparison and refinement, ensuring alignment with the review objectives. This cyclical process continued until the analytical themes were effectively captured and the descriptive themes were explained. Miro software https://miro.com/ is used to illustrate the iterative process of thematic synthesis (Figure 3.11).

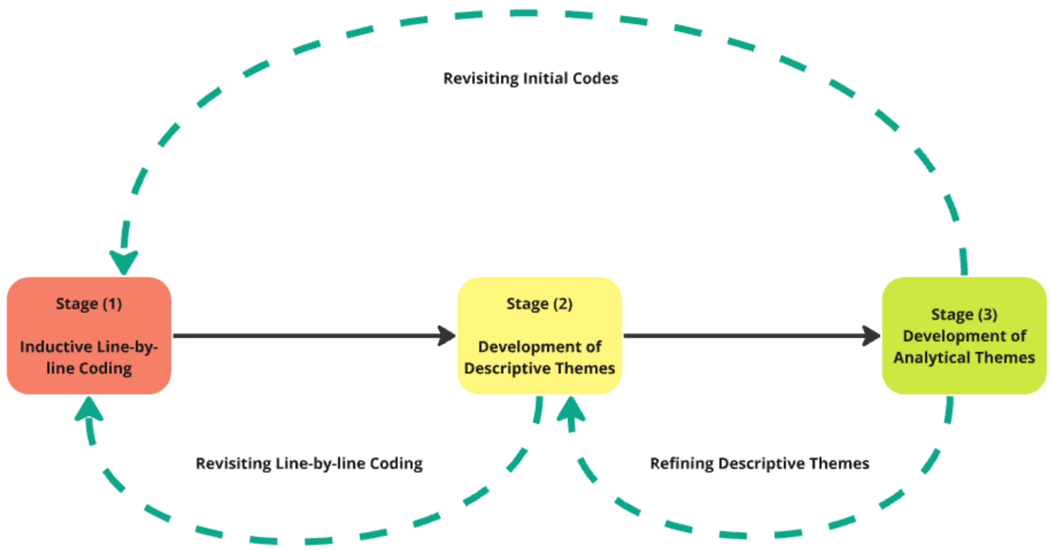

Figure 3.11 An Iterative Thematic Synthesis Process Employed in the Study

3.3.10 Writing up the Report

The final step of the review process involves drafting a report, revising it, finalising it, and submitting it to the supervisor. Upon receiving feedback from the supervisor, the report was revised and resubmitted. After receiving the final approval from the supervisor, the report was submitted to the external and internal examiners for their assessment.

The software and templates used in this thesis writing process (Appendix AC) were obtained through licensed purchases. All images included are freely available online and used in accordance with their respective usage rights. A list of the abbreviations used in this thesis is provided in Appendix AD to enhance clarity and readability.

3.3.11 Ethical Considerations

Although systematic literature reviews do not involve direct interaction with human participants, ethical considerations are still essential to ensure rigour, integrity, and responsible research conduct. Key ethical considerations relevant to this study are described in the following sections.

3.3.11.1 Compliance with Institutional Ethical Guidelines

An ethics application form for the study was submitted to Moodle of Lancaster University on 18 June 2020 and was approved by the supervisor. The submitted form is shown in Appendix M.

3.3.11.2 Data Protection and Confidentiality

All information collected from the included studies is stored in password-protected folders on a personal laptop for ten years as per the ethical guidelines specified in the form.

3.3.11.3 Ethical Use of Secondary Data

Since this study relies on previously published data, ethical considerations included checking that the reviewed studies themselves adhered to ethical standards by obtaining informed consent from participants in primary studies and getting the ethical approval of the Institutional Review Board (Vergnes et al., 2010). Appendix N shows the participants' consent and the ethical approval for each study included in the review.

3.3.11.4 Proper Attribution to Original Authors of the Included Studies

As a systematic review builds upon the work of other researchers, proper attribution and citation are essential. This study ensures that all sources are accurately cited using APA referencing guidelines, acknowledging the contributions of original authors.

3.3.11.5 Maintaining the Confidentiality of Participants' Data

While systematic reviews do not involve collecting primary data from individuals, care is taken to ensure that sensitive data within reviewed studies are handled responsibly. Any secondary data that involve personal information (e.g., anonymised qualitative responses from primary studies) are handled with respect to the ethical guidelines followed by the original authors.

3.4 Chapter Summary

This chapter commenced by outlining the philosophical assumptions of the study, followed by a detailed description of a ten-step process for conducting a qualitative systematic review and concluded with ethical considerations. The next chapter will present the results of data synthesis, including descriptive and analytical themes.

Chapter 4: Results

This qualitative systematic literature review study explores undergraduate medical students' experiences of using mobile devices for learning during their preclinical and clinical years.

The purpose of this chapter is to present the results of the study based on a thematic synthesis approach. The chapter is organised into four sections: the first section describes the results of the literature search, the second presents descriptive findings of the included studies, the third explains methodological quality assessment of the included studies, and the fourth provides a detailed account of themes and sub-themes, each theme corresponding to the research questions and supported with relevant excerpts.

4.1 Results of the Literature Search

This section describes the results of the electronic database searches and supplementary searches.

4.1.1 Electronic Database Searches Results

The initial search from ten databases yielded 1,529 records, which were exported to EndNote 20. After identifying and removing 517 duplicates, the remaining 1,012 records were exported to Rayyan software for title and abstract screening. Appendix O shows the number of articles retrieved from each database.

The review process was conducted independently and followed the strategy described in Section 3.3.5. Table 4.1 presents the results of screening by two reviewers.

Table 4.1 Screening Results Between Two Reviewers

The first reviewer (Eugenie)	The second reviewer (Phyu)		Total records
	Included	Excluded	
Included	21	1	22
Excluded	3	987	990
Total records	24	988	1,012

The number of observed agreements between two reviewers, Eugenie and Phyu, was 1,008 (two cells shaded green), representing 99.60% of the observations. Disagreements between the two reviewers (two cells shaded yellow) were four, accounting for 0.4%. Interrater agreement between the two reviewers was calculated using Kappa statistics (Landis & Koch, 1977), and it was 0.907, indicating almost perfect agreement. The calculation of Kappa statistics was performed using a calculator freely available at (https://www.graphpad.com/quickcalcs/kappa2/).

Although the agreement was nearly perfect, four records exhibited conflicts and required resolution. Upon retrieving and reviewing the full papers in question, two studies were included, and two were excluded. Appendix P details the process of resolving conflicting papers. After these disagreements were resolved, the total of included studies was 23.

4.1.2 Supplementary Search Results

Five supplementary search strategies discussed in Section 3.3.3 were employed to complement the electronic database searches. Appendix Q presents the results of these supplementary searches, and details of these search strategies are documented in Appendix R.

From the supplementary search, seven additional relevant studies were identified, resulting in the total number of studies included in the final review being 30. The citations of these 30 papers were exported to EndNote 20, and their full texts were searched using the three strategies described in Section 3.3.6.

A PRISMA flow diagram (Page et al., 2021) was adapted to document the number of articles identified, included, excluded, and the reasons for exclusions, as shown in Figure 4.1.

After describing the results of the literature search, the next section describes the characteristics of the included studies.

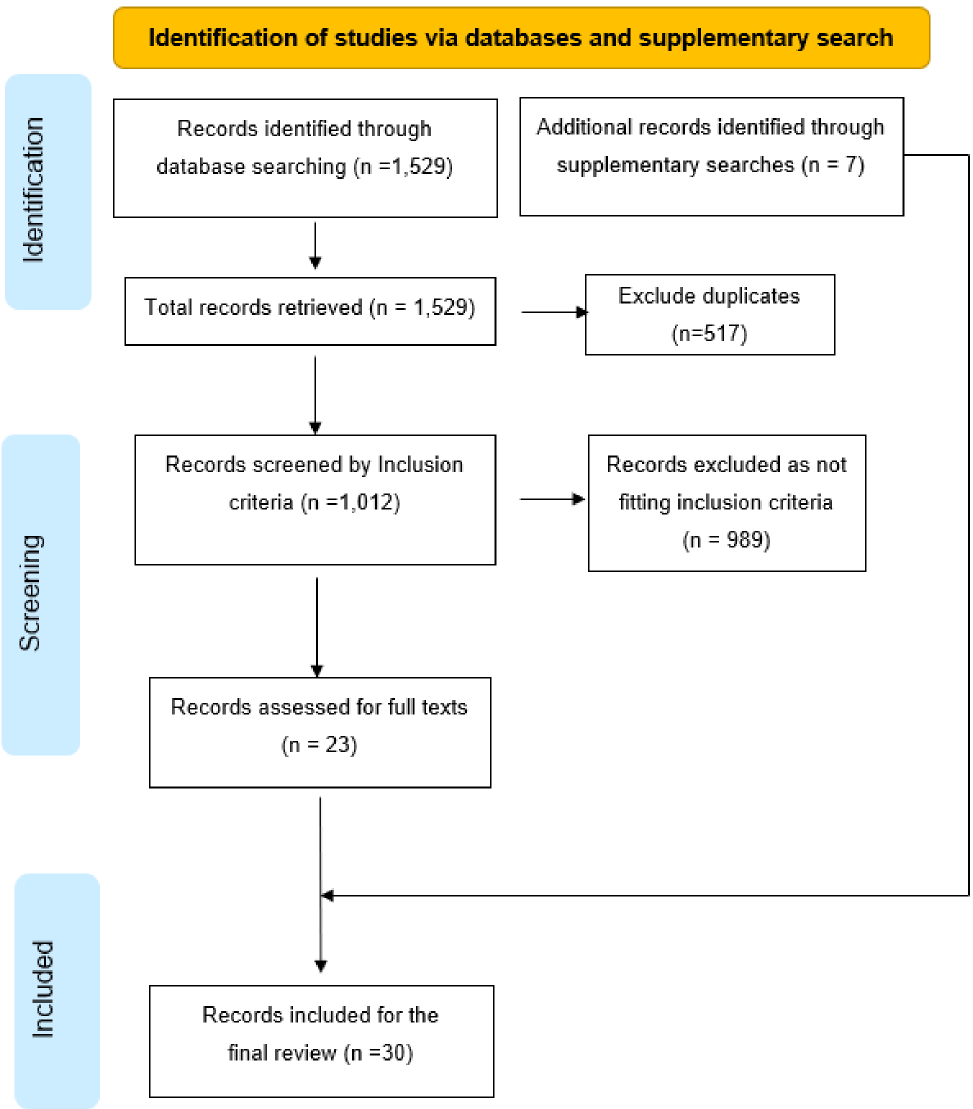

Figure 4.1 A PRISMA Flow Diagram showing Search Outcomes, Screening, and Selection of Articles for the Final Review

4.2 Description of Characteristics of Included Studies

The characteristics of the included studies are described under 11 headings: (1) type of document, (2) year of publication, (3) country where the study was conducted, (4) setting, (5) research questions, (6) study population, (7) type of intervention, (8) study design, (9) use of control groups, (10) data collection and (11) data analysis methods. An extracted data table of characteristic features of the included studies can be found in Appendix U.

4.2.1 Types of Documents Included in the Review

Of the 30 included studies, the majority were journal articles, accounting for 27 studies (90%). Two studies (7%) were a dissertation and a thesis, both submitted for Doctor of Philosophy degrees. One study (3%) was a research paper presented at the 2021 Academy of Medical Educators (AoME) Conference, and this was shared as a blog post.

4.2.2 Year of Publication of Included Studies

The review included 30 studies published over a decade, from 2012 to 2022. The distribution of included studies across the years is illustrated in Figure 4.2. The earliest studies in this review were published in 2012 (Pimmer et al., 2012; Wallace et al., 2012), and the most recent study included was published in 2022 (Oo et al., 2022).

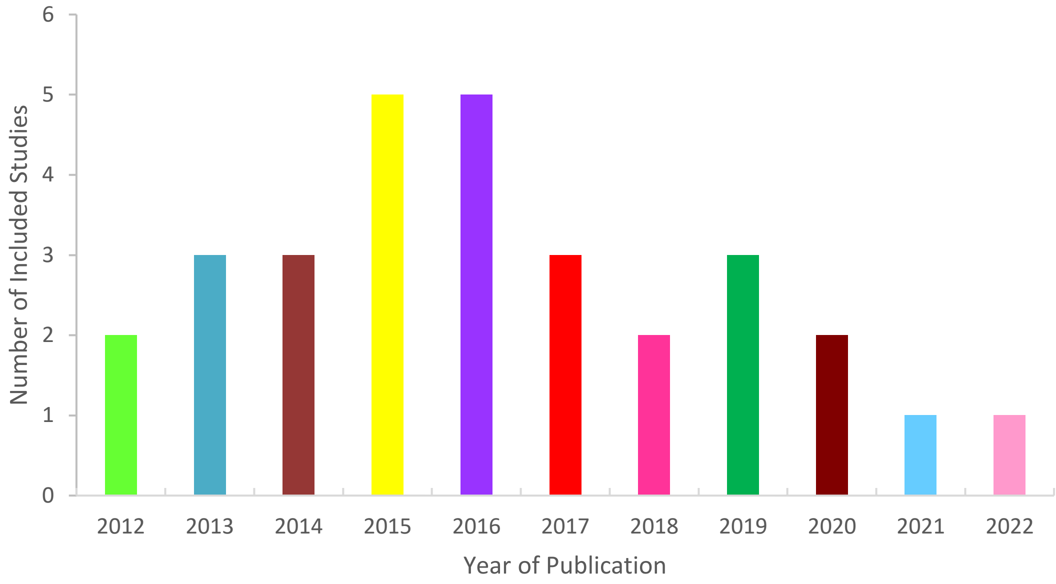

Figure 4.2 Years of Publication of the 30 Included Studies

4.2.3 Countries where Included Studies were Conducted

The 30 studies included in the review represented a diverse geographical spread across 13 countries and one broader region. The countries where the included studies took place are shown in Figure 4.3.

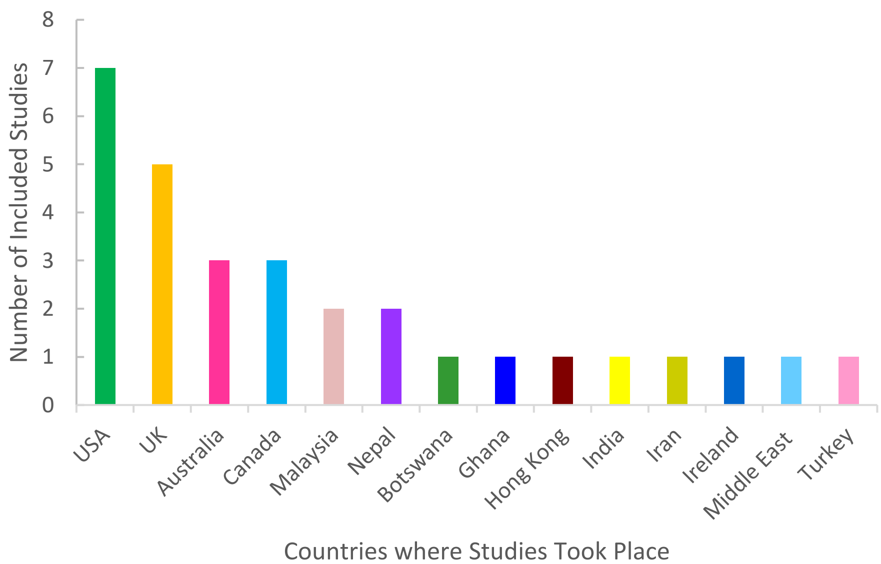

Figure 4.3 Countries where the Included Studies Took Place

4.2.4 Settings of Included Studies

The 30 studies in the review were conducted within undergraduate medical education, encompassing a range of settings. Clinical settings were the most prevalent, featuring in 20 of the studies. Preclinical settings were the focus of six studies, and four studies in the review did not specifically mention the setting; instead, they examined the use of mobile devices more broadly in undergraduate medical education.

4.2.5 Research Aims Addressed in the Included Studies

The research aims of 30 studies are categorised into five groups (Table 4.2). A significant number of studies (20 studies) focused on how mobile devices and apps supported students' learning. As most studies focused on more than one area, the total number of studies exceeded 30.

Table 4.2 Research Aims of Included Studies

Category	Description	Number of Studies
1. Support learning using a mobile device or an app	Studies focusing on mobile devices or apps supporting students' learning	20
2. Factors affecting mobile device use in clinical settings	Studies exploring what enables or inhibits mobile device use	10
3. Students' perceptions and attitudes to mobile device use	Studies focus on students' opinions, acceptance, values, beliefs	10
4. Mobile device usage patterns	Studies on how devices are used	8
5. Benefits and challenges of mobile device use	Studies that report learning outcomes, pros/cons of mobile device use	7

4.2.6 Study Populations of the Included Studies

The study populations across the 30 included studies comprised a range of participants from different stages of medical education, as well as faculty members, postgraduate students, and patients or carers. While preclinical students were included in 12 studies, clinical students participated in 31 studies. These findings showed that students in their clinical years were most represented in this study. Several studies included more than one group, resulting in a total number of studies greater than 30.

4.2.7 Types of Interventions

Of the 30 included studies, 10 studies (33%) provided mobile devices to the students. Among these, iPads were issued in eight studies, iPhones in three, and tablets in two. In 20 studies (67%), the BYOD scheme was used, where students utilised their own devices. Figure 4.4 shows the types of interventions in the included studies.

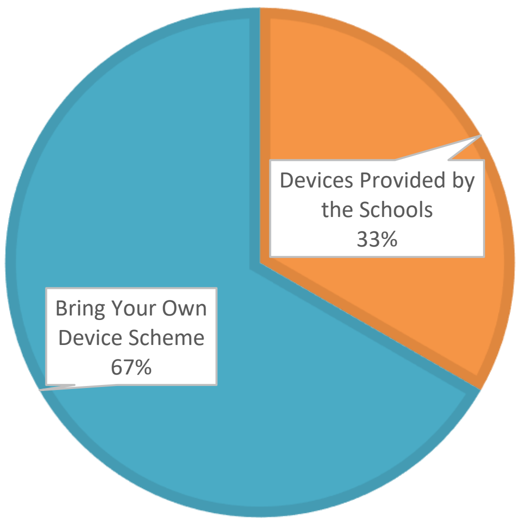

Figure 4.4 Types of Interventions in the Included Studies

4.2.8 Types of Study Designs

Among the 30 included studies, 18 (60%) employed mixed methods, and 12 (40%) utilised qualitative approaches (Figure 4.5).

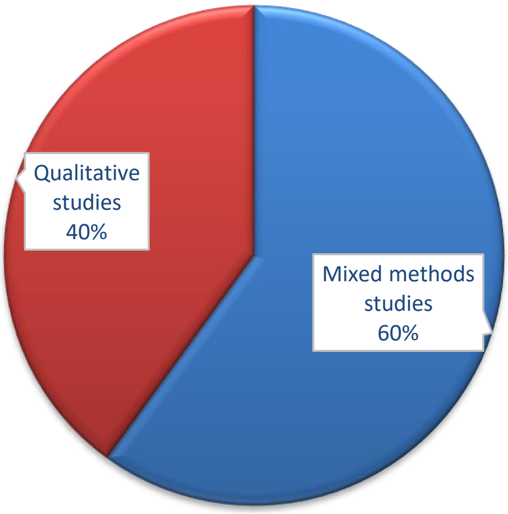

Figure 4.5 Types of Studies Included in the Review

4.2.9 Use of Control Groups

Of the 30 included studies, two mixed-methods studies (Grover et al., 2020; Küçük et al., 2016) used control groups. They compared traditional teaching approaches, such as lectures and the use of textbooks, with mobile applications in teaching pathology and anatomy, respectively.

4.2.10 Data Collection Methods

Across the 30 included studies, various qualitative data collection methods were used. Semi-structured interviews and focus group discussions were the most commonly used methods, accounting for 17 and 15 studies, respectively. Additional methods included the analysis of messages and observation in two studies, as well as expert panel opinions in one study. Some studies utilised more than one method of data collection, resulting in a total number of data collection methods exceeding the number of studies. Figure 4.6 illustrates the data collection methods used by the included studies.

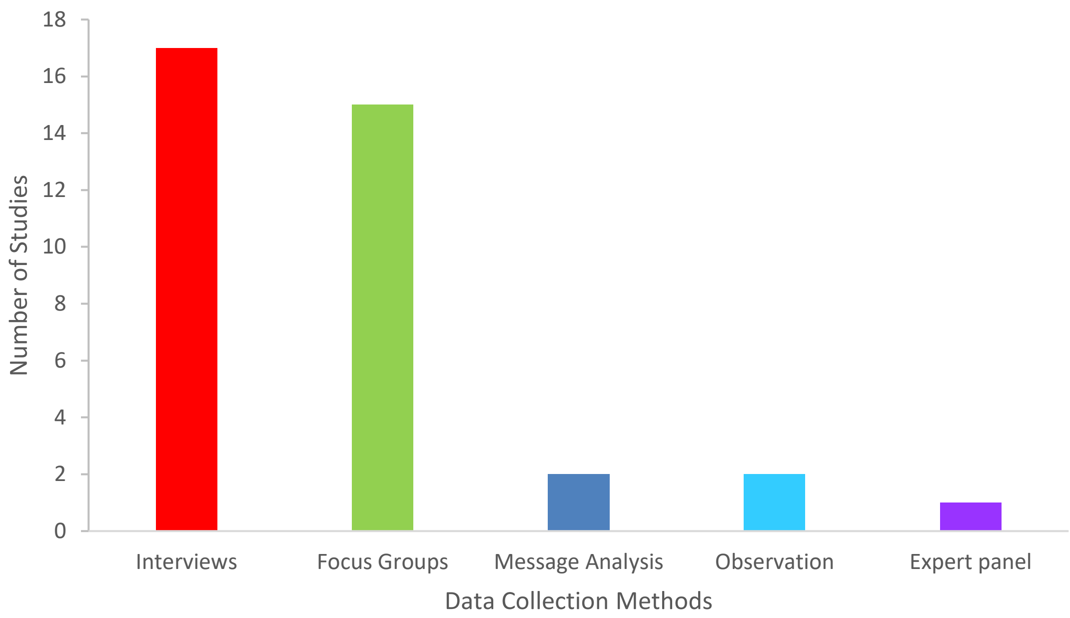

Figure 4.6 Qualitative Data Collection Methods Used by the Included Studies

4.2.11 Data Analysis Methods for Qualitative Data

Among the 30 included studies, 26 (87%) used thematic analysis, with one specifically mentioning Braun and Clarke's reflexive thematic analysis. Four studies (13%) did not indicate the methods they employed (Figure 4.7).

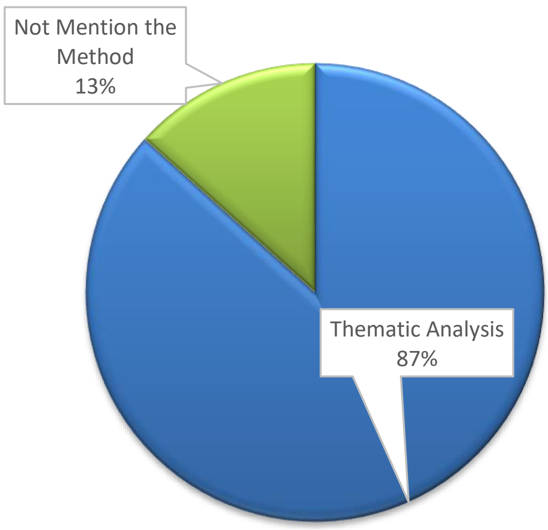

Figure 4.7 Qualitative Data Analysis Methods of the Included Studies

After presenting the characteristic features of the included studies, the next section describes the assessment of their methodological qualities.

4.3 Methodological Quality Assessment of the Included Studies

A detailed quality assessment table for the 30 included studies can be found in Appendix V. A summary of the quality appraisal of studies included in the review is presented in Appendix W.

The quality of the 30 included studies was assessed based on two key dimensions: trustworthiness and usefulness of findings. Each dimension was evaluated using three criteria, and studies were rated as low, medium, or high, depending on how they scored across these criteria.

For Trustworthiness of Findings, 13 studies (43%) received an overall high rating, while 17 studies (57%) received a medium rating. A few studies (Harmon, 2015; Johnson and Howard, 2019; O'Donovan and Maruthappu, 2015) were rated as low in the sampling dimension.

Regarding the Usefulness of Findings, 25 out of 30 studies (83%) were rated high, indicating that most studies provided valuable, well-supported insights. However, a few studies, for example, Fan et al. (2015), Harmon (2015), Johnson and Howard (2019), and Küçük et al. (2016), received a medium rating due to limitations in data support or a narrow focus in their findings. Notably, 11 studies (37%) were rated both highly reliable and useful.

The next section describes themes, sub-themes, and relevant verbatim extracts that emerged from thematic synthesis.

4.4 Findings of Thematic Synthesis

The findings of thematic synthesis revealed that although the students faced certain challenges, they benefited from using mobile devices in terms of enhancing their learning and actively sought out strategies to overcome these challenges.

The process of performing thematic synthesis was organised as coding the texts from included studies, developing descriptive themes, and synthesising analytical themes.

4.4.1 Coding the Texts

Initial line-by-line coding of the 30 included studies, conducted using MAXQDA version 24.5.1 software, generated 499 codes. These initial codes were revised to achieve both a general overview and a detailed understanding of the phenomena under investigation. Some codes were eliminated, while others were merged. After 10 iterative rounds of revisions, a final set of 370 codes was retained for further analysis and synthesis. The initial coding of 499 codes and the final set's codebook and coded segments are shown in Appendix X.

4.4.2 Developing Descriptive Themes and Construction of a Conceptual Framework

The descriptive themes in this study were developed using inductive thematic synthesis, whereby key findings were identified and integrated. The analysis centred on students' use of devices, which served as the core category, and this was influenced by surrounding descriptive themes and sub-themes.

The experiences of students using mobile devices for their learning can be likened to a journey. This journey began when students became aware of and acknowledged the affordances of devices, including connectivity, portability, and multifunctionality. Once these functionalities were recognised, their actual usage was influenced by external factors, such as the policies and cultures of medical schools and hospitals, perceptions and attitudes of teachers, patients, and peers, as well as personal factors, including individual beliefs, perceptions, behaviours, motivations, and technological efficacy.

As students engaged with mobile devices in their various learning environments, they reported a range of perceived benefits, such as enhanced learning, improved patient care, and the development of soft skills. However, they also encountered some challenges, including disruptions to learning, impacts on professionalism, and device limitations. Recognising the benefits of mobile technology in the learning process, students adopted various strategies to mitigate these challenges and balance the benefits and challenges of mobile device usage.

A conceptual framework (Figure 4.8) was developed to represent these interrelated factors. This framework provides a structured understanding of students' mobile device adoption in medical education by illustrating the relationships between external and personal factors, the device's usability features, benefits, challenges, and coping strategies.

The framework consists of six descriptive themes and 21 associated sub-themes. Each theme was constructed from the integration of its respective sub-themes, which are described in the following sections.

1. External Factors Affecting Device Usage: This theme was developed from four external influences – institutional factors, educators' attitudes and behaviours, patient perceptions, and peer influence – which served as sub-themes.
2. Personal Factors Affecting Device Usage: This theme was developed from four personal factors – beliefs, emotions, technology experience, and learning needs – which served as sub-themes.
3. Device Usability: This theme was developed from four functional features of mobile devices – connectivity, portability, multifunctionality, and environmental friendliness – which served as sub-themes.
4. Benefits of Mobile Technology in Medical Education: This theme was developed from three pedagogical benefits of using mobile technology – enhanced learning, improved patient care, and development of soft skills.
5. Challenges Encountered in Using Mobile Devices: This theme was developed from three sub-themes associated with the challenges of mobile device usage, including disruption to learning, impacts on professionalism, and limitations of devices.
6. Strategies to Overcome Challenges: This theme was developed from three sub-themes that identify the strategies students employ to navigate these challenges, including negotiation with educators, negotiation with patients, and negotiation with themselves.

Figure 4.8 illustrates the above-mentioned themes and sub-themes developed from the thematic synthesis. In this diagram, circle shapes represent themes, and rectangular shapes represent sub-themes. Appendix Y shows the number of primary studies contributing to each theme.

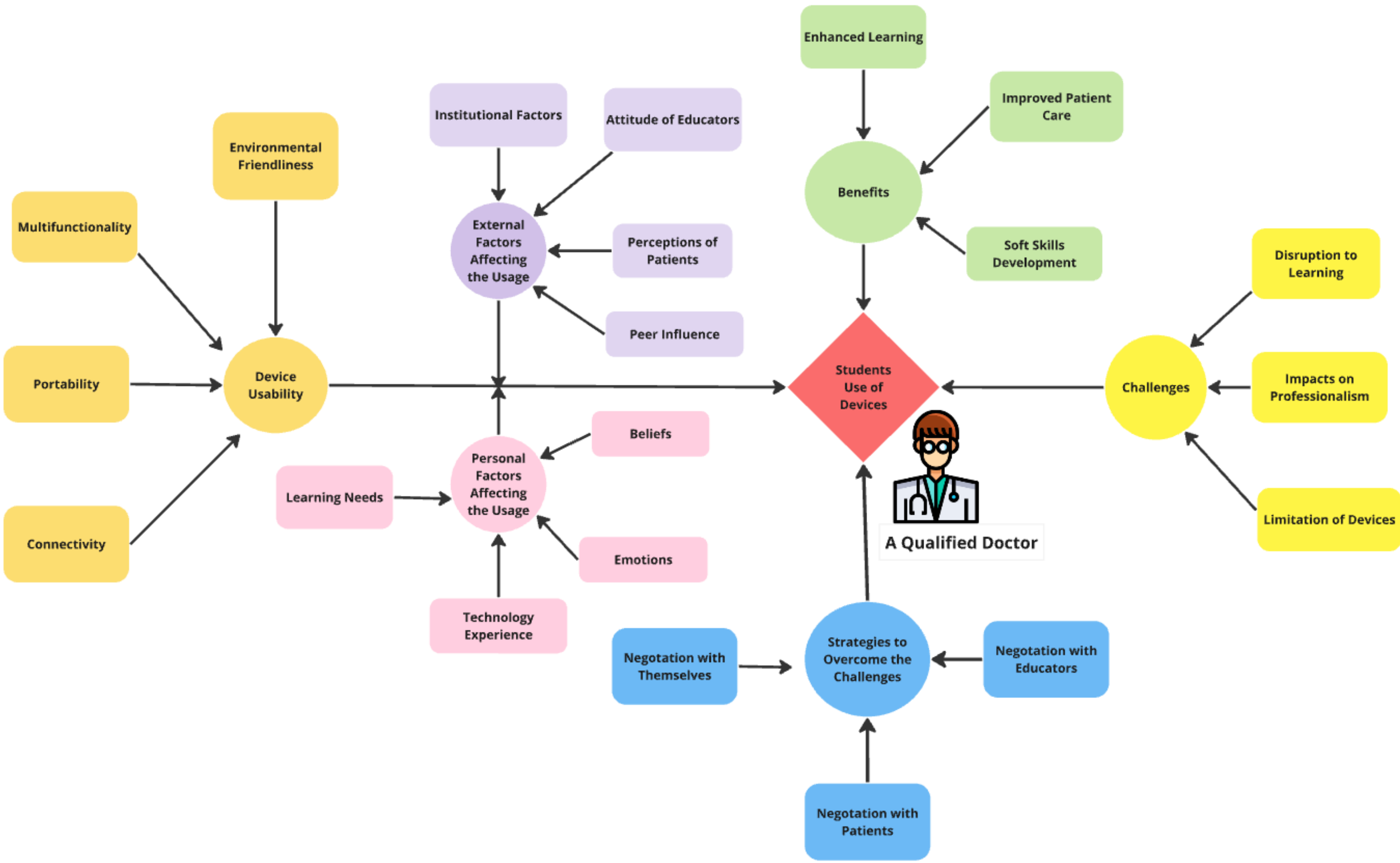

Figure 4.8 A Conceptual Framework for Medical Students' Use of Mobile Devices for Their Learning

4.4.3 Developing Analytical Themes

The six descriptive themes described in Section 4.4.2 were synthesised into three overarching interpretive, analytical themes to capture students' experiences with mobile devices in undergraduate medical education. Figure 4.9 provides an overview of the thematic synthesis process for developing descriptive and analytical themes. The three analytical themes are briefly explained in the following sections.

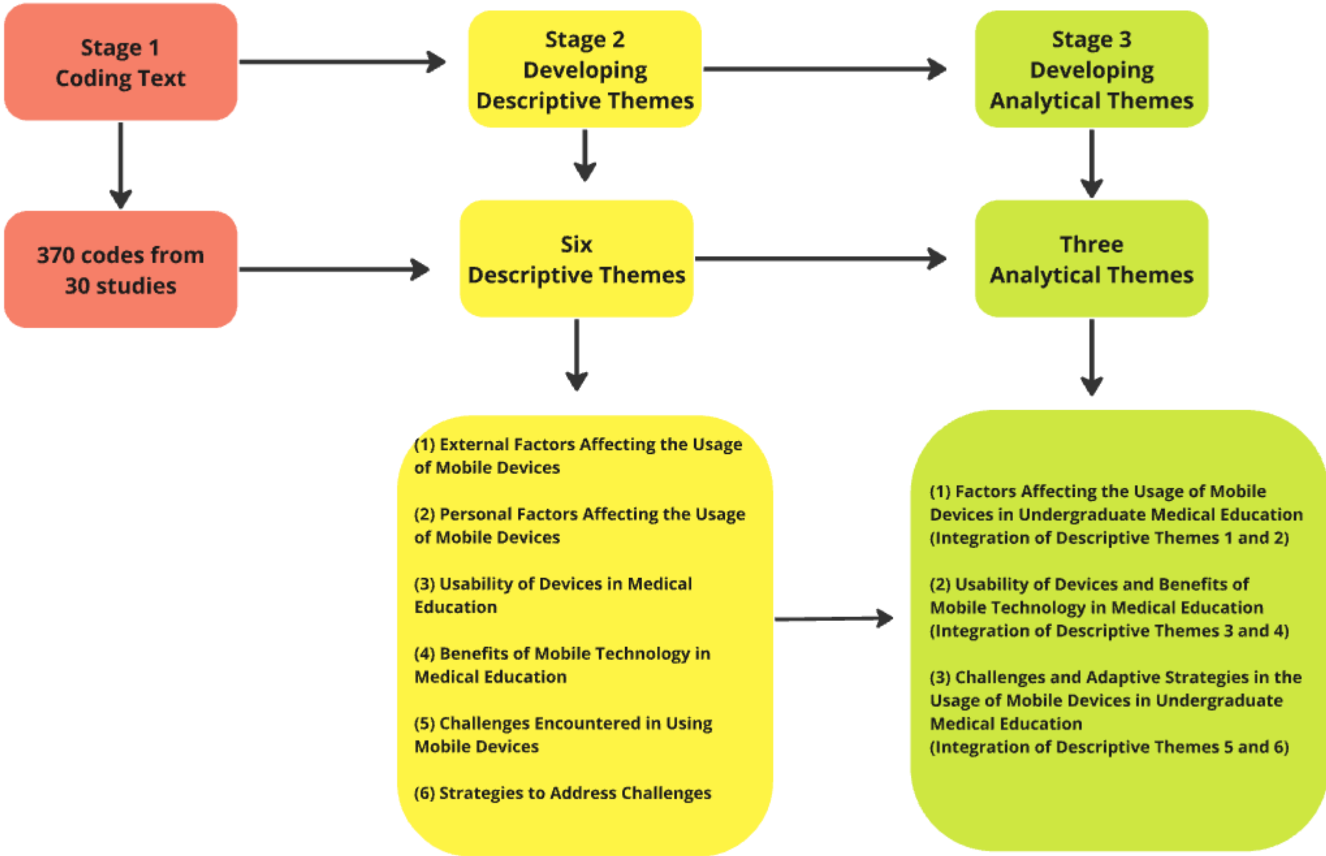

Figure 4.9 A Process of Thematic Synthesis Showing Emerged Themes

Analytical Theme 1
Factors Affecting the Usage of Mobile Devices Among Undergraduate Medical Students

The descriptive themes of external factors affecting students' usage of mobile devices and personal factors affecting students' usage of mobile devices were integrated into Analytical Theme 1. It reflects how external factors – institutional policies, educators' attitudes, patients' perceptions, and peer influence – and personal factors – beliefs, emotions, technology experience, and learning needs – influenced students' decisions to adopt and utilise mobile technology.

Analytical Theme 2
Usability of Devices and Benefits of Mobile Technology in Medical Education

The descriptive themes of device usability and the benefits of mobile technology in medical education were integrated into Analytical Theme 2. It examines how students use the functionalities of mobile devices, such as connectivity, portability, and multifunctionality, to acquire perceived benefits, including enhanced learning experiences, improved patient care, and the development of soft skills.

Analytical Theme 3
Challenges and Adaptive Strategies in the Usage of Mobile Devices in Undergraduate Medical Education

The descriptive themes of challenges and strategies to address them were integrated into Analytical Theme 3. It examines the challenges students faced in using mobile devices, such as disruptions to learning, professionalism concerns, and technical limitations, and the adaptive strategies they used to overcome them. This theme illustrates how students navigated the complexities of mobile device usage, balancing its benefits with the challenges to optimise their learning and professional experience.

4.4.4 Presentation of Descriptive and Analytical Themes

As the analytical themes were derived from descriptive themes, the themes of these two groups are presented in cohesive blocks rather than separately. This approach ensures a clear linkage and continuity of findings.

Figure 4.10 illustrates the sequence of the presentation of descriptive and analytical themes. Descriptive Themes 1 and 2 are followed by Analytical Theme 1, Descriptive Themes 3 and 4 are followed by Analytical Theme 2, and Descriptive Themes 5 and 6 are followed by Analytical Theme 3.

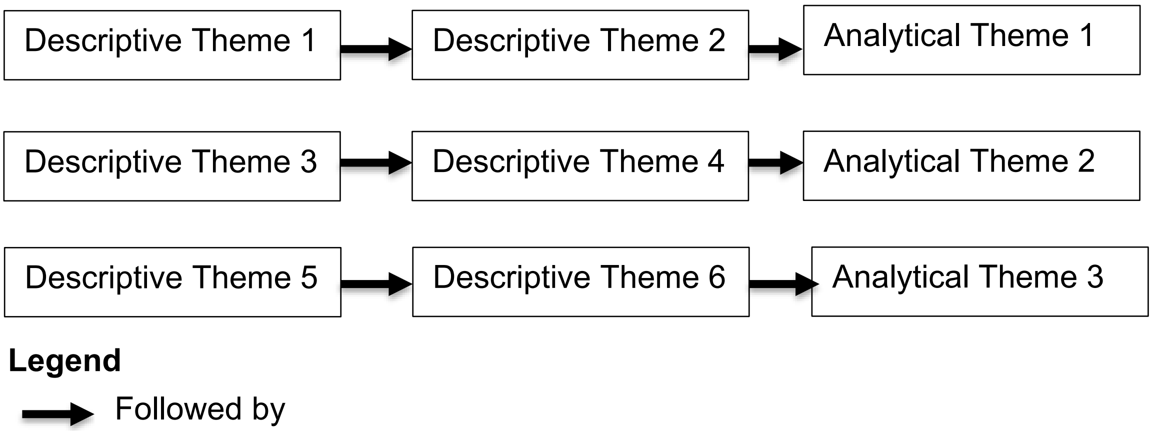

Figure 4.10 Sequence of Presentation of Descriptive and Analytical Themes

4.4.5 Descriptive Theme 1: External Factors Affecting Students' Use of Mobile Devices

This descriptive theme was developed inductively from findings across 17 studies (Appendix Y) and was informed by four sub-themes: institutional factors, factors related to medical educators, perceptions of patients, and peer and family influence (Figure 4.11). These sub-themes reflected external factors affecting students' use of mobile devices and emphasised factors arising from sources outside the students.

Appendix Z shows the number of studies contributing to each sub-theme, which are detailed in the following sections, supported by illustrative verbatim quotes.

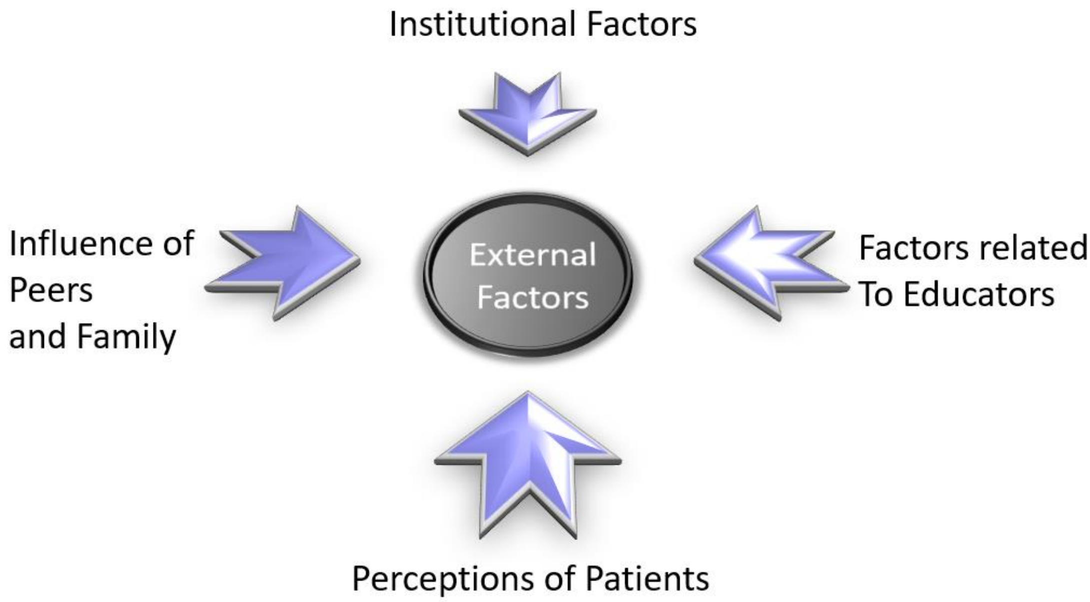

Figure 4.11 External Factors Affecting Students' Use of Mobile Devices

4.4.5.1 Institutional Factors, including Guidelines, Support, and Cultural Factors

This sub-theme was developed based on the findings from six studies. These studies collectively highlighted how institutional guidelines, availability of resources and support, and hospital culture facilitated or hindered students' use of mobile devices.

Students in a study by Harrison et al. (2019) reported that institutional guidelines explicitly discouraged device usage during patient consultations, as outlined in the school handbook and emphasised during orientation sessions: *"Patients find students using their mobile phones during consultations... very offensive.. .. Do not use your mobile phone during consultations."* Similarly, Clarke et al. (2019) highlighted implicit rules, with one registrar instructing students: "*Don't take out your phones, if you need anything just ask me."* These implicit expectations were further reflected in specific hospital settings, such as delivery wards in maternity hospitals, where device usage was discouraged. One student explained, *"...use of mobile phones is a big 'no no'"* (Clarke et al., 2019).

Beyond these guidelines and implicit expectations, insufficient resources and support for mobile learning further discouraged usage. Students emphasised the need for comprehensive tools, such as mobile apps and detailed guides, to enhance their clinical skills training. One student explained*: "The university should definitely be doing more apps and so guides and things. I think our clinical skills teaching in first and second year was a bit hit and miss… here it's sort of like a checklist"* (Thomas, 2021).

Institutional factors affecting device usage also included the prevailing culture within healthcare facilities. The culture of healthcare facilities significantly affected students' comfort in using technology in clinical settings. For instance, students in Rashid-Doubell et al. (2016) noted that hospital culture influenced the general acceptance of mobile device use, with one student commenting, *"I notice that the hospital staff on the rounds uses a tablet. So I think patients are becoming used to it, they're becoming used to seeing it, they now know that's what the purpose of it is."* Another student added, ***"**That's quite a technology-friendly hospital."*

While some institutional factors shaping device usage were discouraging, other institutions actively legitimised the use of mobile learning resources, which positively influenced students' attitudes and behaviours. Joynes and Fuller (2016) highlighted the importance of clear communication from schools, with one student explaining: "*I think the fact that University pushes it, it kind of legitimises that you're allowed to."*

These institutional factors, such as guidelines, rules, resources, support, the prevailing culture, and legitimisation, acted as either barriers or enablers to the effective use of mobile learning tools among medical students.

Following the section on institutional factors, the next section presents how educators' attitudes, behaviours, guidance and technological literacy influenced students' engagement with mobile learning tools.

4.4.5.2 Factors Related to Medical Educators

This sub-theme was informed by the findings from 14 studies. These studies collectively underscored how educators' attitudes, behaviours, guidance, and technological literacy influenced students' behaviours and their ability to integrate mobile technology, either enabling or constraining their learning practices.

Permissions, recommendations, support, positive behaviours, and the technological literacy of medical educators have emerged as enablers facilitating students' use of mobile devices for their learning. Explicit permission from educators to use mobile devices in clinical settings appeared to play a crucial role in shaping students' behaviours (Harrison et al., 2019; Sulley, 2018). When clinical teachers explicitly asked students to look up information, such as drug dosages, while they were with patients, students perceived this as a clear endorsement of mobile device use. One participant remarked, *"I would not be game to use a mobile phone in front of a patient unless someone said, 'Oh, could you look this up?'"* (Harrison et al., 2019). Another student echoed this sentiment, stating, "*It's only when – actually, sometimes they'll tell you to check. I think that's the only way"* (Sulley, 2018). Another student recalled a moment when they were using their phone to look up information discussed in a lecture. Initially, the lecturer objected, saying, *"Stop using the phone!"* but quickly changed their stance after the student clarified, "*I'm looking for stuff related to what you are talking about,"* to which the lecturer responded, *"Okay, no problem"* (Rashid-Doubell et al., 2016).

Educators' recommendations also likely influenced students' adoption of mobile learning resources. Students often based their use of mobile resources on endorsements from their teachers. For example, the BNF (British National Formulary) application was frequently utilised during therapeutic sessions due to educator guidance. As one student explained, "*It's pretty much a recommendation for me. It's like what I've heard from others are good; I just use those ones"* (Thomas, 2021).

Support from educators was another external factor likely to influence students' confidence in using mobile devices. Studies by Ellaway et al. (2014) and Joynes and Fuller (2016) highlighted that faculty support was crucial for students to feel confident and comfortable using mobile resources during clinical placements. Students believed that endorsement and assistance from educators legitimised the use of these tools, making their usage more acceptable in clinical settings.

The behaviour of clinicians and other health professionals may also have potentially influenced students' use of mobile devices in clinical environments (Harrison et al., 2019; Scott et al., 2015). Students often modelled their behaviour based on the actions of clinicians, many of whom frequently used mobile devices without restrictions. One student explained: *"[Use of mobile devices] is seen by consultants, primary registrars, like the practice kind of filters down because of what we see"* (Harrison et al., 2019). Additionally, observing clinicians using mobile devices encouraged students to follow suit. As one participant remarked, *"Usually I gauge a sense of what the doctor's like before I do it"* (Harrison et al., 2019). Similarly, students usually observed whether clinicians used mobile devices before using their own, as they were concerned about being misinterpreted as using devices for personal rather than educational purposes (Scott et al., 2015).

Technological literacy among educators may have played a role in shaping their acceptance and support for the use of mobile devices in medical education. Participants in studies by Rashid-Doubell et al. (2016) and Sulley (2018) identified a group of clinical educators they referred to as "new school" teachers who were more open-minded and supportive of using mobile technology in clinical settings. These educators often accepted and, in some cases, actively encouraged the use of mobile devices, provided that students explained the purpose of their usage beforehand. For instance, one participant shared an experience during ward rounds: *"So if we're doing a round and nobody knows the answer to something they'll [the doctor] be like (snaps fingers) 'Look it up', and then it's just the race of who can type faster"* (Rashid-Doubell et al., 2016).

Conversely, negative attitudes, behaviours, perceptions, and the technological inefficacy of medical educators can hinder students' use of devices in both classroom and clinical settings.

One recurring issue across the studies was the influence of the hidden curriculum**,** whereby educators' implicit expectations and assumptions about mobile device usage shaped students' learning experiences. Students expressed some concerns that even when they used devices for educational purposes, their teachers might perceive them as engaging in non-educational activities. For instance, some educators assumed students were "texting or checking emails" rather than using their devices for legitimate learning tasks (Alegría et al., 2014; Harrison et al., 2019; Scott et al., 2015; Witt et al., 2016).

Several students shared negative experiences stemming from these misunderstandings. One student recounted being misunderstood while using LexiComp, a drug information app: *''I found that some preceptors don't know what you're using it for and think you're using it socially. I've actually been commented on that 'Oh you use your phone a lot' and things like that, so I always show them, look it's LexiComp.''* Another student noted that such a misunderstanding was even documented in a formal evaluation form: *''That was actually written on one of my formal evaluations about my cellphone use, which sent me right over the edge, because I was furious. I'm not socialising while I'm working, I'm looking things up''* (Ellaway et al., 2014).

In a study by Harrison et al. (2019), similar experiences were reported. Students feared receiving negative remarks on personal and professional evaluation reports for using devices during clinical placements. One student shared: *"They were quite serious about it and they were like, 'We are going to discipline you'."*

Educators' misinterpretations sometimes escalated to confrontational situations. In a study by Sulley (2018), some educators viewed students' device usage as attempts to verify their teaching or find errors, creating tension in the learning environment. One student described such an experience: *"They would shout on you – some of them will actually shout on you, if they see you with your phone. I mean, thinking you are in an attempt of finding out whether what they are teaching you is sure or not. So, most of them actually feel that we go online to try and find mistakes."*

In certain situations, mobile device usage was entirely prohibited in the classrooms, reflecting traditional norms and attitudes. A study by Pimmer et al. (2013) highlighted this institutional rigidity, where mobile technology was viewed as incompatible with conventional education. One student shared their experience: *"We did not [use devices] in front of the teachers [...]. Most of the* *teachers don't like using mobiles. [.. .] It's not a rule but they don't like it."* Similarly, in a study by Sulley (2018), students reported that their request to use mobile devices was denied, even though they sought their teachers' permission.

Disapproval of mobile device usage extended to clinical environments, where educators were concerned about its potential to distract students. Some educators felt that devices interfered with students' focus during bedside teaching (Rashid-Doubell et al., 2016; Witt et al., 2016). Two students shared their experiences: "*They don't really want us to have laptops or anything because I think they don't really trust us to be focusing on them if we're typing away or something"* and " …*That student is supposed to be focusing on me. Instead, he's looking at his mini iPad"* (Rashid-Doubell et al., 2016).

Some educators were either unwilling or unable to use the devices for essential tasks. Green et al. (2015) reported that certain educators preferred marking clinical assessments on a computer instead of using a mobile device. One student recounted their experience: "*On one of my placements the doctor just couldn't use the iPhone and he was like, 'Oh but I'll do it on a computer'."* Similarly, students encountered discouragement from educators who preferred textbooks over mobile resources. One student shared: "*I was looking up something with one of the surgical registrars and the consultant came by and said, 'Well, there are textbooks for that' and to look at a textbook which was sitting next to us'"* (Harrison et al., 2019).

Educators' lack of engagement with mobile technology further discouraged students' adoption of it. For instance, students in a study by Oo et al. (2022) expressed their frustration when their queries posted in Whatsapp groups were ignored: *"Lecturers ignored the question posted by a student and neither replied nor answered. This is very disappointing and frustrating."*

Regarding the technological inefficacy of educators, Rashid-Doubell et al. (2016) highlighted the generation gap among some educators. One student explained their experience: *"Many of the old, especially the old generation, they don't know how to use the technology properly. And they don't know like how we use it and how do you put books and notes and whatever on the phone…*

they don't know how we live on our phone nowadays" (Rashid-Doubell et al., 2016).

Following the section on the factors related to medical educators, the next section examines how patients' perceptions influence students' use of mobile devices in their learning environments.

4.4.5.3 Perceptions of Patients

The findings from six studies contributed to the development of this sub-theme. These studies collectively explored how patients' perceptions and reactions affected students' comfort and behaviour when using mobile devices in clinical environments, either positively or negatively.

At one end of the spectrum, some patients misunderstood students' use of devices, perceiving it as engagement with social media rather than for studying. Students shared their experiences, noting that patients often assumed they were merely playing with their devices whenever they saw them using them (Green et al., 2015; Shenouda et al., 2018) or either texting or taking pictures of them (Harrison et al., 2019). One student shared his experience: *"…As a medical student, if you're fiddling around on your phone, even just to look something up, or to do something relevant and useful, people might still think you're texting someone… I'm always going to feel slightly uncomfortable using my phone on the wards*" (Shenouda et al., 2018).

Some students viewed the concern about patients' misunderstanding from a different perspective, noting the size of the device (Rashid-Doubell et al., 2016). They assumed that smaller devices, like smartphones, might be mistaken as being used for non-educational purposes. In contrast, larger devices, like tablets, were more likely to be seen as tools for study. One student commented: " '*Look, I'm going to look something up now', and you put your tablet down and you're looking something up. They know you're looking something up because it's a tablet…*" (Rashid-Doubell et al., 2016).

At the other end of the spectrum, some students reported positive feedback from patients when using devices in clinical settings, citing examples such as using growth charts for children or calculating cardiovascular disease risk during patient encounters (Johnson & Howard, 2019). Similarly, some students found that using the device with paediatric patients received positive perceptions because children enjoyed interacting with tablets. One student shared: *"I feel like I might be able to use it maybe a little bit more now that I'm in paediatrics. Just because kids love tablets*" (Clarke et al., 2019).

Following the section on patients' perceptions, the next section examines how interactions with classmates and family members contributed to students' decisions to adopt and use mobile technology in their education.

4.4.5.4 Influence of Peers and Family

This sub-theme emerged from the findings of three studies. These studies revealed how peers and family could support or hinder students' use of mobile devices for their learning.

Some students, being more technologically adept than their peers, provided technical support when needed (Ellaway et al., 2014). In certain situations, students relied on resources recommended by their friends rather than exploring new ones independently (Thomas, 2021). One student shared how he was introduced to a useful website by a friend, which helped him locate a book he had been looking for: *"One time my friend introduced me to a website and … I was going to download … it was one of the books that I was really looking for"* (Sulley, 2018).

Beyond peer influence, family members also played a role. For example, one student recounted how her father encouraged her to use specific applications for her studies, such as Coursera and Khan Academy (Sulley, 2018).

While external factors such as institutional rules, educators' attitudes, patients' perceptions, and peer and family recommendations influence students' use of mobile devices, personal factors – including beliefs, emotions, technology experience, and learning needs – play a crucial role in their decision-making process. These personal factors are discussed in the next section.

4.4.6 Descriptive Theme 2: Personal Factors Affecting Students' Use of Mobile Devices

This descriptive theme emerged from an inductive analysis of findings across 17 studies (Appendix Y) and was developed from four sub-themes: personal beliefs and perceptions, emotional factors, technological experiences, and individual learning needs (Figure 4.12). These sub-themes focused on factors that arose from individual perspectives, setting them apart from external influences.

The number of studies leading to the development of four sub-themes is presented in Appendix Z. Subsequent sections discuss each sub-theme, incorporating relevant quotes for further clarity.

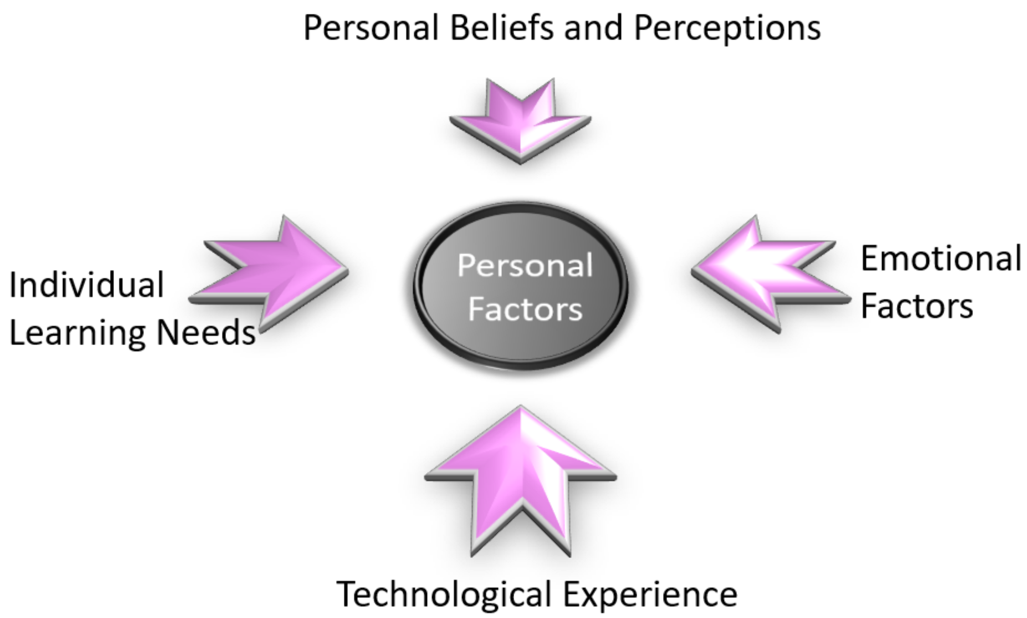

Figure 4.12 Personal Factors Affecting Students' Use of Mobile Devices

4.4.6.1 Personal Beliefs and Perceptions of Using Mobile Devices

This sub-theme was derived from the findings of 12 studies that emphasised the role of personal beliefs and perceptions in shaping students' use of mobile devices. While students' perceptions of usefulness, ease of use, and professional image encourage the adoption of mobile technology, concerns about patient relationships, appropriateness, and professionalism act as barriers to device usage.

Students' intention to use mobile devices in clinical settings was closely tied to their perceived usefulness. Some students valued devices for their ability to have immediate access to clinical information, motivating them to use their devices. One student explained: *''The only thing I've used it for in the clinical setting was for looking up drugs or looking up a symptom straight away... If it's going to help me take better care of patients, then I'm going to do it''* (Ellaway et al., 2014).

The ease of using mobile technology was a significant motivating factor for students to adopt mobile devices, as it simplified their learning processes and boosted their confidence. For instance, the use of WhatsApp in PBL sessions made it easier for students to navigate and engage with their studies (Raiman et al., 2017). One student shared this experience: *"I felt really confident in using instant messaging in PBL, and I feel as though it benefitted my learning."*

Similarly, mobile apps with specific functionalities, particularly in anatomy education, further encouraged adoption. Across studies (Harmon, 2015; Mansouri et al., 2020), students highlighted features, such as 3D visualisations, user-friendly interfaces, and user support, that enabled them to use the apps with ease and facilitated their engagement with content and active learning.

Adopting mobile technology was often seen as a means to build an institutional reputation and professional image. Several learners believed that using new technologies represented the future of medicine and elevated the status of their schools. Additionally, students valued mobile devices for addressing gaps in their knowledge, using them to build confidence and improve their image in front of senior doctors (Ellaway et al., 2014; Rashid-Doubell et al., 2016).

While these perceptions facilitated the adoption of mobile technology, students also reported significant barriers to its use. These barriers, rooted in concerns about patient interactions and perceptions of professionalism, are explored below.

Students' perceptions of using mobile devices in clinical environments highlighted four main concerns: their impact on rapport with patients, perceptions of inappropriateness or disrespect, concerns about appearing rude, and fears of being perceived as unprofessional. These perceptions shaped students' comfort with and willingness to use devices in clinical settings.

Many students believed that using a device in the presence of a patient could hinder rapport. One student shared: "*I tend not to take it out because I just think it kind of creates a barrier between me and the patient"* (Clarke et al., 2019). Another remarked: *"I think it would be strange to type in front of the patient, and I think it interferes with the rapport"* (Clarke et al., 2019). These concerns reflected students' fears that device use could distance them from patients, potentially affecting the quality of interactions.

Some students worried that patients might view their use of mobile devices as inappropriate or disrespectful, even when used for educational purposes. For instance, one student stated: "*I don't feel like it's appropriate to use it in front of the patient; they might think that I'm just like playing with my iPad instead of doing something so"* (Clarke et al., 2019). Another echoed this concern, describing how device use could be misinterpreted: *"The patient might think that you're actually texting about them or taking a photo of them"* (Harrison et al., 2019).

Students also expressed concerns that using devices in front of patients might be perceived as rude. One student explained: *"I wouldn't use it in front of a patient, I think that would be pretty rude."* Another commented: *"I haven't seen anyone literally use their phone while talking to a patient. Now that would be very rude*" (Rashid-Doubell et al., 2016). These perceptions highlighted students' sensitivity to how their actions might be interpreted by patients, regardless of intent.

Students expressed concerns about being perceived as unprofessional when using mobile devices in clinical settings. For example, some students noted that mobile device use might appear as socialising or non-medical activity. One student shared: *"If they see that, and it's their opinion that you're texting your mate [friend] or doing something else, then they may perceive that as unprofessional."* Another student recalled, *"I've been in the clinic, as a student, with somebody else who was looking something up on their phone, and the patient actually said something to the doctor about it, and it was really uncomfortable"* (Shenouda et al., 2018). Additionally, advice from senior doctors reinforced these concerns. As one student noted: *"It's unprofessional to use your phone. Older patients especially won't appreciate it"* (Clarke et al., 2019).

Following the section on personal beliefs and perceptions, the next section explores how students' feelings and emotions impact on their device usage and learning experiences.

4.4.6.2 Emotional Factors

Based on evidence from two studies, this sub-theme illustrated the impact of students' emotions on their acceptance of mobile technology in their learning.

Satisfaction from receiving immediate feedback or encouragement from educators when using mobile learning platforms created positive emotional responses, which promoted students' use of devices. Conversely, negative emotions, such as discouragement from critical feedback, hindered their adoption. A student shared their experience: "*It gives me satisfaction; since whenever I have a question, then I can ask and get an instant reply. I feel very delighted whenever my answer is correct; it really improves my self-esteem."* Conversely, another student remarked that, "*Some negative responses can give discouragement"* (Oo et al., 2022).

Following the section on students' emotions and feelings, the next section examines the impacts of students' technological proficiency and training on their use of mobile devices.

4.4.6.3 Technology Experience

This sub-theme was developed from the findings of eight studies that highlighted the role of technology experience in facilitating or impeding students' efficiency and confidence in using these tools for clinical and educational purposes.

Students' efficacy in using mobile devices enabled them to integrate the technology into their clinical and academic routines. For instance, one student remarked, "*Everyday use of the iPad is a habit now, and I do not have to think about where to find information and how to use it*." (Nuss et al., 2014). Another student who self-identified as a technophile used a tablet to increase the efficiency of patient care in the clinic (Alegría et al., 2014).

While some students demonstrated technological efficacy, others required training and technical support to use devices effectively. This need was highlighted by Witt et al. (2016), noting that students requested tailored introductory training and ongoing technical support. One student suggested: "*I was suggesting that maybe we could have been given some sort of. . .manual that we would use later on our own, especially when we encounter problems when we are using the [mLearning] device at school or our places."*

Following the section on technological experience affecting students' use of devices, the next section explores how students' learning needs shape their device usage to meet these needs.

4.4.6.4 Individual Learning Needs

This sub-theme was informed by the findings of two studies. These studies collectively explored how students' specific learning needs contributed to their motivation to adopt mobile devices.

Many participants in the study by Nuss et al. (2014) demonstrated a targeted approach in selecting mobile apps tailored to their educational requirements. One student shared: "*I learned to use the apps that were appropriate for each case more effectively… As time went by, I knew which apps would have the information that I was looking for."*

Similarly, students in Joynes and Fuller (2016) reported selecting mobile applications aligned with their learning objectives. One participant explained: I*" use the [app 2] for ECG because I found that really difficult as a skill... ."* Another student highlighted*:" I use [app 4] it's just really good for drug interactions, how drugs work and body systems, things like that… ."*

An interplay of personal beliefs, emotions, technology experiences, and individual learning needs guides students' adoption and selective use of mobile technologies in their learning environments.

4.4.7 Analytical Theme 1: Identifying Enablers of and Barriers to Mobile Device Usage by Unifying External and Personal Factors

The findings from Descriptive Theme 1 (external factors) and Descriptive Theme 2 (personal factors) affecting students' use of mobile devices were integrated, and they are presented in Analytical Theme 1 as enablers of and barriers to mobile device usage among medical students (Figure 4.13). The synthesis highlights how these external and personal factors determine the extent to which students leverage mobile devices to enhance their learning and clinical practice.

To avoid repetition, detailed quotes are not included in this section. However, relevant verbatim quotes can be referred to in the respective descriptive themes where they are presented in context.

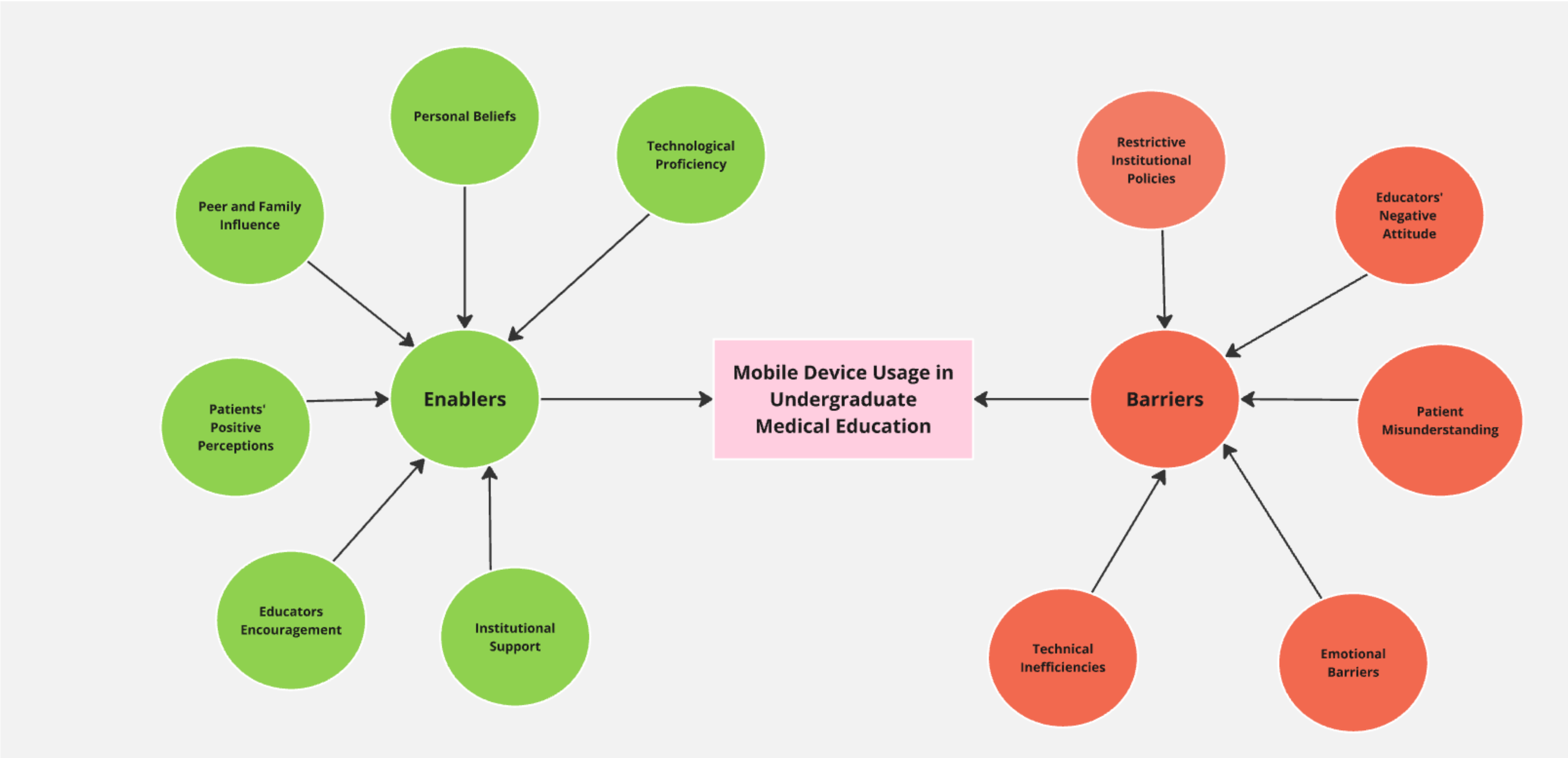

Figure 4.13 Enablers and Barriers of Mobile Device Usage in Undergraduate Medical Education

4.4.7.1 Enablers of Mobile Device Usage

Six key enablers of mobile device usage among medical students emerged: institutional support, including legitimisation and resources; educators’ encouragement and guidance, which fostered confidence; positive patient perceptions, especially when usage was explained; peer and family influence, through recommendations and technical support; and personal factors like beliefs in device utility and technological proficiency, which streamlined integration into clinical and academic settings. These factors facilitated the adoption and effective use of mobile technology in medical educational settings.

4.4.7.1.1 Institutional Support and Resources

Institutional support was a significant enabler that legitimised the use of mobile devices in clinical and educational settings. Institutional endorsements provided students with confidence in integrating mobile devices into their routines, as highlighted by Joynes and Fuller (2016). Moreover, the availability of resources, such as mobile apps and video guides, enhanced students’ confidence and practical knowledge, as reported by Thomas (2021).

4.4.7.1.2 Educators' Encouragement and Permission

Educators played a pivotal role in facilitating mobile device adoption by providing explicit permission and encouragement. When educators demonstrated openness to technology, students felt less ambiguous about device use and were motivated to incorporate it into their learning practices. Studies showed that educators’ explicit support reduced uncertainty and fostered confidence in using mobile technology (Rashid-Doubell et al., 2016; Harrison et al., 2019).

4.4.7.1.3 Patients’ Positive Perceptions

Transparent communication about device usage helped patients understand its educational or diagnostic purposes, fostering acceptance. Patients in certain settings, particularly paediatric environments, expressed positive attitudes when devices were used in appropriate ways (Rashid-Doubell et al., 2016; Clarke et al., 2019).

4.4.7.1.4 Peer and Family Influence

Peers and family members significantly influenced students' willingness to explore and adopt mobile technology. Recommendations and technical support from peers often introduced students to new learning tools (Ellaway et al., 2014). Family encouragement, such as suggestions for relevant applications, broadened students' adoption of mobile learning resources (Sulley, 2018).

4.4.7.1.5 Personal Beliefs

Students' personal beliefs in the usefulness of mobile devices shaped their willingness to adopt and integrate these tools. Many students valued mobile technology for its practical benefits, including enhanced learning and improved patient care (Ellaway et al., 2014; Raiman et al., 2017).

4.4.7.1.6 Technological Proficiency

Technological proficiency and frequent use enabled students to integrate mobile devices seamlessly into their routines (Alegría et al., 2014). Familiarity with technology reduced cognitive load and enhanced efficiency in accessing information, as reported by Nuss et al. (2014).

4.4.7.2 Barriers to Mobile Device Usage

Five barriers to mobile device usage among medical students were identified: restrictive institutional policies and insufficient resources, which limited effective integration; negative attitudes and technological inefficacy among educators, which hindered support; patient misunderstandings, particularly regarding smaller devices like smartphones; and emotional and technological challenges, including discouragement from critical feedback and a lack of training or technical support. These barriers constrained the optimal use of mobile technology in clinical and academic contexts.

4.4.7.2.1 Restrictive Institutional Policies and Limited Resources

Restrictive institutional policies often discouraged mobile device usage in clinical settings. For example, explicit rules prohibited device use during patient interactions, reflecting concerns about perceived discomfort (Harrison et al., 2019). Limited institutional resources, such as a lack of comprehensive guides or tools, further hindered integration by leaving students feeling unsupported (Thomas, 2021).

4.4.7.2.2 Educators' Negative Attitudes and Technological Inefficacy

Negative attitudes and limited technological proficiency among educators significantly hindered mobile device adoption. Resistance to mobile technology, often rooted in a preference for traditional methods, created challenges for students (Pimmer et al., 2013). Educators' assumptions that mobile devices were being used for non-educational purposes led to misunderstandings and criticism (Ellaway et al., 2014; Harrison et al., 2019). Additionally, some educators lacked the technological literacy needed to support or endorsed mobile device use, further discouraging students (Harrison et al., 2019; Rashid-Doubell et al., 2016). Instances where educators viewed device use as undermining their teaching authority also contributed to tensions in learning environments (Rashid-Doubell et al., 2016; Sulley, 2018).

4.4.7.2.3 Patient Misunderstandings

Patients' misunderstandings about mobile device usage often acted as barriers, particularly when smaller devices like smartphones were perceived as distractions rather than educational tools. These perceptions may lead to discomfort for students and limit their willingness to use devices during patient interactions (Rashid-Doubell et al., 2016; Shenouda et al., 2018).

4.4.7.2.4 Emotional Barriers

Negative feedback from educators significantly affected students' confidence in using mobile devices. Discouraging responses from educators created an environment of hesitation and reduced students' willingness to engage with mobile technology (Oo et al., 2022).

4.4.7.2.5 Technical Inefficiencies

Inadequate training and a lack of technical support further hindered students' ability to use mobile devices effectively. Insufficient resources, such as manuals or tailored guidance, left students unprepared to address technical challenges, which reduced the utility of mobile technology in education (Witt et al., 2016).

The enablers and barriers outlined above demonstrate the complex interplay of external and personal factors affecting mobile device usage in medical education.

4.4.8 Descriptive Theme 3: Usability of Devices in Medical Education

This descriptive theme of the usability of devices in medical education was inductively derived from 17 studies (Appendix Y). It was informed by four sub-themes: connectivity, portability, multifunctionality, and environmental friendliness, which represent essential functional features of mobile devices critical for effective learning (Figure 4.14).

The contributing studies for these four sub-themes are shown in Appendix Z. Each sub-theme is elaborated in the following sections and illustrated with relevant verbatim quotes.

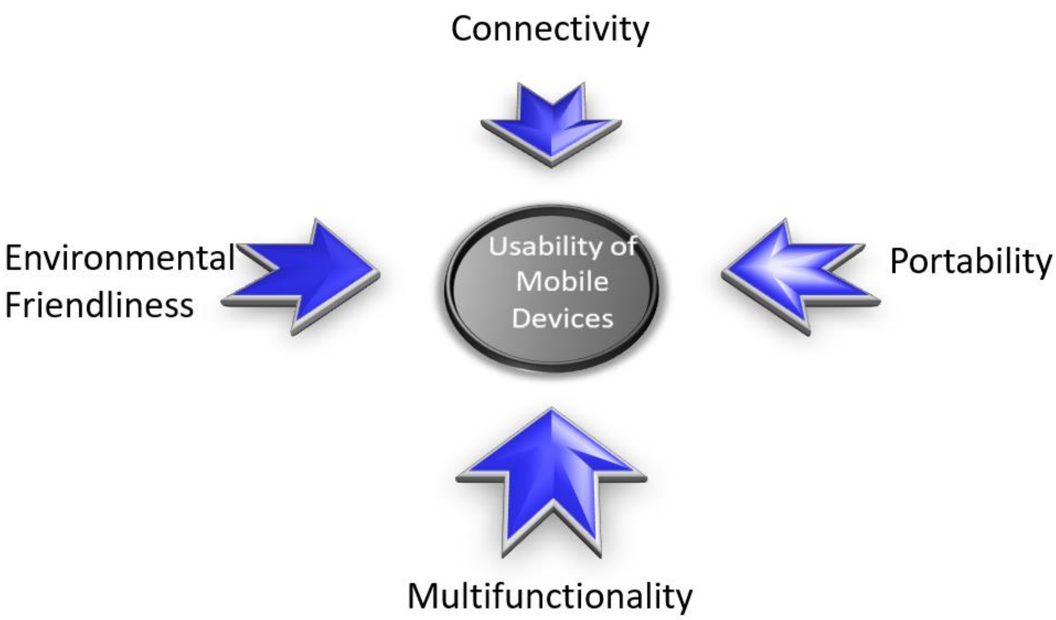

Figure 4.14 Usability Features of Mobile Devices in Medical Education

4.4.8.1 Connectivity

The findings from two studies underpin this sub-theme, which focuses on the importance of the capability of devices to connect with the Internet, various networks, and other devices to provide instant access to information and learning resources.

For example, in Clarke et al. (2019), students reported being almost continuously connected, frequently accessing online clinical information to support their studies. One participant described themselves as a *"connectaholic*", highlighting the particular impact of this behaviour in clinical settings.

Following the section on connectivity, the next section explores how portability contributes to the usability of mobile devices in medical education.

4.4.8.2 Portability

Rooted in evidence from seven studies, this sub-theme examined the ways in which the physical characteristics of devices, such as weight and size, allowed students to carry them from one place to another easily and how the convenience of carrying these devices impacted on students' learning, particularly in clinical environments.

For instance, the portability of a tablet– fitting conveniently into a pocket of a white coat – was seen as advantageous for carrying the device and accessing information anywhere (Witt et al., 2016). One student remarked: *"[I would keep the tablet] in my white coat…"* (Alegría et al., 2014). Similarly, Twiss-Brooks et al. (2017) highlighted the convenience of devices like the iPad mini, which fits easily into scrub pants and is ideal for use in hospital settings.

The lightweight nature of these devices further added to their practicality. Some students preferred lighter devices like iPads over laptops for their portability and ease of use. One student explained: *"I bring my laptop to work to study, and it's way too heavy and cumbersome … with the iPad, I can just carry the size of a small textbook and have access to multiple textbooks"* (Wallace et al., 2012). Another student added: "*Using iPad, not needing to carry books back and forth between the medical school and home"* (George et al., 2013).

Following the section on portability, the next section examines the positive impact of the multifunctional features of devices in medical education.

4.4.8.3 Multifunctionality

This sub-theme was informed by the findings of 13 studies, which collectively examined the role of the multifunctional features of mobile devices, such as a camera, voice recorder, video recording capability, and note-taking applications, in facilitating students' learning.

One notable feature of mobile devices is their camera functionality, which students use to capture medical procedures or surgical instruments for exam preparation and future learning. For example, one student shared: *"The teacher would show an instrument, and we will be asked about this in the exam, so we will take a picture."* Another student explained: *"[I take pictures] for cases that are difficult to see – that's for future purpose and learning purpose"* (Pimmer et al., 2013).

In addition to capturing still images, audio and video recording functionalities were often used during lectures or discussions. These recordings allowed students to revisit the lessons and reinforce their understanding later.

One student commented: “*It is very helpful to look back at discussions during PBL sessions…”* (Raiman et al., 2017).

Last, mobile devices were widely adopted for note-taking, both in lecture and clinical settings. Some students highlighted the benefits of specialised note-taking apps, such as Evernote, which helped them organise their learning materials (Alegría et al., 2014). Another student described using iAnnotate to mark up lecture slides, which facilitated a structured approach to learning: “ … *I use iAnnotate to mark-up my lecture slides… and my system is 100% paperless”* (George et al., 2013).

Following the section on the multifunctional features of mobile devices, the next section examines how their environmental friendliness impacts on students’ learning.

4.4.8.4 Environmental Friendliness

This sub-theme was developed from the analysis of three studies, which collectively examined the environmental benefits of mobile devices in terms of their ability to reduce paper usage through the use of on-screen notes and digital copies.

One student commented: *“Advantages include … environmentally friendly. It reduces the consumption of ink and papers …”* (Doherty et al., 2015).

The usability of mobile devices in medical education, encompassing features such as connectivity, portability, multifunctionality, and environmental friendliness, underscore their practicality and adaptability across diverse educational and clinical contexts.

The following section explores how students benefited pedagogically and achieved professional growth through the use of mobile technology in various educational settings.

4.4.9 Descriptive Theme 4: Benefits of Mobile Technology in Medical Education

This descriptive theme was constructed through an inductive analysis of findings from 19 studies (Appendix Y) and was organised around three sub-themes: enhanced learning, improved patient care, and development of soft skills (Figure 4.15). These sub-themes collectively emphasised the benefits and advantages students received from using mobile technology in educational and clinical settings.

Each sub-theme, detailed in the following sections, is supported by evidence from the studies listed in Appendix Z and accompanied by verbatim quotes for clarity.

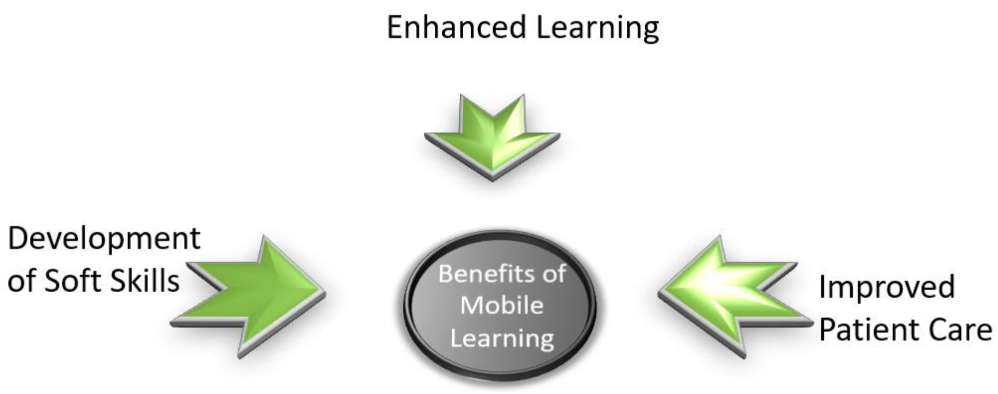

Figure 4.15 Benefits of Mobile Learning in Medical Education

4.4.9.1 Enhanced Learning

The development of this sub-theme was based on the findings from 19 studies, and these studies provided evidence of how mobile technology enhanced students' learning experiences.

This sub-theme was further divided into five sub-sub-themes of mobile-enabled learning approaches: just-in-time learning, self-regulated learning, self-directed learning, collaborative learning, and informal learning (Figure 4.16). Each sub-sub-theme is informed by the studies shown in Appendix Z and is illustrated through selected quotes in the next sections.

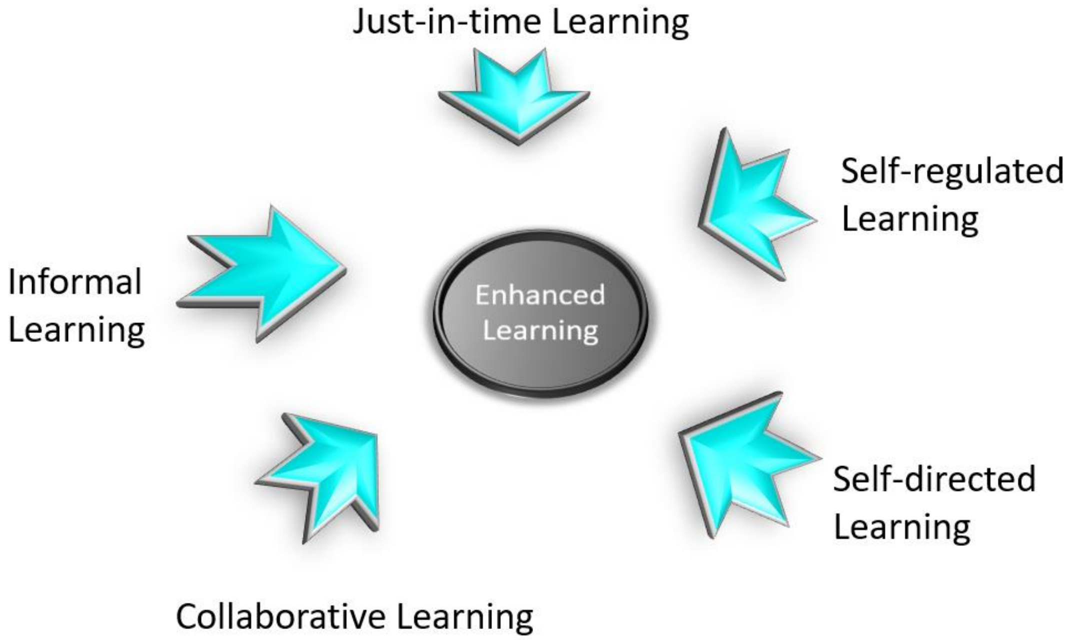

Figure 4.16 Mobile-enabled Learning in Medical Education

4.4.9.1.1 Just-in-time Learning

This sub-sub-theme focused on a mobile-enabled learning approach that provided learners with access to information when they needed it. The findings from seven studies highlighted the critical role of this learning approach across various settings, including classrooms, hospital wards, and operating theatres, with evidence provided to illustrate its impact.

Instant access to learning resources through mobile devices helped students effectively engage in classroom discussions. For example, one student highlighted the advantage of using mobile devices in a classroom, "W*hen we're in classroom, an app like DailyRounds, it has what she mentioned, that clinical cases that other doctors or medical students have seen…"* (Sulley, 2018).

Building on this classroom engagement, instant access to information enabled by mobile learning also transformed clinical experiences into learning opportunities. Students not only engaged with clinical cases but also searched for relevant information through their devices, integrating this knowledge with real-case scenarios to facilitate contextual learning. One student emphasised this advantage: "*When you're on wards … You can look up things there and then instead of trying to remember to go back and read up on it"* (Green et al., 2015).

Moreover, students often used their devices to quickly search for unfamiliar terms during patient interactions, further supporting their understanding. As one student remarked: *"I went to the hospital and there was one lady who was diagnosed with [...] and I didn't know what it was. So I looked it up what it was … "* (Pimmer et al., 2013).

Transitioning from patient interactions to ward rounds, immediate access to information during these ward rounds enabled students to keep up with clinical discussions. One student described this experience: *"If you are going on ward rounds and maybe there's a case you're talking about, you can't go back for your huge books. It's just there, you just type, and you can get the information"* (Sulley, 2018).

In highly stressed environments like operating theatres, just-in-time learning also proved invaluable. Students quickly searched for relevant information, enabling them to prepare for surgeries effectively. As one student explained: *"I've used it many times, in theatre before going into surgery to check stuff. You can watch the surgery as a video before you go in"* (Green et al., 2015).

Additionally, in emergency medical situations, just-in-time learning became a vital tool. It allowed students to access crucial information quickly when immediate decisions were necessary. For instance, one student recounted: "*I've seen mobile technology being used effectively during emergencies or when they are not really sure about what's going on"* (Sulley, 2018).

Finally, just-in-time learning not only supported students' knowledge acquisition but also helped them feel prepared and confident in clinical settings. By discreetly looking up information before patient encounters, students could present themselves as knowledgeable and competent. One student shared: "*It's saved face a couple of times for me when I've been in clinic, when I've known somebody's coming in and I've not got a clue, and if I hadn't had the phone ... I just wouldn't have known…"* (Joynes & Fuller, 2016). Similarly, another student expressed feeling reassured by having the device readily available during bedside teaching: *“It’s a horrible thing to be on the wards and not know what’s going on and not know what you’re dealing with. So it’s very comforting to have it, have the phone there and be able to go on straight away and look at things”* (Clarke et al., 2019).

Following the section on mobile-enabled just-in-time learning, the next section explores self-regulated learning, which empowers students to take ownership of their learning processes.

4.4.9.1.2 Self-regulated Learning

Addressing self-regulated learning, this sub-sub-theme explored how mobile technology enabled students to self-identify their learning needs, monitor their progress, evaluate their performance, and determine whether they had achieved their learning goals. The presentation was supported by relevant findings from six studies with contextual examples.

One notable example of mobile technology enhancing self-regulated learning was demonstrated in Alegría et al.’s (2014) study, where senior medical students were equipped with tablets during their clerkship training programmes. These tablets provided access to the EHR for tracking their patients’ records, along with Evernote, a note-taking application, to support documentation and the retrieval of self-identified clinical learning issues. Additionally, the tablets enabled students to self-monitor their progress through practice tests, communicate with educators via texts or emails, and receive feedback on their performance. The use of tablets demonstrated their effectiveness as self-regulatory learning tools in the clerkship training programme.

4.4.9.1.3 Self-directed Learning

In addition to the use of mobile devices in clerkship training, they have also been increasingly applied in anatomy education for self-directed learning. Three studies by Harmon (2015), Küçük et al. (2016), and Mansouri et al. (2020) explored mobile apps specifically designed to enhance self-directed learning for anatomy education. Across these studies, students consistently reported positive learning experiences, highlighting the effectiveness of the apps in enhancing self-directed learning and improving academic performance.

A key theme identified in all three studies was the ability of the apps to enable students to self-study, evaluate their understanding, and identify their learning needs. For example, Harmon's (2015) app was praised for its comprehensiveness in helping students learn complex anatomical structures. Students commented: *"I think the app was great overall with lots of potential benefits for students to learn anatomy in a more comprehensive manner,"* and *"The app was really helpful for reviewing multiple parts of the anatomical structures. The definitions and explanations were clear and concise. A very good way to synthesise the material."*

Similarly, Küçük et al. (2016) developed a mobile augmented reality app for a neuroanatomy topic. The app was well-received by students, who highlighted the critical role of self-assessment and their improvements in academic performance. Two students shared their experiences of improved academic performance with the app. The first student remarked: *"I think it has improved my achievement. I got 87 points on such a difficult subject."* The second student also felt that the app supported their self-directed efforts: *"I absolutely think it has improved my achievement...it was a topic requiring hard work for a long time.*"

Extending this theme, Mansouri et al. (2020) highlighted the importance of self-assessment in their mobile app, which featured quizzes with varying difficulty levels. These quizzes facilitated not only self-regulated learning but also enabled adaptive learning by guiding students to focus on areas needing improvement. Students found this feature particularly beneficial for enhancing their overall learning experience.

Beyond anatomy-specific apps, students widely utilised mobile resources to assess their knowledge and understanding through practice tests, such as question banks from USMLE (United States Medical Licensing Examination) or Kaplan. One student emphasised the utility of mobile devices for this purpose, stating, *"The iPad was VERY useful for doing practice questions"* (Nuss et al., 2014).

Following the section on self-directed learning, the next section examines how mobile devices and applications facilitate collaborative learning and promote peer interaction, shared resources, and collective knowledge construction.

4.4.9.1.4 Collaborative Learning

This sub-sub-theme provides insights into collaborative learning facilitated by mobile apps. The findings from five studies revealed that these apps enabled students to work together in groups to learn and solve problems, supported by illustrative examples.

Mobile apps such as WhatsApp, Skype, and Google Docs played a pivotal role in facilitating collaborative learning in CBL and PBL environments. Each app brought unique functionalities that supported various aspects of group interactions, from communication to resource sharing and co-creation of content.

WhatsApp has been widely adopted as a tool for real-time discussions and group interactions in PBL and CBL sessions. It enabled students to communicate seamlessly, share resources, and provide peer feedback, which contributed to a deeper understanding of the subject matter. As highlighted by Raiman et al. (2017), one student expressed*, "I thoroughly enjoyed the use of instant messaging to continually develop the learning objectives and communicate within the PBL group."* Beyond communication, WhatsApp facilitated collaborative problem-solving in clinical contexts. Grover et al. (2017) emphasised how students used WhatsApp to discuss case scenarios and share diagnostic insights, fostering group learning: *"WhatsApp gave us the freedom to discuss with our group mates, share views, and increase our understanding of topics."*

Skype supports collaborative learning by enabling live discussions, immediate feedback, and rapport-building, especially in cross-cultural learning contexts. This platform allowed students from different regions to connect and share clinical perspectives. One student in O'Donovan and Maruthappu (2015) remarked, *"Doing it more over the weeks has meant we have built up a rapport, and the students seem more at ease."* Additionally, Skype facilitated meaningful dialogue, helping students refine their clinical skills and collaborate effectively. Another participant noted, "*During the feedback time, I gained a lot of new* *knowledge, especially in how to relate anatomy with clinical skills."* These interactions not only built teamwork but also enhanced students' understanding of clinical concepts.

Google Docs provided a platform for students to collaborate on documents in real time, making it particularly useful during PBL sessions. Students could collectively contribute ideas, create shared notes, and refine their understanding of learning objectives. As one student highlighted in Doherty et al. (2015), *"If you can put your notes on Google Docs, where all other students can access, then we can give some ideas about each learning issue in PBL tutorials."* This co-creation of content fostered an inclusive learning environment where students collectively worked towards academic goals.

Following the section on collaborative learning, the next section presents informal learning, where students use these tools beyond formal educational settings to share resources, explore topics of interest, and engage in various learning activities.

4.4.9.1.5 Informal Learning

Informal learning, facilitated by mobile technology and social media platforms, supported students' learning in various settings, including unstructured downtime and while commuting. The findings from six studies contributed to the emergence of informal learning through mobile technology.

One significant example of informal learning through mobile technology was the use of Facebook as an informal learning tool. Studies by Pimmer et al. (2012) and Pimmer et al. (2013) revealed that nearly all interviewed students frequently accessed Facebook via their mobile phones. While the primary use of Facebook was for entertainment and social interaction, many students used it for educational purposes, especially through specific groups dedicated to medical and clinical topics. These groups, popular among international users, particularly from developing countries, provided a space for informal learning outside formal academic settings. One student shared their experience with a group called *"Medical profession, I love it. That's a [Facebook] group… there are more than 15000 people,"* noting its interactive nature where members could answer questions and receive immediate feedback (Pimmer et al., 2013).

Students further explained how the group's interactive nature: *"He [convenor of the site] asks questions to medical students. […] I answer by myself. […] Finally he used to give the right answers*" (Pimmer et al., 2012).

By participating in such communities, students engaged in informal learning activities, such as discussing clinical scenarios, answering multiple-choice questions, and exploring multimedia-enhanced cases. This engagement allowed students to deepen their understanding and address gaps in their knowledge. One participant emphasised the value of this informal practice: *"It's very beneficial. There are so many things we don't learn from textbooks. While reading Facebook, it's important, and you need to remember it."* Another student remarked on how the platform helped to reinforce learning: *"When I miss something in my studies, we get that point as well" (Pimmer et al., 2013)*.

In addition to social media, mobile devices enabled students to transform unstructured time into productive learning opportunities, tailoring their study activities to fit their schedules. For instance, students used mobile devices to maximise unscheduled time, such as waiting for clinical activities to begin, commuting, or during breaks. One student described the convenience of having a device ready for learning: "*When [clinical] activities are lacking and there is more downtime, it's very valuable in having the [tablet] just there, ready to do some work, like reading, and not necessarily having a computer nearby ... I think that's nice and empowering"* (Alegría et al., 2014).

Similarly, another student described using preparation time before clinics to study relevant topics: *"If I turn up ten minutes early to my clinic, I'm going to read up what it is"* (Joynes & Fuller, 2016). Clarke et al. (2019) echoed this sentiment, with one student sharing: *"I found it really invaluable. I mean… when you're on rotation, every once in a while you'll get an hour or two when your team is not really up to anything. And besides, I guess carrying a textbook around with you all the time, there's really no better way than just having the iPad."*

Students also used waiting time in hospitals or travel time during commuting for self-assessment activities, as one student noted: *"I have question banks on phone that are good to do during waiting times in hospital, very efficient"* (Harrison et al., 2019). Another student also shared their experience: “*Once I was on the bus, I was using my phone to again do questions”* (Twiss-Brooks et al., 2017).

Travel time was another opportunity for informal learning. Mobile technology enabled students to study while commuting by bus, train, or even on foot. One student remarked: *“… when I’m walking from school back to the hostel, maybe a particular topic or it’s theory we’re having the next day, all I have to do is listen …”* (Sulley, 2018).

Other creative uses of mobile devices during unstructured time included listening to educational content during unexpected moments. One student shared a unique experience: *“I love listening to lectures, listening to YouTube videos while I shower and while I get ready”* (Twiss-Brooks et al., 2017).

From facilitating real-time access to information through just-in-time learning to fostering self-regulation, collaborative engagement, and informal learning, mobile technology has become an integral part of students’ educational journeys.

The impact of mobile technology extends beyond education to patient care. The next section examines how mobile devices contribute to improved patient care by supporting evidence-based practices, enhancing communication, and enabling more informed clinical decision-making.

4.4.9.2 Improved Patient Care

This sub-theme was informed by 11 studies, and it focused on the critical role of mobile technology in providing patient care. This sub-theme encompassed four sub-sub-themes, highlighting various dimensions of a clinical-decision process: retrieving patient information, evaluating clinical examination performances, making informed therapeutic decisions, providing counselling and patient education, and collaborating with healthcare teams (Figure 4.17).

Appendix Z lists the studies informing these sub-sub-themes, which are discussed in detail in the subsequent sections with supporting quotes.

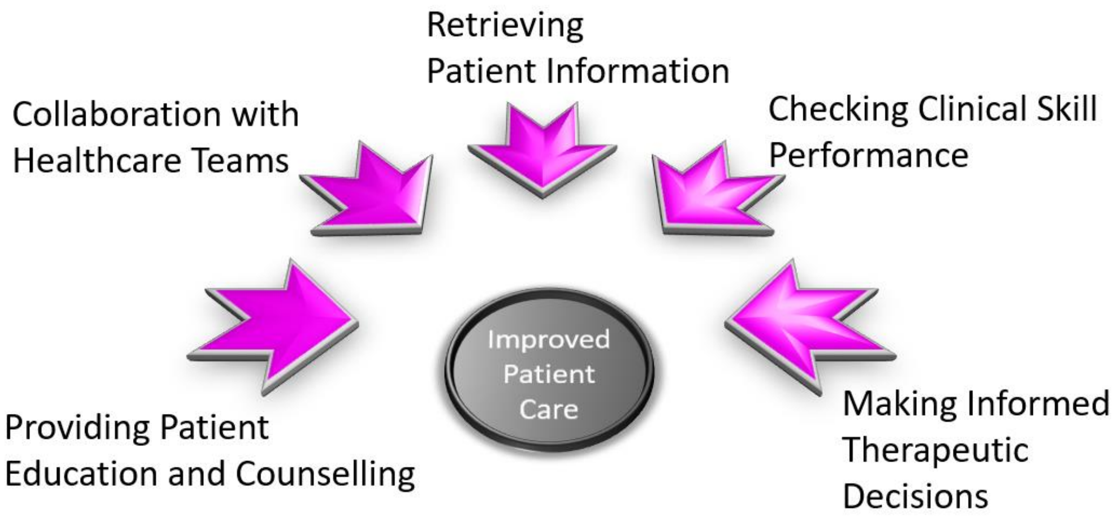

Figure 4.17 Mobile-enabled Improved Patient Care

4.4.9.2.1 Retrieving Patient Information

The findings from eight studies collectively highlighted how mobile devices facilitated the retrieval of patient information in the process of clinical decision-making. One channel for obtaining patient data was through EHR, which students used to access real-time information about patients. One student highlighted the benefits of using an iPad for this purpose: *"When we're doing rounds, to have access to the medical record if there's a lab value or something that I forgot to check or needed to pull up ... I can use the iPad ... I've used it a lot for accessing the medical records"* (Nuss et al., 2014).

Similarly, another student emphasised the advantages of the EHR system: "… *They just have your information on their data system. So, when you come, all what the doctor has to do is to key in your name and then some other things. Then your information comes; so, he reads the previous history and then the diagnosis and everything"* (Sulley, 2018).

Notably, students accessed EHR data not only in hospital settings but also remotely, enabling them to prepare for patient care even when away from the clinic (Alegría et al., 2014).

In addition to accessing patient information, students used their devices to document medical histories and present their findings to educators during bedside teaching. One student described this practice, stating: *"I'm taking patient histories on the iPad and I'm presenting the patient histories off of the iPad to the preceptor…"* (Nuss et al., 2014).

Following the section on students' use of mobile technology for obtaining patients' data, the next section explores how mobile technology supports medical students in conducting and refining their clinical examination skills, contributing to patient care.

4.4.9.2.2 Checking Clinical Skills Performance

The findings from Rashid-Doubell et al. (2016) showed that students utilised mobile devices for self-assessment of clinical skills. They used these devices to reference correct methods for patient examination and compare them with their own performance. However, the study also revealed that while mobile devices were valuable for acquiring knowledge, clinical skills could only be developed through observation and hands-on practice.

Two students highlighted this concept. One student explained: *"This is the clinical knowledge where we use our phone but on the clinical skills, you have to watch because nobody is going to teach you that unless you use it."*

Following the section on the role of mobile devices in supporting clinical skills assessment, the next section explores how mobile devices facilitate informed therapeutic choices, ensuring patient-centred care.

4.4.9.2.3 Making Informed Therapeutic Decisions

The findings from five studies collectively highlighted the critical role of mobile-enabled drug applications, clinical guidelines, and reference information in enhancing patient care. Students consistently cited mobile medical apps as invaluable tools for clinical decision-making. Commonly used apps included Medscape, Epocrates, VisualDx, Micromedex, Ucentral, Skyscape, Prognosis: Your Diagnosis, OnExamination, and OSCE Trainer. These apps served distinct purposes: Micromedex was used to check drug side effects, VisualDx was used to view images of disease conditions, and Epocrates was used to find recommended treatments (Nuss et al., 2014; Witt et al., 2016). Another example of the effective use of mobile apps was Microguide, which offered antibiotic guidelines tailored to specific National Health Service (NHS) trusts. As reported by Shenouda et al. (2018), students appreciated this app for its trust-specific content, user-friendly design, organised layout, convenience, intermittent Internet dependency, and overall efficiency. Additionally, context-specific apps, such as Botswana Guidelines, were particularly valued for providing treatment recommendations tailored to specific patient populations, such as paediatric patients (Witt et al., 2016).

Beyond these specific apps, students frequently used evidence-based tools such as DynaMed and UpToDate to facilitate informed clinical decisions. Johnson and Howard (2019) documented in students' reflective journals how these resources provided quick access to clinical information and supported patient care. Similarly, most students regarded their devices as indispensable reference tools to access patient-related information during clinical placements. One student in Harrison et al. (2019) shared, *"I would not get so much out of my time on the wards if I did not have a mobile device to look information up."*

In addition to apps, mobile devices facilitated access to broader reference information to support patient care. For instance, students used tablets at the point of care to review anatomy before procedures. One participant in Alegría et al. (2014) noted: "… *If I go to the operating room, we can go over the anatomy of where we're going today."*

Concluding this perspective, a student in Fan et al. (2016) succinctly captured the critical role of mobile technology in staying updated with constantly evolving medical knowledge: *"It is impossible to stay updated with all the changes in medical recommendations (e.g., first-line treatments seem to change year-by-year). Apps such as the therapeutic guidelines can be put on mobile phones and iPads, etc."*

Following the section on the role of mobile devices in clinical decision-making and patient management, the next section explores how medical students use these tools to enhance patient education, facilitate effective communication, and provide counselling.

4.4.9.2.4 Providing Patient Education and Counselling

The findings from six studies collectively highlighted how students utilised their devices for counselling and health education with patients. A number of students in a study by Alegría et al. (2014) expressed their intention to use the tablet for patient counselling. However, they also acknowledged that student-driven patient education in clinical settings might not always be feasible. One student commented: *“At this level we don’t do that or even explicitly are requested not to because if we get it wrong our preceptor has to backtrack.”*

Mobile devices have also proved useful for educating patients about their conditions and procedures. One student described how mobile apps were used to explain certain operating procedures to patients: *“...after the procedure was done, the surgeon then used the application and the diagrams of the (iPad) app to explain which muscles exactly he was cutting and which ligaments he was tightening, which approach he took, etcetera. So it was actually very useful”* (Clarke et al., 2019).

Furthermore, mobile devices enhanced students’ ability to provide accurate information to patients. For instance, a group of senior medical students highlighted its benefits during patient consultations (Joynes & Fuller, 2016). One student shared: “*In some situations, it’s really useful because especially oncology or something like knowing different types of cancer drugs and cancers, when you speak to a patient, it’s nice if they think that you know a bit about the medication ... I can remember this really rare cancer, and no one really knew about it on the ward ... but because you’ve got the phone, you can just search it yourself so before you go and speak to them.”*

In addition to supporting patient education and counselling, mobile devices are also used to facilitate collaboration with the healthcare team, helping to align care plans across disciplines. This usage is discussed in the following section.

4.4.9.2.5 Collaborating with Healthcare Teams

Mobile devices also facilitated collaboration with senior doctors and healthcare teams. This collaborative effort enabled more informed decision-making and improved patient care (Ellaway et al., 2014; Harrison et al., 2019; Witt et al., 2016). One student described their experience: *"During ward rounds, they ask us to check on our tablets to look up information to make sure what they are doing is right, so it helps them as well in managing patients"* (Witt et al., 2016).

Following the section on how students use mobile devices to facilitate patient education, communication, and counselling, the next section explores how these tools contribute to the development of soft skills, including organisational skills, time management, interpersonal communication, and academic writing, among medical students.

4.4.9.3 Development of Soft Skills

This sub-theme was identified through the synthesis of findings from five studies. There were three sub-sub-themes under this sub-theme, each examining the role of mobile technology in developing four soft skills: organisational skills, time management, interpersonal skills, and academic writing skills (Figure 4.18). Appendix Z presents the studies underpinning these sub-sub-themes, which are elaborated on in the following sections, enriched with verbatim quotes.

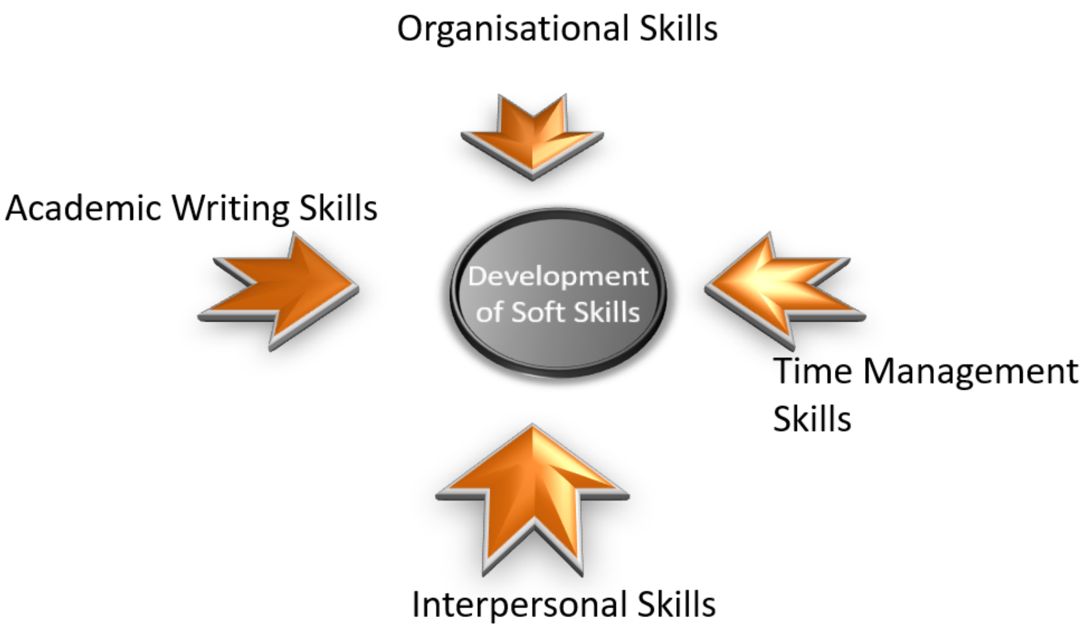

Figure 4.18 Development of Mobile-enabled Soft Skills

4.4.9.3.1 Organisational and Time Management Skills

The findings from four studies collectively highlighted how mobile devices helped students organise and manage time efficiently. As one student explained: "*I'm very dependent on my iPad. It helps me organise pretty much everything"* (Clarke et al., 2019). Students also highlighted their ability to manage their time, particularly during clinical attachments, by accessing timetables through their devices. One student noted: *"There's a timetable attached to email on your iPhone and a map via Google. You can be more organised and you don't get caught out going to strange places"* (Green et al., 2015).

The time-saving advantage of mobile technology was also highlighted, particularly in accomplishing tasks more efficiently. One student highlighted this benefit, sharing their experience of submitting feedback through a device instead of using paper: "*You could do that [feedback] in a few minutes on your phone, rather than doing it or on a piece of paper…"* (Green et al., 2015).

Following the section on the role of mobile devices in enhancing organisational skills and time management, the next section examines how these tools contribute to the development of interpersonal skills among medical students.

4.4.9.3.2 Development of Interpersonal Skills

The findings from a study by Oo et al. (2022) highlighted how mobile technology contributed to the development of interpersonal skills, such as communication, intellectual, and or organisational skills.

One student emphasised this benefit, stating: *"This learning platform helps me to improve my communication skills with health-care professionals, educators, colleagues, and peer groups"* (Oo et al., 2022).

Following the section on how students use mobile devices to develop interpersonal skills, the next section explores how mobile technology supports the enhancement of academic writing skills among medical students.

4.4.9.3.3 Development of Academic Writing Skills

The findings from a study by Oo et al. (2022) also highlighted the role of mobile technology in enhancing students' writing skills. One student emphasised this benefit, stating: *"One of the skills that I have developed is when we answer the question online, we have to type it out, so it trained us to write it appropriately and to practise for essay-writing skill"* (Oo et al., 2022).

Mobile devices play a multifaceted role in medical education by enhancing learning, improving patient care, and fostering the development of soft skills. These benefits underscore their integral role in supporting the development of competent future medical doctors.

4.4.10 Analytical Theme 2: Harnessing Mobile Device Usability to Enhance Learning and Patient Care

The usability of mobile devices (Descriptive Theme 3) – connectivity, portability, and multifunctionality – directly impacts on the identified benefits (Descriptive Theme 4): enhanced learning, improved patient care, and the development of soft skills. These relationships, illustrated in Table 4.3, are presented as Analytical Theme 2, demonstrating how the functionalities of mobile devices foster practical outcomes for students.

The following sections explain these relationships in detail by focusing on the individual columns of Table 4.3. As in Analytical Theme 1, detailed quotes are excluded in this section to avoid repetition. However, the reader can refer to relevant verbatim quotes in descriptive themes 3 and 4, where they are presented in context.

4.4.10.1 Just-in-time Learning and Usability Features of Mobile Devices

Just-in-time learning is characterised by instant access to information at the point of need, and the integration of the usability features of mobile devices, such as connectivity, portability, and multifunctionality, facilitates it. These features enable students to access, retrieve, and apply information instantly across diverse settings, ensuring their preparedness for clinical and educational activities.

Connectivity underpins just-in-time learning by allowing students to access information instantly during critical moments, such as ward rounds or patient interactions. This access ensures that students can immediately search for and integrate new knowledge into their clinical practice. For instance, one student remarked that having a connected device during ward rounds enabled them to quickly find relevant information, which supported their understanding of the topic and participation in discussions (Sulley, 2018). Similarly, when faced with unfamiliar medical terms, students used connectivity to bridge knowledge gaps in real time, transforming challenges into learning opportunities (Pimmer et al., 2013). Connectivity ensures that every interaction – whether in classrooms, wards, or operating theatres – becomes an opportunity to acquire and apply knowledge effectively.

Table 4.3 Mapping Usability Features of Mobile Devices to Pedagogical and Clinical Benefits

Usability Features of Mobile Devices	Benefits of Mobile Technology in Undergraduate Medical Education					
	Just-in-Time Learning	Self-Regulated Learning	Collaborative Learning	Informal Learning	Patient Care	Soft Skills Development
Connectivity	Provides instant access to real-time information during clinical and classroom settings.	Supports monitoring progress through practice tests and real-time feedback.	Enables real-time group discussions via messaging apps like WhatsApp.	Provides access to informal learning platforms like Facebook groups.	Offers access to clinical guidelines, drug references, and clinical decision support apps.	Improves communication through collaborative tools.
Portability	Allows access to resources anytime and anywhere during clinical rotations.	Facilitates learning in various settings like hospitals or while commuting.	Allows collaboration synchronously or asynchronously	Enables study during downtime in clinics or during travel.	Allows quick retrieval of patient information via portable devices.	Supports time management by enabling on-the-go organisation.
Multifunctionality	Enables viewing resources for immediate learning tasks.	Offers apps for self-assessment quizzes and adaptive learning.	Supports video conferencing and co-creation of resources.	Facilitates engagement with multimedia tools for informal learning.	Provides tools for visualising anatomical structures to educate patients.	Enhances note-taking and organisational skills with apps.

Portability ensures that students can bring their devices to any setting, enabling fast access to information across various learning environments. Devices like tablets and iPad mini that fit into white coat pockets or surgical scrub pants allow students to consult resources during ward rounds or surgeries (Twiss-Brooks et al., 2017; Witt et al., 2016). As one student noted, having their tablet in their white coat ensured they were always prepared to look up relevant clinical information without carrying cumbersome textbooks (Alegría et al., 2014). This portability transforms devices into learning tools for dynamic clinical learning environments.

Multifunctionality enhances just-in-time learning by providing diverse tools, such as video tutorials, that support real-time knowledge acquisition. For instance, a student described using video demonstrations on their device to prepare for surgeries, which helped them feel more confident and prepared (Green et al., 2015). The ability to access multimedia content tailored to specific clinical scenarios ensures that students can adapt their learning to immediate needs.

4.4.10.2 Self-regulated Learning and Usability Features of Mobile Devices

Self-regulated learning empowers students to independently plan, monitor, and evaluate their learning progress. This process is greatly supported by the usability features of mobile devices – connectivity, portability, and multifunctionality. These features collectively provide students with the tools to personalise their learning experiences, enabling them to identify their learning needs, set goals, and adapt strategies to enhance their academic performance.

Connectivity empowers self-regulated learning by giving students access to online resources like question banks and providing students with instant feedback on their progress. Mobile apps with built-in practice tests provide immediate feedback, allowing students to self-assess their understanding. As one student shared, using connected tools like question banks on an iPad helped them consistently test their knowledge and identify weak areas (Nuss et al., 2014).

The portable nature of mobile devices allows students to engage in self-regulated learning regardless of their location. Whether on hospital rotations or during breaks, students can access learning materials to track their progress and address gaps in their understanding. One student shared that having a portable device readily available allowed them to make productive use of unscheduled time, such as waiting for clinical activities to begin (Alegría et al., 2014). This flexibility ensures that students can seamlessly integrate learning into their daily routines.

Multifunctionality supports self-regulated learning by offering features like quizzes and annotation tools. These tools enable students to evaluate their understanding, identify weaknesses, and focus on areas needing improvement. One student highlighted the role of quizzes in enhancing their academic performance, stating that these features helped them tailor their study efforts effectively (Küçük et al., 2016). The availability of specialised apps for note-taking or annotation further enhances the learning experience by promoting a structured and efficient approach to managing educational content (Alegría et al., 2014; George et al., 2013).

4.4.10.3 Collaborative Learning and Usability Features of Mobile Devices

Collaborative learning is grounded in the active exchange of ideas and collective problem-solving among peers. The usability features of mobile devices – connectivity, portability, and multifunctionality – play a pivotal role in facilitating this interactive approach. By leveraging these features, students can engage in real-time communication, share resources, and co-create knowledge, fostering a dynamic and inclusive learning environment.

Real-time collaboration among students is facilitated through platforms like WhatsApp and Skype. These tools enable instant messaging, live discussions, and resource sharing, which are vital for group-based learning activities such as PBL and CBL. One student explained that WhatsApp allowed their group to discuss learning objectives seamlessly and provided a platform to give and receive peer feedback (Raiman et al., 2017). In cross-cultural learning contexts, Skype further extended this connectivity, enabling students to build rapport, exchange ideas, and collaboratively refine clinical skills through live interactions (O’Donovan & Maruthappu, 2015).

Portability enhances collaborative learning by enabling students to bring their devices to group meetings or clinical discussions. During CBL sessions, students use mobile devices to share insights, discuss case scenarios, and refine their understanding collectively. One participant described how WhatsApp allowed their group to collaborate effectively by sharing views and resolving complex medical cases (Grover et al., 2017). This portability ensures that students can actively participate in collaborative activities, regardless of the setting.

Multifunctionality facilitates collaborative learning by enabling the co-creation of content and efficient resource sharing. Platforms like Google Docs allow students to collaboratively create and refine shared notes during PBL sessions. As one student explained, this feature fostered a collective learning environment where all group members could contribute ideas and insights (Doherty et al., 2015). Similarly, video conferencing tools like Skype support synchronous interactions and rapport building, especially in cross-cultural learning contexts (O’donovan & Maruthappu, 2015).

4.4.10.4 Informal Learning and Usability Features of Mobile Devices

Informal learning takes place beyond structured educational settings, often during students’ downtime or daily activities. The usability features of mobile devices – connectivity, portability, and multifunctionality –serve as essential enablers of this flexible learning process. By utilising these features, students can explore topics of interest, reinforce their knowledge, and make efficient use of otherwise idle moments.

Connectivity plays a significant role in informal learning by providing access to online communities and social media platforms focused on medical education. Facebook groups, for instance, allow students to discuss clinical cases, share resources, and answer each other’s queries. One student highlighted the utility of these groups, stating that answering questions and receiving immediate feedback helped reinforce their knowledge (Pimmer et al., 2013).

The portable nature of mobile devices makes them ideal for informal learning during commutes or downtime. Students can access educational content, such as question banks or video lectures, while travelling or waiting between clinical activities. One student highlighted how they used their devices to engage in self-assessment activities during hospital waiting time, emphasising their efficiency in transforming idle moments into learning opportunities (Harrison et al., 2019).

Multifunctionality enriches informal learning by enabling students to engage with a variety of educational content, such as videos and interactive apps, during downtime. One participant described how they used YouTube videos to reinforce their understanding while taking a bath (Twiss-Brooks et al., 2017). This versatility ensures that students can customise their informal learning experiences according to their preferences.

4.4.10.5 Improved Patient Care and Usability Features of Mobile Devices

Patient care is enhanced by the ability to access evidence-based resources and make informed decisions in real-time clinical contexts. The usability features of mobile devices – connectivity, portability, and multifunctionality – support this critical process by providing students with reliable tools to retrieve patient data, review guidelines, and communicate with healthcare teams effectively. Together, these features contribute to delivering accurate and timely patient care.

In clinical settings, the connectivity of mobile devices directly facilitates improved patient care by enabling real-time access to patient data. Students emphasised that seamless connectivity allowed them to retrieve patient information swiftly, thereby enhancing their clinical decision-making (Nuss et al., 2014; Sulley, 2018).

Connectivity also enhances patient care by ensuring students can access clinical guidelines, drug references, and evidence-based tools in real time. Mobile apps like Epocrates and Micromedex enable informed therapeutic decisions by providing accurate information on drug interactions, side effects, and recommended treatments (Nuss et al., 2014; Witt et al., 2016).

Portability allows students to carry their devices during ward rounds, bedside teaching, and patient consultations, ensuring they have essential resources at their fingertips. For example, one student explained how having an iPad readily available during ward rounds enabled them to quickly look up patient records or medical guidelines, facilitating better patient care (Nuss et al., 2014). This ease of access ensures that students can respond promptly to clinical challenges, enhancing their ability to manage patients effectively.

Multifunctionality enhances patient care by enabling students to use visual aids and interactive apps to explain medical procedures or conditions to patients. One student described how the device's diagrammatic features were used to clarify surgical techniques, improving patient understanding and satisfaction (Clarke et al., 2019). Multifunctionality also enhances patient care through apps tailored to specific clinical needs. For example, Microguide provided trust-specific antibiotic guidelines, enabling students to deliver accurate treatments (Shenouda et al., 2018).

4.4.10.6 Development of Soft Skills and Usability Features of Mobile Devices

The development of soft skills, such as communication, time management, and organisational abilities, is essential for medical students. The usability features of mobile devices – connectivity, portability, and multifunctionality – facilitate the growth of these competencies. Through their integration into daily academic and clinical routines, these features help students refine their professional skills, ensuring they are well-prepared for future challenges.

Connectivity supports the development of communication and teamwork skills by enabling students to interact with peers, educators, and healthcare professionals through messaging and video-conferencing platforms. As one participant explained, using platforms like WhatsApp helped them improve their ability to communicate effectively in professional contexts, thereby enhancing their interpersonal skills (Oo et al., 2022). These tools also encourage collaborative problem-solving, fostering a team-oriented approach in clinical and academic settings.

Portability contributes to the development of organisational and time management skills by providing tools that help students structure their schedules and manage tasks efficiently. Devices with integrated calendars, timetables, and note-taking apps enable students to stay organised during clinical attachments. One student noted that accessing timetables and maps through their mobile device helped them navigate unfamiliar hospital settings and maintain punctuality (Green et al., 2015).

Multifunctionality supports the development of academic writing and organisational skills through apps that facilitate note-taking, essay-writing, and task management. One student shared how answering questions online helped them practise and refine their writing skills, preparing them for academic and professional demands (Oo et al., 2022). These features enable students to cultivate essential soft skills.

Although mobile technology has brought significant pedagogical benefits to students, its usage is not without challenges. The next section examines Descriptive Theme 5 of “Challenges in the Usage of Mobile Devices in Undergraduate Medical Education”, focusing on the difficulties students encounter using mobile devices on their learning journeys.

4.4.11 Descriptive Theme 5: Challenges Encountered in Using Mobile Devices

This descriptive theme emerged through inductive analysis of findings from 12 studies (Appendix Y). It comprised three sub-themes of challenges students face when integrating mobile technology into their learning. These are disruption to learning, impacts on professionalism, and limitations of devices, illustrated in Figure 4.19. The number of studies contributed for each sub-theme is summarised in Appendix Z, with detailed explanations and illustrative quotes in the following sections.

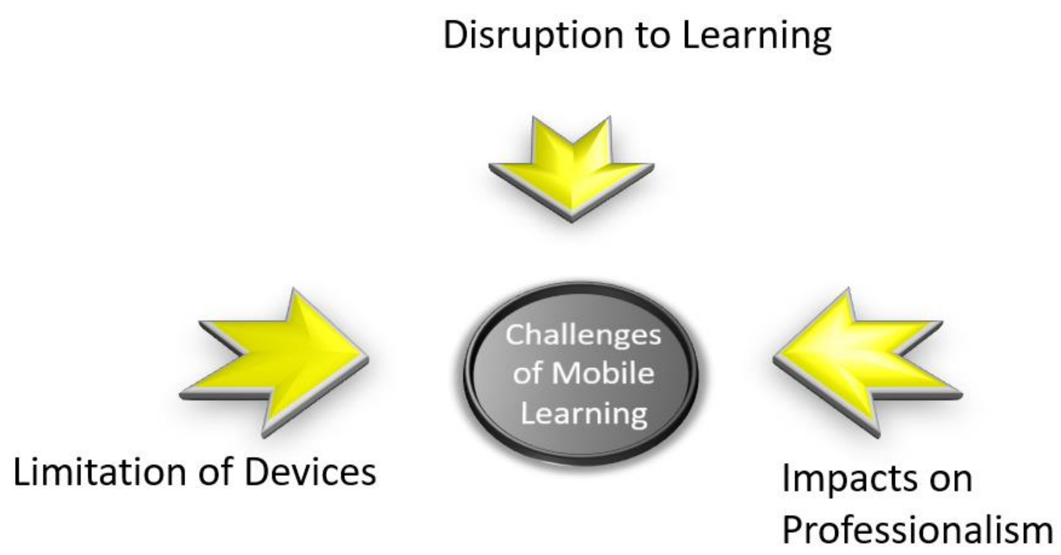

Figure 4.19 Challenges Students Encounter in Using Mobile Devices

4.4.11.1 Disruption to Learning

This sub-theme emerged from the analysis of 12 studies, which collectively examined how mobile devices negatively affected students' learning across various settings.

This sub-theme was structured around three sub-sub-themes, with each focusing on a specific aspect of learning disruption due to mobile technology: information overload and superficial learning, missing learning opportunities, and distractions (Figure 4.20). Appendix Z shows the studies informing each sub-sub-theme, which are explored in the following sections with supporting verbatim evidence.

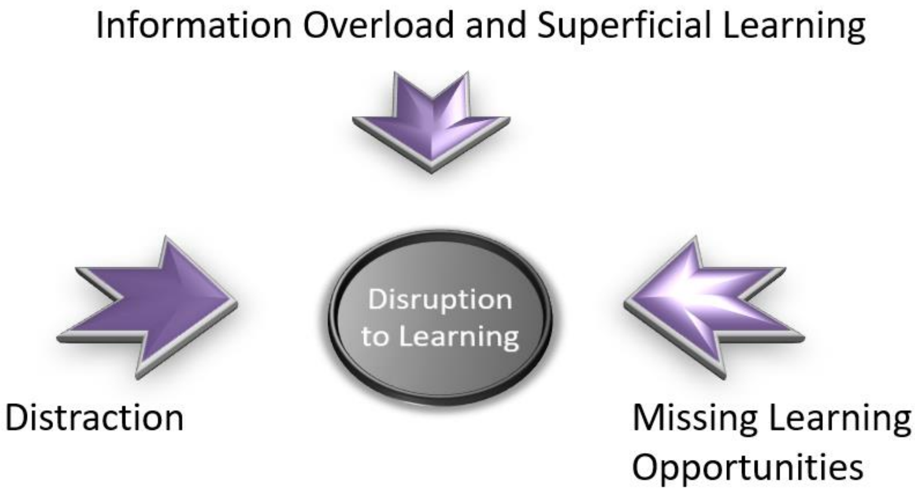

Figure 4.20 Sub-themes of Disruption to Learning

4.4.11.1.1 Information Overload and Superficial Learning

Based on the findings from six studies, this sub-sub-theme examined how instant access to information via mobile devices overwhelmed students and contributed to superficial learning.

This phenomenon of information overload arose from the vast amount of information accessible via mobile devices, making it difficult for students to process and digest information (Fan et al., 2016). One student expressed this concern, stating, *"Information overload is one of the main issues in mobile learning platforms*" (Oo et al., 2022).

The findings of the studies revealed that the cognitive burden was closely linked to "superficial learning", a phenomenon where students relied on immediate access to information and prevented them from brainstorming ideas and using their prior knowledge and critical reasoning. One student highlighted this challenge*: "You can end up relying on it … rather than memorising all the terms and having a good differential, you can always just pull up a list."* (Wallace et al., 2012).

A similar concern was raised by students in a study by Sulley (2018), who noted that the ease of access to information, with everything just a few clicks away, reduced their effort and contributed to a sense of laziness. Furthermore, the setting in which information was accessed plays a role. For instance, Scott et al. (2015) found that students accessing information while on the move rather than during dedicated study time were more prone to superficial learning.

This lack of deep engagement extended to the sharing of information among peers. As one student explained, *"Sometimes students share online information to the group without deep understanding … they do not digest what they have found before sharing."* Another student echoed this sentiment, saying, "*It's like when you can find something from the Web immediately… so amazing … but you are just stating the facts without deep understanding …"* (Doherty et al., 2015).

Moreover, the time-consuming nature of critically assessing and selecting relevant information added to the cognitive burden. One student elaborated: *"It took a lot of time and effort ... to critically assess the information generated from online searches"* (Doherty et al., 2015).

At the other end of the spectrum of learning disruptions was the issue of missed learning opportunities caused by mobile device usage. The next section examines these challenges in detail.

4.4.11.1.2 Missing Learning Opportunities

This sub-sub-theme was drawn from evidence provided by two studies, which collectively shed light on how the use of mobile devices in clinical settings interrupts students' learning opportunities.

Some students expressed concerns about missing learning opportunities due to frequent use of mobile devices during clinical placements. One student in a study by Harrison et al. (2019) explained this perspective: *"… There's a risk that in the end, you can follow them around all day, fumbling with your phone and not have seen things you would have otherwise seen."*

Another way mobile devices contributed to missed learning opportunities was through delays in feedback. Many students in Robertson and Fowler's (2017) study highlighted that mobile communication methods, such as emails, did not always ensure timely feedback. Delays occurred because educators often failed to check emails promptly or struggled to recall specific students when responding, leading to less effective feedback. Students shared their frustrations: *"Feedback will not be timely if they [supervising physicians] don't check their email,"* and *"They may not remember me by the time they check their email."*

Following the section on students' experience of missing learning opportunities due to device usage, the next section explores how mobile devices contribute to distractions in both classroom and clinical settings, disrupting students' focus and engagement during learning and practical activities.

4.4.11.1.3 Distraction in Educational and Clinical Settings

Findings from nine studies informed this sub-sub-theme. The studies provided a nuanced understanding of how distraction from the use of mobile devices compromised students' ability to engage with learning materials.

One significant source of distraction arose from social media and messaging notifications. Students often noted that these distractions hindered their ability to focus. For example, one student explained, *"You have an exam, and then you just open Opera Mini, and then there's a pop-up. A friend just says hi, and then you go, and then you spend time"* (Sulley, 2018).

Another student echoed the same sentiment: *"If you're using the phone, you might be looking something up, but then you get distracted to go into Facebook or something else … so it's distracting"* (Rashid-Doubell et al., 2016).

Distractions were prevalent not only during individual studies but also in classroom and clinical settings. One student shared the experience: *"It's very distractive ... you'll end up all the time Facebooking and Whatsapping, and you can't really study as you're supposed to"* (Sulley, 2018).

Distraction usually occurs during lectures, and students cited social media and online browsing as major sources of distraction (George et al., 2013). One student supported this, saying, *"The use within the classroom really can be a bit distracting because it's too easy to flip onto Facebook"* (Wallace et al., 2012).

Similarly, in clinical settings, mobile devices affected patient observations and disrupted focus in real-time clinical interactions. One student stated: "*You're not really paying as close attention as you could be if you're always looking stuff … like we were on rounds this morning … and I was too busy looking up how to spell. Downloaded from one of the drugs and what it did … I just managed to jot down but didn't get to hear anything else about it* (Wallace et al., 2012).

Another student echoed a similar sentiment: *"A patient is much more than just listening to them; it's the whole patient experience and screens are potentially much more distracting than anything else"* (Harrison et al., 2019).

Similarly, participants in a study by Rashid-Doubell et al. (2016) extensively discussed the distractive nature of mobile technology during bedside learning, particularly how it can interfere with building a strong learning relationship with their clinical teachers. Some students highlighted that using devices at the bedside could detract from focusing on the clinical teacher, whom they view as their most essential learning resource.

While using WhatsApp instant messaging for group discussions, some students felt distracted when too many people discussed simultaneously (Grover et al., 2020). One student shared: *"I definitely find myself in a dilemma, as it is very annoying; and it disturbs our concentration on study, because of constantly messaging in WhatsApp group discussions"* (Oo et al., 2022). Students also described getting distracted by pictures and messages from other friends who were online at the same time, with one noting that this distraction led to significant time wastage (Sulley, 2018).

As a result of various distractions induced by mobile devices, students may face challenges in their professional practice when interacting with patients, educators, and peers. This challenge is discussed in the next sections.

4.4.11.2 Impacts on Professionalism

This sub-theme was informed by the findings from three studies. These studies collectively highlighted ethical dilemmas students face when using devices in clinical settings.

For example, in one case, students were asked to take pictures and record a surgical procedure using the surgeon's phone (Harrison et al., 2019). They were uncertain whether patient consent had been obtained or whether this practice complied with the university's guidelines.

A significant challenge students identified when using mobile devices was maintaining patient privacy and confidentiality (Shenouda et al., 2018; Wallace et al., 2012). One student emphasised this concern, cautioning against sharing sensitive information via instant messaging services: *"This patient needs seeing, they're here and their name's this," because that's obviously is a bit … and obviously keeping it confidential." (Shenouda et al., 2018).* Another student highlighted the additional concern of managing both personal and professional use on the same device (Wallace et al., 2012). One student explained: *"I think there's problems having personal stuff and professional stuff on the same device."*

Taking pictures of patients using mobile devices emerged as another ethical concern. Most participants in a study by Shenouda et al. (2018) confirmed that they would never take patients' pictures, emphasising adherence to a professional code of conduct. Their responses included statements such as *"I would never", "I don't think it's professional", "no, absolutely not", "I would not take a picture, not take a picture of a patient",* and *"you're not supposed to".*

Following the theme of impacts on professionalism, the next theme explores the limitations of devices. This theme discusses factors related to devices that hinder their effective use in medical education.

4.4.11.3 Limitations of Devices

This sub-theme emerged from the synthesis of findings from 11 studies. These studies collectively highlighted how the limitations of device usage negatively impacted on students' professional practice.

This sub-theme included four sub-sub-themes, each of which addresses the limitations of mobile devices, including barriers related to physical features of mobile devices, overdependence on mobile devices, security concerns, and technical and connectivity barriers (Figure 4.21). Each of these sub-sub-themes is detailed in the following sections, along with illustrative verbatim quotes, and is supported by a number of studies, as shown in Appendix Z.

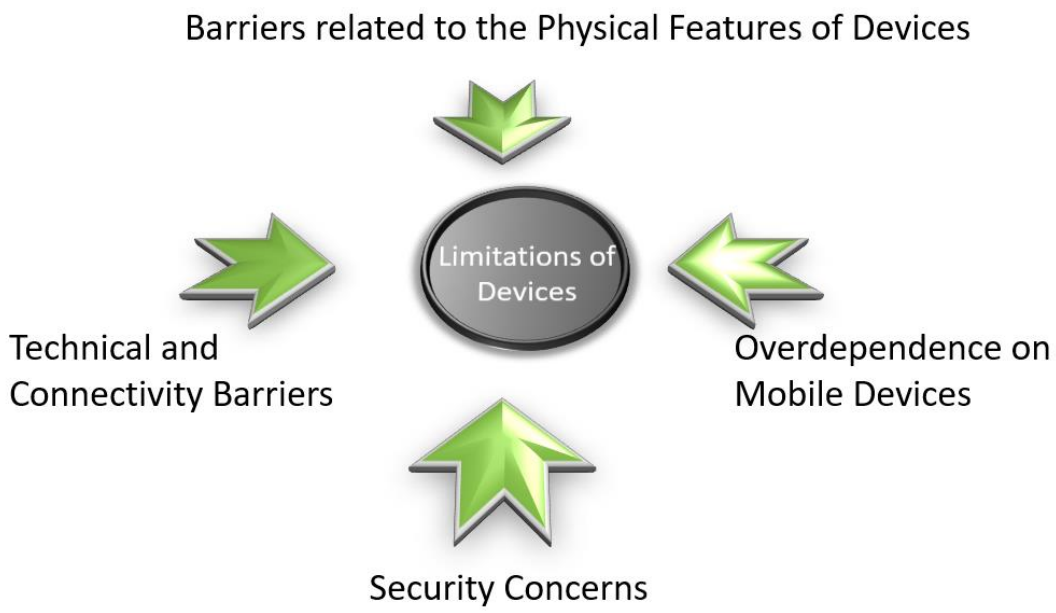

Figure 4.21 Sub-themes of Limitation of Devices

4.4.11.3.1 Barriers Related to Physical Features of Mobile Devices

This sub-sub-theme was informed by the findings from seven studies. These studies highlighted how the physical features and cost of mobile devices, as well as additional barriers such as power outages leading to limited Internet access, hindered students' use of devices and impacted on their learning experiences.

The physical limitations of mobile devices, such as small screens, resolution issues, and keyboard functionality, reduced usability, especially for tasks requiring sustained engagement (Alegría et al., 2014; O'donovan & Maruthappu, 2015). One student remarked, *"It is too small to read for a long time. I'm alright with one page; two pages that's fine. But if you want me to look at a 45-page study guide – that's just too much*." (Green et al., 2015). Similarly, some students noted that the small screens of devices hindered their ability to search medical databases (Harrison et al., 2019).

Additionally, “restricted portability” in certain clinical environments, such as labour and delivery rooms, limited device use. Students often avoided bringing their devices into such settings due to practical concerns, as one student explained: *“Devices are often left outside just because it can get messy in there”* (Twiss-Brooks et al., 2017).

Beyond physical limitations, “cost” was another significant challenge identified by students, encompassing the high cost of quality devices and recurring costs of applications and Internet services. One student described the financial burden: “*I think that one of the challenges is the cost. At times the cost; especially the very good ones. Not everybody is able to afford those ...”* (Sulley, 2018).

Similarly, another student echoed this concern, stating: *“It’s a pretty expensive cost for students ... especially because most of our money is in loans”* (Alegría et al., 2014).

In addition to hardware costs, students identified high-quality apps as another significant expense. Some apps that were deemed essential for students were expensive, prohibiting their use. One student shared: *“There was this one app that I saw was really interesting, and I thought it would really benefit me if I would get it, but then I had to pay for it, and it was really expensive”* (Sulley, 2018).

The cost of accessing the Internet also emerged as a barrier. Students explained that mobile devices were often ineffective without affordable Internet access. As one student noted: “*The device in this rotation [Public Health] has not been academically helpful. Looking at the fact that we don’t have access to the Internet, which means there is no way we can access unless or otherwise you have extra cash to be able to subscribe to the Internet”* (Witt et al., 2016).

Some students mentioned that while subscriber identity module (SIM) cards could provide an alternative source of Internet access, this option was too costly for students to use. When asked about purchasing airtime, one student explained: *“It would depend on how much I have to pay. If it’s affordable for a student, then I’ll be willing to pay”* (Witt et al., 2016).

In addition to physical limitations and cost, students also highlighted challenges related to power outages and Internet access. The reliance on electricity for powering devices was identified as another challenge, particularly in regions with frequent power outrages. One student highlighted the impact of a prolonged power outage: *“A couple of weeks back there was a substation that was burnt down. And then for days there wasn’t electricity. So, the cost of trying to get alternative source of power to be able to sustain these mobile technology devices is also a challenge”* (Sulley, 2018).

Finally, the functionality of software and hardware was considered as a potential barrier to the usage of devices. Students reported that issues with app reliability and hardware performance sometimes limited their ability to use devices for academic purposes (Green et al., 2015; Witt et al., 2016).

Following the section on barriers related to physical features, the next section examines overdependence on mobile devices. It explores how reliance on these devices impacts on students’ learning, critical thinking, and overall academic experience.

4.4.11.3.2 Overdependence on Mobile Devices

Drawing from three studies, this sub-sub-theme highlighted the negative impact of students being overdependent on mobile devices.

The convenience of mobile devices often led to overreliance on technology for information retrieval, which negatively affected students’ retention of knowledge and critical thinking skills. One student described how this reliance impacted on their exam performance, saying, *“I find I am having more and more problems with exams because I cannot look up easily what I normally look up ... everyday on my iPhone”* (Ellaway et al., 2014).

Similarly, another student reflected on the long-term challenges of device dependency, saying, “*If you can’t function without having something in your hand like a phone then that’s not really going to be sustainable long-term”* (Thomas, 2021*)*.

In addition to affecting learning habits, this reliance on mobile devices contributed to **“**work-life balance disturbance”, as connectivity extends academic demands beyond study hours. One participant expressed frustration with this intrusion, noting that “*Another bad thing is that if you do go home and you’ve still got your phone, […] you can leave [your bleep] with the next*

FY1[foundation year 1 trainee], but your phone you have to take home with you and [...] that's not a very good work/life balance" (Shenouda et al., 2018).

Following the section on overdependence, the next section addresses security concerns. It explores issues such as theft, damage, and malware and their impact on students' ability to utilise mobile devices in educational and clinical settings effectively.

4.4.11.3.3 Security Concerns with Mobile Devices

This sub-sub-theme was drawn from evidence provided by four studies, which highlighted how security concerns, such as theft, damage or malware, threatened students' use of mobile devices and impacted their learning experiences.

A prominent security concern identified in the studies was the fear of theft or damage to devices. Many students, according to a study by Witt et al. (2016), chose not to bring devices to certain places, such as malls or public transport, due to these risks. As one student explained: *"I feel uncomfortable using [the device] outside...because it could attract thieves"* (Witt et al., 2016).

Similarly, the risk of theft discouraged some students from using school-provided devices. One student noted: *"One of the big limitations of the [tablets] ... is that they get stolen"* (Alegría et al., 2014).

Concerns about accidental damage also affected students' use of devices. Several students reported deliberately leaving their school-provided iPhones at home for fear of breaking or losing them (Green et al., 2015).

In addition to theft and damage, malware risks further deterred students from downloading certain resources, as one student shared an incident where a download led to malware, causing them to "lose everything" on their phones (Sulley, 2018). The student further emphasised the importance of training to mitigate such risks, noting: *"You have to be very careful. You have to be trained to know … ."*

Following the section on security concerns, the next section describes technical and connectivity issues. It highlights challenges such as software malfunctions, poor Internet connectivity, and delays in technical support, which hinder the effective use of mobile devices in educational and clinical settings.

4.4.11.3.4 Technical and Connectivity Barriers

This sub-sub-theme was derived from six studies that collectively explored how technical and connectivity issues impacted on students' use of devices and their learning experiences.

Poor Internet connectivity emerged as a recurring barrier to the effective use of mobile devices in learning environments. Students frequently described disruptions caused by limited or unavailable connectivity, which hindered access to educational resources and tools. For instance, some students reported having to rely on library Wi-Fi due to inadequate connectivity elsewhere: *"...you need to go into the library to access [Wi-Fi]...the major slip back has been...connectivity issues"* (Sulley, 2018).

Connectivity challenges were particularly pronounced in cross-country activities, such as distant peer-tutoring sessions conducted via Skype video calls. Frequent disruptions in audio and video caused delays in communication, negatively affecting the learning experience. One student described their experience: *"The problem was the Internet connection dropping, which was a bit of an inconvenience …''Delays in audio meant that I had to type things when students couldn't hear me speak''* (O'donovan & Maruthappu, 2015).

Limited Internet access also affected students in clinical rotations and public health settings, where real-time access to medical resources was essential. Witt et al. (2016) reported that learners studying outside school campuses during public health training faced significant disruptions due to unreliable connectivity.

Similarly, Green et al. (2015) highlighted that poor Internet connectivity impeded students' ability to upload their assignment papers, further illustrating the negative impact on academic responsibilities. Similar issues were observed in CBL sessions using WhatsApp, where students experienced difficulties downloading and discussing cases due to unreliable Internet connections (Grover et al., 2020).

Moreover, some students did not have Internet access at home and, therefore, could not fully utilise their tablets at home. In both hospital and home settings, inadequate or inconsistent Internet access through Wi-Fi was a common challenge (Witt et al., 2016).

Additionally, "delays in technical support" further compounded these issues (Ellaway et al., 2014; Witt et al., 2016). As one participant explained, "*Once the tablets malfunctioned, participants perceived the technical support turn-around time to be too long and inconvenient"* (Witt et al., 2016).

Technical difficulties were also evident in interactive learning attempts where software malfunctions prevented a smooth experience. For instance, one clinical year student talked about an occasion when a lecturer tried to use a mobile game to teach microbiology. However, it did not go well due to technical issues, and a lot of time was spent (Sulley, 2018).

After examining the challenges associated with mobile device usage, the next theme focuses on the strategies students adopt to overcome these challenges. This theme highlights how students negotiate their interactions with devices, educators, patients, and themselves to optimise their learning experience and professional practice.

4.4.12 Descriptive Theme 6: Strategies to Overcome Challenges

This descriptive theme highlighted the strategies students adopted to negotiate their device usage to mitigate the challenges discussed in Section 4.4.11. It was informed by three sub-themes –negotiation with educators, patients, and themselves – and grounded in the findings from eight studies (Appendix Y) using an inductive analysis approach. These strategies (Figure 4.22) aimed to balance the advantages and challenges of device use in learning and clinical practice.

The following sections explore the studies contributing to these sub-themes, and Appendix Z shows the number of studies contributing to each sub-theme.

Figure 4.22 Strategies to Overcome Challenges

4.4.12.1 Negotiation with Educators for Optimising Educator-student Dynamics in Device Usage

This sub-theme, informed by the findings of four studies, explored the strategies students adopt to navigate educators' perceptions and expectations regarding mobile device usage. Subsequent sections detail these approaches, supported by relevant examples.

Students used various strategies to address potential misunderstandings from educators. For instance, some students adopted discreet strategies to avoid disapproval of using a device in the ward. One student shared: *[the clinical teacher] was busy examining and talking with the patient, so I just went behind the curtain and just Googled it quick"* (Clarke et al., 2019).

While some chose to stop using devices to avoid conflicts, others continued with confidence, justifying their usage as necessary for their learning purposes (Ellaway et al., 2014; Harrison et al., 2019). One student articulated this perspective: *"The only thing I've used it for in the clinical setting was for looking up drugs or looking up a symptom straight away... let people think what they think. If it's going to help me take better care of patients then I'm going to do it regardless"* (Ellaway et al., 2014). Another student echoed a similar stance: "*When I don't understand what they're saying I look it up. I don't care if I'm in the room with a patient. I'm going to use my time usefully. I'm here to learn. I don't like wasting time"* (Harrison et al., 2019).

Additionally, some students took proactive measures to ensure clarity about their intentions by explicitly stating that they were using devices for educational purposes. As one student explained: *"I'm going to write that into my notes, and then I'll pull out my phone to make it really clear that I'm going to do it on my phone"* (Ellaway et al., 2014).

Another strategy involves seeking permission from educators to use devices for specific tasks, such as checking drug dosage or calculating clinical indices. One student shared: *"You know with their permission. When they tell you, look this up, or you know, calculate this index number or ratio"* (Rashid-Doubell et al., 2016).

Following the section on students' adapting device practices to address educator concerns, the next section focuses on negotiation with patients. It highlights how students navigate device usage in clinical interactions to maintain professionalism while optimising their learning experience.

4.4.12.2 Negotiation with Patients for Optimising Device Use Acceptance

This sub-theme synthesised data from four studies and explored the strategies students adopted to negotiate with patients to optimise their learning experiences.

Some medical schools provided university-branded cases to facilitate students' use of devices in clinical settings in order to address the challenge of patient acceptability regarding device use (Green et al., 2015). Many students understood the rules of using phones in clinical settings, and they behaved with professionalism and demonstrated etiquette when interacting with patients (Harrison et al., 2019).

Another strategy was to ask permission from patients before using their devices or letting them know that they were using their mobile devices for learning purposes (Harrison et al., 2019; Rashid-Doubell et al., 2016). One student shared their approach: *"If I'm in an outpatient clinic ... and if for some reason the consultant is tied up with something else, I might say to the patient,* *'Look, I don't know so much on this. I'm just going to look it up'"* (Harrison et al., 2019).

A similar strategy was adopted by another student, who ensured the patient understood that the device was being used to search for medical information: "*I kept telling her 'I'm just looking that up' when I got my phone out, to make sure she knew, because I wouldn't want to [...] look rude"* (Shenouda et al., 2018). This strategy appeared to be effective in certain situations, as one student noted that patients generally accepted their use of devices when provided with an explanation: *"They appreciate it as well. They kind of get to see that, O.K., we don't know everything and need to look it up"* (Witt et al., 2016).

Following the section on strategies for device usage in clinical contexts, the next section explores how students regulate their own device usage to align with institutional guidelines, maintain professionalism, and optimise their learning opportunities.

4.4.12.3 Negotiating Themselves to Optimising Device Use in Clinical Contexts

This sub-theme, derived from four studies, was a detailed exploration of the strategies students adopted to negotiate with themselves to optimise their learning experiences.

The first strategy was to focus on the type of device they use. Many students reported that larger devices, such as tablets or iPads, were more readily perceived as tools for learning compared to smaller devices like mobile phones (Alegría et al., 2014; Harrison et al., 2019; Rashid-Doubell et al., 2016). This strategic selection of devices helps to mitigate concerns from patients and educators about inappropriate usage.

One student highlighted this tactic, noting, *"iPads are acceptable, and phones are not …They [patients or educators] don't like it when you usually use your phones, as opposed to iPads"* (Rashid-Doubell et al., 2016). Another student further explained the rationale behind this preference, emphasising that larger screens allowed both educators and patients to view the content being accessed. This transparency reinforced the impression that the device was being used for educational purposes: *“You hold [the iPad] in such a way that they can see you are actually looking up a reference rather than texting or whatever”* (Harrison et al., 2019).

The second strategy was to restrict the device usage to appropriate times and spaces. Some students limited their usage to break times between consultations. During these intervals, they often stepped into a corridor outside a consultation room to search for relevant information using their devices (Harrison et al., 2019).

A similar strategy was observed in a study by Rashid-Doubell et al. (2016), where students postponed device use until after patient interactions. One student explained: *“I don’t use my phone immediately. I will write down the things we didn’t know, we nod our heads and then when we leave we’ll sit on our tea break and look them up quickly to make sure we understand or we know what we are talking about”.*

Another student adopted a similar approach, choosing not to use a device in the presence of patients or during a ward round. Instead, they opted to use their phone at the desk or alongside a drug chart. The student explained: “*I won’t do it by the patient bedside, and I won’t do it in the middle of a ward round, unless you’re in-between patients. But I will quite comfortably stand at the desk and look up something on my phone, or if I’m filling out a drug chart, I have my phone next to me, and just be checking things about those drugs, while I’m going along”* (Shenouda et al., 2018).

Having an awareness of ethical dilemmas, most students demonstrated awareness of the appropriate use of devices in clinical environments and refrained from taking pictures. As one student stated: *“We do things in hospitals to care for patients. I think broadly the same rules should apply with electronic devices as with anything else…”* (Harrison et al., 2019).

Students adopted strategies to negotiate with educators, patients, and themselves to address barriers associated with mobile device usage. These strategies reflect various approaches students use to navigate challenges in different educational and clinical contexts.

4.4.13 Analytical Theme 3: Strategies for Addressing Key Challenges and Barriers to Mobile Device Usage in Medical Education

This analytical theme synthesised the barriers and challenges faced by students, as identified in Descriptive Theme 5, and the strategies they adopted to address these challenges presented in Descriptive Theme 6. It is important to note that while students can mitigate certain challenges through their strategies, many barriers remain beyond their control. This synthesis focused on the strategies used to address key actionable challenges: mitigating educators' misunderstandings, alleviating patients' misconceptions, resolving ethical dilemmas, and preventing theft or loss of devices.

As in Analytical Themes 1 and 2, this section does not include detailed quotes to avoid redundancy. However, the reader can find relevant verbatim quotes within Descriptive Themes 5 and 6, where they are presented in their original context.

4.4.13.1 Mitigating Educators' Misunderstandings

Students frequently encounter challenges due to educators' misconceptions about the purpose of their mobile device use, often being perceived as engaging in non-educational activities (Green et al., 2015; Harrison et al., 2019; Shenouda et al., 2018). Such misconceptions often lead to criticism and tension between educators and students (Sulley, 2018).

Three distinct strategies were identified to address these challenges. First, students adopted discreet usage strategies to avoid drawing unnecessary attention, such as using devices away from educators (Clarke et al., 2019) or during break times (Harrison et al., 2019). Second, they justified their usage by explicitly communicating that devices were being used for educational purposes, such as looking up clinical information or taking notes (Ellaway et al., 2014). Finally, seeking explicit permission from educators for specific tasks, such as calculating clinical indices, helped to align device use with educators' expectations and reduce conflicts (Harrison et al., 2019; Rashid-Doubell et al., 2016).

4.4.13.2 Alleviating Patients' Misconceptions

Similar to educators, patients often misunderstand students' mobile device usage in clinical settings as a distraction or engagement in non-professional activities, posing another significant challenge (Green et al., 2015; Harrison et al., 2019; Shenouda et al., 2018). To mitigate this, three approaches adopted by students and universities were identified. First, students explained their intentions before using devices during patient interactions, such as looking up medical information (Shenouda et al., 2018). This transparency fostered patient acceptance and trust. Second, they sought patients' consent and permission before using devices (Harrison et al., 2019). Last, some schools provided university-branded device cases to legitimise device usage (Green et al., 2015).

In addition to these strategies, students used larger devices like tablets and iPads to ensure that both educators and patients can clearly see their screens and recognise that academic tasks, rather than social media, are being undertaken (Harrison et al., 2019; Rashid-Doubell et al., 2016) since patients often perceive smaller devices, such as smartphones, as tools for personal rather than educational use (Rashid-Doubell et al., 2016).

4.4.13.3 Resolving Ethical Dilemmas

Ethical challenges, including maintaining patient confidentiality and adhering to professional conduct, represent critical barriers to mobile device usage (Harrison et al., 2019; Shenouda et al., 2018; Wallace et al., 2012). To address these dilemmas, students strictly adhered to institutional guidelines and professional codes of conduct, ensuring their device usage remains aligned with ethical standards (Harrison et al., 2019; Shenouda et al., 2018).

4.4.13.4 Preventing Theft or Loss of Devices

Theft, loss, and damage of mobile devices were prevalent challenges that students encountered (Alegría et al., 2014; Green et al., 2015; Witt et al., 2016). To minimise these risks, students adopted practical strategies, such as avoiding device usage in high-risk locations. By being mindful of where and how they use their devices, students reduce their vulnerability to theft or accidental damage.

Table 4.4 maps the key challenges and barriers students face in using mobile devices, along with the corresponding strategies they adopt to address them.

Table 4.4 Key Challenges and Barriers in Mobile Device Usage and Corresponding Mitigating Strategies

Challenges/Barriers	Description	Mitigating Strategies
Educators' misunderstandings	Misconceptions of educators about the purpose of students' device use	1. Discreet usage strategies 2. Explicit justification 3. Seeking permission to perform specific educational tasks
Patients' misconceptions	Devices perceived as tools for distraction or non-educational activities	1. Explaining usage intentions 2. Seeking consent 3. Using larger devices like tablets
Ethical dilemmas	Breach of patient privacy and confidentiality	Adhering to institutional guidelines and professional codes
Theft, loss or damage of devices	Risk of theft or damage, especially to school-issued devices	Avoiding usage of devices in high-risk locations

Students employed a range of strategies to address key challenges in mobile device usage, focusing on educators' misunderstandings, patients' misconceptions, ethical dilemmas, and theft prevention. However, many broader barriers, such as technical inefficiencies and institutional policies, remained unaddressed.

4.5 Overall Summary of the Findings

The findings of this study revealed a multi-layered exploration of mobile device usage in undergraduate medical education. Through a thematic synthesis, data were synthesised into six descriptive themes and subsequently integrated into three broader analytical themes. The six descriptive themes include the usability of devices, external factors affecting their use, personal factors influencing usage, the benefits of mobile technology, challenges encountered, and strategies to address these challenges. These themes were further synthesised into analytical themes that explore factors affecting mobile device usage, the usability and benefits of such technology, and challenges coupled with adaptive strategies for overcoming them. The analysis underscored the nuanced dynamics of integrating mobile devices into medical education, offering a holistic perspective on their potential and limitations.

4.6 Chapter Summary

This chapter presents the findings of the literature search, characteristic features of the included studies, themes, and sub-themes that emerged from a thematic synthesis of the 30 included studies.

The following Discussion Chapter explores how these results resonate with existing literature, providing explanations and interpretations with reference to educational theories and technology acceptance models.

Chapter 5: Discussion

This study employs a qualitative systematic literature review approach to examine the experiences of undergraduate medical students in using mobile devices for learning throughout their preclinical and clinical education.

This chapter is divided into five sections. It begins with a summary of the key findings, followed by a comparative analysis of this review's features with other systematic reviews, interpretations and explanations of the key findings, implications, contributions, and limitations of the study.

5.1 Main Findings of the Review

This review synthesised qualitative data from 30 primary studies to address the research questions described in Chapter 2.

The findings identified a range of factors that influence medical students' use of mobile devices to facilitate their learning. Six key enablers were identified: institutional support, educators' encouragement, patients' positive perceptions, peer and family influence, personal beliefs, and technological proficiency. In contrast, five barriers emerged: restrictive institutional policies, educators' negative attitudes, patients' misunderstanding, emotional discomfort, and technical difficulties. These findings addressed the first research question, which explores the enablers and barriers influencing mobile learning adoption.

In response to the second, third, and fourth research questions, which explored how students use mobile devices to support their learning and what pedagogical benefits they acquire from these tools, the study found that students took advantage of the usability features of mobile devices, such as connectivity, portability, and multifunctionality, to enhance their learning experiences. These devices facilitated knowledge acquisition, clinical skill development, and improvements in patient care.

Despite these benefits, students encountered certain challenges, particularly in clinical settings, such as stakeholders' perceptions. Recognising the advantages of mobile technology, students actively sought to balance the benefits and challenges by employing various mitigation strategies. These findings addressed the fifth and sixth research questions, which focused on the challenges of mobile device use and the strategies students employ to overcome them.

After presenting the main findings of the review, the next section compares these findings with those of previous systematic reviews to contextualise the study's contributions within the existing literature.

5.2 Comparative Analysis of the Features of this Review with Other Systematic Reviews

This section compares and contrasts the features of this review with those of other systematic reviews discussed in Chapter 2. The comparison is structured using four elements of systematic reviews: population, intervention, control, and outcomes.

The study population of previous systematic reviews included medical and health professional students, with the exception of one study by Kyaw et al. (2019), which focused on medical students. Including diverse groups of health professionals provides insights into their use of mobile devices in different career stages. However, the roles and responsibilities of each profession are unique; for example, the primary responsibility of medical doctors is to make decisions for patient management, whereas that of nurses is to provide nursing care to patients. Therefore, summarising their mobile learning experiences can obscure the benefits and challenges that each group faces.

Although this review study is limited by focusing on undergraduate medical students, this targeted approach allows a more in-depth exploration of the experiences and learning behaviours within this group. It reduces the dilution effects that may arise from combining data from different groups.

The studies included in this review cover different phases of medical education, from preclinical to clinical training. While the focus on the use of mobile devices in clinical settings reflects their critical importance in providing training in clinical decision-making, studies focusing on preclinical training provide insights into the role of mobile learning in the acquisition of basic medical knowledge.

Another distinguishing feature of this review is its exclusive focus on mobile devices, including smartphones, iPads and tablets, while many other reviews encompassed a broader range of digital education tools. For instance, Bajpai et al. (2019) and Brusamento et al. (2019) evaluated interventions involving high-fidelity mannequins, virtual reality, and augmented reality. By concentrating on mobile devices, this review highlights the specific usability, benefits, and challenges associated with these tools and identifies practical implications for their integration into undergraduate medical education. An additional benefit of focusing on mobile devices is their ubiquity. Unlike specialised digital tools, such as virtual reality and augmented reality, which require special equipment and are often limited to certain centres, mobile devices are widely accessible to almost all students.

While other previous reviews, such as those by Brusamento et al. (2019), Chandran et al. (2022), and Kyaw et al. (2019), compared mobile learning interventions with traditional teaching methods, this study does not aim to compare but rather to understand students’ mobile learning experiences.

Regarding outcomes, most previous reviews investigated students’ acquisition of knowledge, skills and attitudes. Although the outcomes determined by Lall et al. (2019) were similar to those in this review, their inclusion of both medical and nursing students limits the specificity of their findings to either group. By focusing exclusively on medical students, this study offers greater relevance for informing mobile learning practices in medical education. Furthermore, this review’s findings emphasise the critical role of stakeholder perceptions, including those of educators, patients, and institutions, in shaping mobile learning experiences. This dimension has been explored in less detail in other reviews.

After comparing and contrasting the essential elements of the systematic reviews, the next section focuses on this study’s methodology in comparison with other studies.

It is common practice to register a protocol for systematic reviews at PROSPERO. However, some reviews, including this one, did not register their protocols at PROSPERO. Although this review’s protocol was not registered with PROSPERO, it was submitted to the Department of Educational Research at Lancaster University and approved for the study.

Regarding methods, while most other reviews focused on quantitative evaluations of the effectiveness of mobile learning, this study aligns with Lall et al. (2019) in using a qualitative approach and including both mixed-methods and qualitative studies. Other quantitative studies, such as those by Dunleavy et al. (2019) and Kyaw et al. (2019), were limited to RCTs to assess the effectiveness of mobile devices quantitatively. As this study aims to explore the lived experiences of students using mobile devices, a qualitative approach was deemed most suitable, as it provides depth and context that are often overlooked by quantitative methods.

As previous systematic reviews did not report the geographical locations of included studies, a direct comparison of the geographical distribution between this review and other reviews is not possible. Therefore, the geographical distribution of the studies included in this review is discussed independently. The included studies represent a diverse range of contexts, with many originating from Western countries. However, contributions from Asia, Africa, and the Middle East offer a broader perspective and provide valuable insights into the use of mobile devices in different educational environments.

The studies included in this review were published between 2012 and 2022, while those of previous reviews were from 1990 to 2020. As mobile learning in medical education has become increasingly important, particularly since 2010 (Klímová,2018), focusing on studies from 2012 onwards aligns closely with the mainstream adoption of mobile devices in medical education, ensuring greater relevance to current practices and devices used. In contrast, although previous reviews offered a broader historical perspective, this broader range may include findings from earlier technologies, for example, PDAs, which are no longer used in current medical practice.

Regarding electronic databases, the types of databases used for literature searches in this review were similar to those used in previous systematic reviews. The broader range of databases used in this review ensured the comprehensive inclusion of diverse research studies, particularly those addressing qualitative insights. Most previous reviews employed supplementary searches, which aligns with the methodology used in this review. This study’s use of a pilot-tested data extraction form mirrors the structured data collection methodologies of other reviews.

In terms of data analysis, this review employed thematic synthesis, which closely aligns with the thematic analysis used by Maudsley et al. (2019).

Lall et al. (2019) used framework synthesis by applying the pre-existing FRAME model for their qualitative data. While pre-existing models may simplify data analysis, they may constrain emerging themes by forcing themes into models. Thematic synthesis, being inductive and flexible, allows themes to emerge naturally without being forced into predefined categories. Quantitative reviews, including those by Dunleavy et al. (2019) and Kyaw et al. (2019), performed meta-analyses and pooled effect sizes to determine the effectiveness of interventions. Although these methods provided quantitative measures, they may have been limited in capturing the depth of students' experiences.

For a critical appraisal of the methodological quality of the studies included in previous systematic reviews, quantitative reviews adopted Cochrane's risk of bias assessment, whereas qualitative reviews used various methods. This review followed the approach used by Lall et al. (2019) due to the similarities in the types of studies included. The methodological quality of the included studies of this review was high, as the majority of the findings were trustworthy and useful. The inclusion of high-quality studies contributes to the overall credibility of the results and the conclusion of this review.

This study adheres to PRISMA reporting guidelines, aligning with most of the other reviews. However, the GRADE criteria for assessing the overall quality of reviews were applied in only three previous quantitative reviews. This quality assessment is intended to evaluate the confidence in the findings of systematic reviews, particularly for decision-making in policy formulation and guideline development (Lewin et al., 2018). As this review does not aim to advise high-level policymakers but rather to provide insights for educators and curricula planners in medical education, it does not include a GRADE assessment.

Unlike the other nine systematic reviews, where multiple researchers were involved in screening and data extraction, this review was conducted individually, with self-checking for these processes. While this distinction can be a limitation of conducting reviews individually, it underscores the focused effort to maintain methodological rigour. This limitation is further discussed in Section 5.6.

Following this comparative analysis, the discussion now turns to interpreting and explaining the key findings through the lens of relevant learning theories and conceptual frameworks presented in Chapter 2.

5.3 Interpretations and Explanations of Key Findings with Reference to Previous Systematic Reviews, Educational Theories and Technological Models

This section discusses the interpretations and explanations of the key findings from the review: enablers and barriers, usability of devices, mobile-enabled learning behaviours, challenges and strategies, with reference to previous systematic reviews, relevant learning theories and the technology-accepted models presented in Chapter 2.

5.3.1 Empirical Insights into Enablers and Barriers Affecting Mobile Device Usage

Analytical Theme 1 of this review identifies six enablers and five barriers affecting mobile device usage among medical students. The following sections interpret and explain these factors, referencing previous systematic reviews.

Institutional support, including the presence of clear policies, guidelines, infrastructure, and resources, emerged as a key enabler of mobile device usage in undergraduate medical education. Legitimising the use of mobile devices strengthens students' confidence and enables them to use mobile learning effectively. Conversely, restrictive institutional policies were identified as a significant barrier. Prohibitions on the use of mobile devices or unclear guidelines confuse students and limit the utility of mobile tools. Given that the use of mobile devices has become an integral part of everyday life and the role of technology in education has increased exponentially, it no longer makes sense to prohibit students from using such tools in higher education, including in medical education.

These findings are consistent with Lall et al. (2019), who emphasised the importance of institutional support for the successful implementation of mobile learning. Similarly, Maudsley et al. (2019) highlight how restrictive policies, such as informal and hidden curricula and disapproval, hinder the adoption of mobile tools. The findings from this review, along with evidence from previous systematic reviews, underscore the critical role of institutions and medical schools in facilitating students' adoption of mobile devices for their learning.

Medical educators' attitudes were found to be a critical factor influencing students' intention to use mobile devices. Encouragement from medical educators was critical, as supportive faculty members validated the use of mobile devices for learning and guided students in the effective use of these tools. In contrast, negative attitudes from educators, such as viewing mobile devices as distractions or unprofessional, discouraged students from adopting mobile learning practices.

Previous reviews by Maudsley et al. (2019) and Mi et al. (2016) also highlighted that educators' opposing attitudes negatively impacted on students' intention to adopt mobile technology. By building on evidence from this review and previous ones, the present study highlights the crucial role of medical educators in determining students' use of mobile devices for learning. Medical educators who have negative attitudes towards the use of mobile technology for educational purposes should reconsider their stance and adopt a more supportive approach.

Patients' perceptions of students' using mobile devices in clinical settings emerged as an influencing factor from the review. The positive perceptions of patients regarding mobile device use, such as viewing them as tools that enhance students' learning and improve medical care, encouraged students to adopt mobile learning during clinical practice. These perceptions created an environment where students felt comfortable using mobile devices for just-in-time learning and patient education. On the other hand, though, patient misunderstandings, where mobile devices were perceived as distractions or a sign of unprofessionalism, were a significant barrier. Some students reported hesitation in using mobile devices in front of patients because they feared being misunderstood.

A previous review by Maudsley et al. (2019) specifically addressed the issue of perceived unprofessionalism associated with students using mobile devices in front of patients. Their review, which included both quantitative and qualitative data, found that concerns about patients' misconceptions about mobile device usage were shared not only by medical students but also by nursing students. These concerns often made students reluctant to use such devices in clinical settings. As the usefulness of mobile devices for accessing clinical information in real time to support patient management was evident in this review, explaining that patients understand and accept mobile devices' role in enhancing medical care is critical.

Personal beliefs about the value and effectiveness of mobile devices emerged as an enabler in the present review. Students who believe that mobile devices improve their learning and clinical performance are more likely to adopt and integrate them into their educational practices. No previous systematic reviews explicitly reported these factors governing people's intention to use technology. However, Lall et al. (2019) discussed them indirectly as one of the sub-themes of device usability. They discussed how students acknowledged the use of technology for their learning purposes, such as working on an e-portfolio and taking notes during lectures. Findings from the present review, along with those of Lall et al. (2019), highlight the importance of students' personal beliefs in shaping their adoption of mobile learning, emphasising that fostering positive perceptions of mobile devices can enhance their integration into medical education.

Technological proficiency among students has emerged as another enabler, as it equips them with the skills needed to navigate mobile devices and applications effectively. Proficient students were more confident in using mobile tools for tasks such as accessing resources, managing schedules, and collaborating with peers. Conversely, technical inefficiencies raised significant barriers, disrupting students' learning processes and reducing their reliance on mobile tools.

A qualitative systematic review by Lall et al. (2019) examined the challenges faced by students struggling with technology, emphasising that providing training and technical assistance to these students could be highly beneficial. Although younger students are often assumed to be more tech-savvy, evidence from both Lall et al. (2019) and the present review suggests that this assumption may not always be true. Therefore, planning user-training and providing technical support should be integral parts of mobile learning implementation in medical education.

The interaction between enablers and barriers is complex and often interdependent. Institutional support and encouragement from educators can offset the stigma and uncertainty surrounding device use and create a more supportive learning environment for students. Conversely, restrictive policies and negative educator attitudes can undermine even the most motivated students and limit the potential of mobile devices to enhance learning and patient care. Although personal beliefs and technological proficiency enable device use, these factors may be overshadowed by external barriers such as patient misunderstandings or institutional constraints.

By holistically addressing these interrelated factors, medical schools and clinical educators can create an environment that maximises the benefits of mobile technology and lowers the barriers. Clear guidelines, user training, and educators' positive attitudes are essential to bridging the gap between enablers and barriers and ensuring that mobile devices serve as effective learning tools.

5.3.2 Developing a Conceptual Framework for Understanding Students' Adoption of Mobile Learning in Medical Education

Based on the themes regarding enablers and barriers that emerged from this study, a conceptual framework for understanding students' adoption of mobile technology in medical education is developed (Figure 5.1). Key constructs from the Technology Acceptance Models (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003) are applied to construct the framework.

Perceived usefulness (PU), positioned at the top centre of the diagram, described in Descriptive Theme 2, reflects students' beliefs that mobile devices improve their learning outcomes and clinical performance. It plays a key role in facilitating adoption, as students are more likely to use devices they find valuable and useful. PU is influenced by enabling factors positioned at the top left of the diagram, such as personal beliefs (Descriptive Theme 2), positive attitudes of educators (Descriptive Theme 1) and positive perceptions of patients (Descriptive Theme 1). Personal beliefs (Descriptive Theme 2) reflect

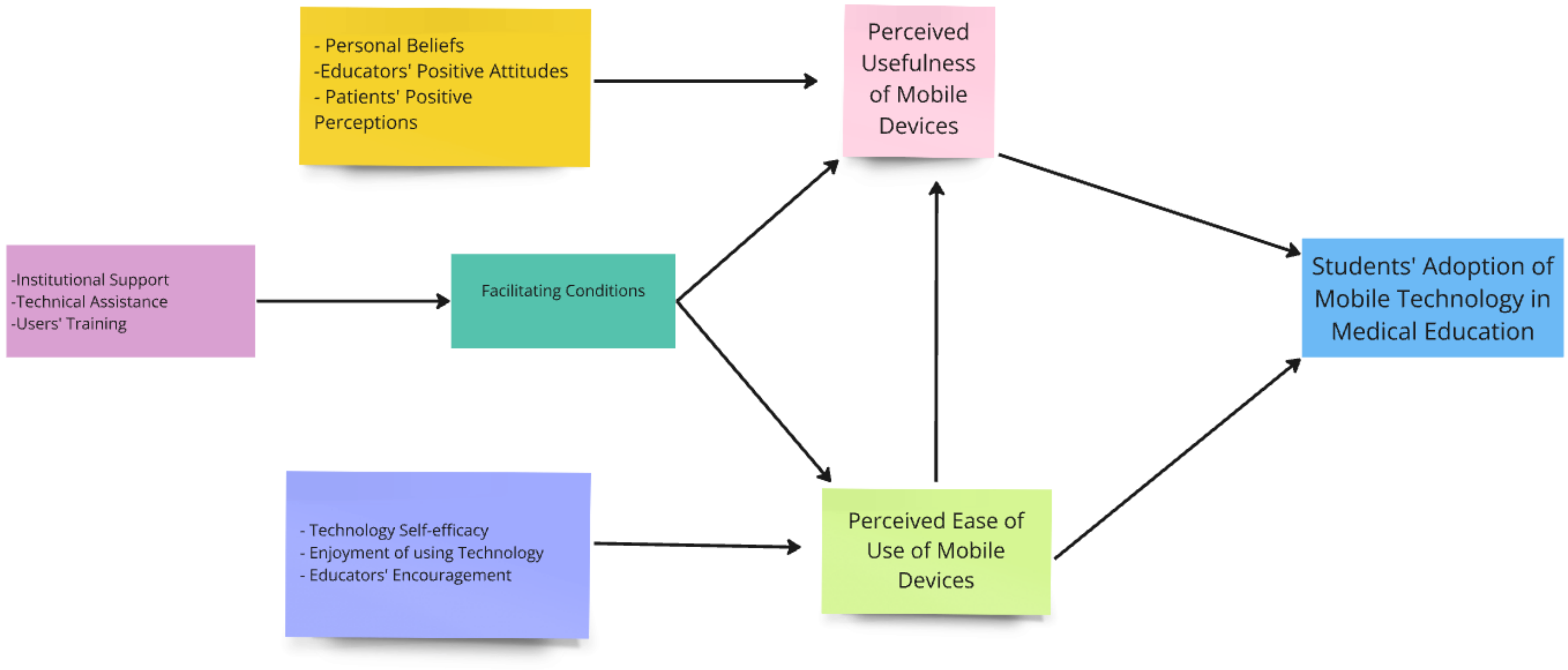

Figure 5.1 The Conceptual Framework for Students' Adoption of Mobile Technology in Medical Education

students' intrinsic understanding of the value of mobile devices in enhancing their learning and clinical practice. Positive attitudes of educators (Descriptive Theme 1) serve to validate the use of mobile devices, while positive perceptions of patients (Descriptive Theme 1) strengthen students' confidence to use these devices in a clinical environment without fear of misunderstandings.

Perceived Ease of Use (PEOU), positioned at the bottom centre of the diagram, described in Descriptive Theme 2, measures how effortless students find using mobile devices. It helps to boost PU as more user-friendly tools are perceived as more useful. PEOU is influenced by enabling factors, such as technological self-efficacy, enjoyment of using technology, and encouragement from educators. They are positioned at the bottom left of the diagram and described in Descriptive Theme 2. Technology self-efficacy refers to students' confidence in their ability to use mobile devices effectively, while enjoyment in using technology ensures that students are excited and enjoy using technology, thereby facilitating its use. Teacher encouragement also plays a critical role in helping students use mobile tools effectively and to integrate them into their learning.

Facilitating conditions, positioned at the centre left of the diagram, act as a critical mediating factor and include institutional support (Descriptive Theme 1), such as policies and infrastructure, and technical support (Descriptive Theme 1), which ensures students receive troubleshooting help and users' training that provides students with the necessary skills to use mobile technology safely. These conditions reduce the complexity of mobile devices, improve PEOU and PU, and create an enabling environment that directly impacts on adoption behaviour.

Finally, students' adoption of mobile technology in medical education, shown at the far right of the diagram, is the result of this framework. High levels of PU and PEOU and strong facilitating conditions combine to promote adoption and lead to the integration of mobile devices into student's learning and clinical practice.

5.3.3 Key Insights into the Usability of Mobile Devices in Medical Education

Descriptive Theme 3 of the study found that mobile devices are particularly useful for clinical environments due to their portability, connectivity, and multifunctionality. These features allow students to access real-time patient information and resources at the point of care, thus facilitating clinical decision-making and enhancing patient care. These benefits highlight the critical role of mobile devices in supporting situated learning during hands-on patient care.

This finding aligns with a qualitative systematic review by Lall et al. (2019), which demonstrated that mobile devices' physical, functional, and technical features improve students' work efficiency and support evidence-based learning during patient care.

This finding of a positive relationship between device usability and benefits can be well explained through the lens of Activity Theory (Engeström, 2014), which highlights the role of tools in mediating learning within an activity system. Mobile devices act as mediating artefacts that facilitate the interaction between medical students (subjects), their learning goals (object), and the clinical environment (community). Mobile devices provide students with immediate access to learning resources, enabling them to quickly find the information they need at the point of care and enhancing their clinical training experience.

A notable usability feature of mobile devices identified in this study is their environmental friendliness, particularly through reduced paper usage. This feature, not highlighted in previous systematic reviews, emerged as a unique contribution to this study. Although only three studies explicitly mentioned it, the ecological benefits it offers are significant. Reduced paper usage directly contributes to the preservation of trees, which play a critical role in mitigating climate change by absorbing carbon dioxide and releasing oxygen as a by-product of photosynthesis. This effect, in turn, supports global efforts to combat global warming and maintain ecological balance. Therefore, mobile device usage demonstrates its potential not only as a learning tool but also as a contributor to environmental protection.

5.3.4 Understanding Mobile-enabled Learning Behaviours

All nine previous systematic reviews presented in Chapter 2 consistently reported that mobile devices improved students' learning outcomes. For instance, the quantitative systematic reviews by Chandran et al. (2022), Dunleavy et al. (2019), and Kyaw et al. (2019) demonstrated improvements in students' knowledge acquisition through numerical data, particularly in terms of effect size. However, none of these reviews attempted to explain the mechanisms underlying these learning improvements. To address this gap, Descriptive Theme 4 of the present review identified five types of mobile-enabled learning behaviours among medical students. These learning behaviours are discussed in the following sections, and their mechanisms are explained by reference to relevant learning theories and frameworks.

The present study found that mobile devices allow students to access information and resources when they need them, thereby supporting just-in-time learning. This capability is particularly valuable in clinical settings, where immediate access to up-to-date knowledge can facilitate evidence-based decision-making and enhance patient care. By providing students with real-time information, mobile devices bridge the gap between theoretical knowledge and its practical application, enabling active learning during clinical tasks. No previous systematic reviews specifically mentioned this learning behaviour as a pedagogical benefit. This may be due to the fact that most of them were quantitative systematic reviews and used meta-analyses and effect sizes to demonstrate the effectiveness of mobile learning.

Just-in-time learning can be best explained by Situated Learning Theory (Bates, 2015b; Naismith et al., 2004), which posits that learning occurs most effectively when situated within the context in which it is applied. Mobile devices act as tools for accessing knowledge in clinical settings, helping students engage in authentic learning experiences directly linked to their professional practice. By using mobile apps to look up treatment guidelines during patient care, students can engage in contextually relevant and immediately applicable learning content.

The study identified SRL as one of the key mobile-enabled behaviours, where students use mobile devices to set goals, track progress, and reflect on their learning. Mobile apps and features allow students to take control of their learning journey, helping them to take responsibility for their learning. Research by Mi et al. (2016) also found that these devices support personalised learning by addressing individual learning needs and preferences, thus fostering self-directed and independent learning.

Self-regulated learning aligns directly with Zimmerman's SRL process (Sandars & Cleary, 2011), as mobile devices and applications enhance the process, allowing students to create learning plans, track their performance, and reflect on it. This proactive approach equips students with lifelong learning skills.

Closely related to SRL is SDL. The study identified SDL as a critical mobile-enabled behaviour, where students take the initiative in diagnosing their learning needs, formulating goals, identifying resources, and evaluating their learning outcomes. Mobile devices facilitate this process by providing access to a variety of educational materials, such as medical apps and e-books, allowing students to learn at their own pace and on their own time. A previous systematic review by Mi et al. (2016) demonstrated that mobile devices supported medical students' self-directed learning.

Self-directed learning aligns closely with Knowles' Andragogy Theory (Taylor & Hamdy, 2013)**,** which emphasises the need for adult learners to take responsibility for their own education. Mobile devices enable this process by providing tools that support independent exploration, goal-setting, and resource identification. By fostering autonomy and resourcefulness, mobile-enabled self-directed learning equips students with the skills necessary for lifelong learning and professional development.

One of the self-directed learning activities reported in the present review is the use of self-assessment quizzes in anatomy apps. These quizzes, often integrated into mobile learning platforms, allow students to test their knowledge independently and receive immediate feedback. This activity can be best explained through Behaviorism Theory (Bates, 2015a), which emphasises learning as a process shaped by reinforcement and feedback. According to this theory, quizzes act as stimuli that encourage engagement and reinforce learning through positive reinforcement when students answer questions correctly. Conversely, immediate corrective feedback on incorrect answers helps students identify gaps in their knowledge, allowing them to revisit these areas. The design features of anatomy apps that students value highly align with Cognitivism Theory (Bates, 2015c). Cognitivism emphasises the mental processes involved in learning, such as attention, memory, and problem-solving, which are supported by the structured and interactive nature of anatomy apps. These apps often organise content into logical modules, include interactive diagrams, and provide step-by-step guidance, allowing students to engage with complex content in a manageable and systematic way.

This study found that mobile devices significantly enhance collaborative learning by enabling students to work together synchronously or asynchronously through tools such as messaging apps, shared documents, and video conferencing. This learning behaviour fosters teamwork, problem-solving, and idea-sharing skills, which are essential for future healthcare professionals. Similar to just-in-time learning behaviour, no previous systematic reviews explicitly reported collaborative learning practices facilitated by using mobile devices. One possible reason is that those previous reviews may have focused primarily on individual learning rather than group learning behaviours.

Collaborative learning aligns with Social Constructivism (Aubrey & Riley, 2019a), which emphasises that learning is a social process constructed through interactions with others. Mobile devices create virtual spaces where students can share resources, co-create knowledge, and discuss complex problems, even when physically separated. For instance, students might use tools like Google Docs to collaboratively draft a patient case analysis or WhatsApp to brainstorm diagnoses during PBL sessions. This interaction fosters critical thinking and deeper learning through shared perspectives.

The study found that mobile devices facilitate informal learning by enabling students to access and engage with educational resources and social media platforms, such as Facebook groups, outside of traditional learning environments. Such learning may take place during commutes, breaks, or other non-academic settings, where students can listen to podcasts or watch videos. Social media platforms, Facebook in particular, allow students to discuss medical topics, share resources, and seek peer support collaboratively and interactively. This form of learning is self-initiated and flexible, making it a complementary learning strategy to formal education.

Informal learning through mobile devices, including social media and non-traditional learning environments, aligns with multiple educational theories. SDL (Taylor & Hamdy, 2013) aligns well with informal learning as students independently search for and engage with mobile-enabled resources, such as Facebook groups or videos, during commutes or other informal settings. This autonomy highlights their ability to manage their learning needs and tailor learning according to their schedules. Platforms such as Facebook groups foster collaborative learning, where students engage in discussions, co-construct knowledge, and provide feedback to each other. Social constructivism (Aubrey & Riley, 2019a) explains this form of learning, emphasising the importance of social interaction in the learning process. Additionally, informal learning on platforms like Facebook groups facilitates conversations between students, mentors, and professionals, enhancing their understanding through enquiry, feedback, and shared reflection. This learning behaviour aligns well with Conversation theory (Pask, 1976), which underscores the critical role of dialogue in learning.

A learning behaviour that did not emerge from this review but was highlighted in the review by Lall et al. (2019) is reflective learning. On examining four verbatim excerpts described as examples of reflective learning in their review, three of these excerpts were from doctors and nurses. These groups fall outside the scope of this review. However, an excerpt from their study overlapped with the data included in this review, and it was coded differently, categorising it as a strategy students adopt to use mobile devices ethically in clinical settings. The difference in naming or coding acknowledges that while the same data were analysed, the interpretation and emphasis may vary between reviews.

5.3.5 An In-depth Discussion on the Challenges of Mobile Learning and Strategies to Overcome Them

Analytical Theme 3 of this review highlights some significant challenges that medical students face in integrating mobile devices into their learning activities and provides strategies to address these challenges. Addressing them is crucial to creating a conducive environment for mobile learning in medical education.

One of the major challenges that students encounter is educators' misconceptions about student use of mobile devices, often viewing them as distractions or inappropriate in academic or clinical settings. These misunderstandings can lead to an uncomfortable learning environment and dissuade students from using mobile devices. Such attitudes may be due to a lack of awareness of the educational value of these devices or to institutional norms that do not encourage their use. Although students employ various strategies to overcome these challenges, as identified in this review, the root cause may lie in the resistance of educators to embrace the changing trend of the academic landscape and recognise the pedagogical benefits of mobile devices in educational settings.

Patients' misconceptions also pose a major challenge in clinical settings. Patients often view mobile devices as tools for recreational activities rather than as essential educational tools. This perception can undermine trust and relationships between students and patients in clinical settings. This review identified various approaches students use to explain and justify their mobile device usage to patients. While increasing public awareness of mobile device usage has led to greater acceptance, older patients may remain sceptical of the technology. Therefore, students should use strategies tailored to suit different age groups, particularly when dealing with older patients.

Previous systematic reviews by Maudsley et al. (2019) and Mi et al. (2016) also identified disapproval by educators and patients of students' use of mobile devices and the potential risk of violating patients' privacy and confidentiality as major challenges that students face when using mobile devices.

Ethical dilemmas related to patients' privacy and confidentiality represent another critical issue identified in this review. Mobile devices can increase the risk of data breaches and inadvertent disclosure of sensitive patient information, potentially undermining trust and professionalism in clinical environments. Students who are unaware of or do not follow data protection policies may risk violating ethical standards. Compliance with institutional policies and professional codes is critical to addressing these concerns. Students must ensure that their use of mobile devices adheres to established protocols for data security and ethical conduct, maintaining the integrity of the doctor-patient relationship while leveraging technology for learning.

The risk of theft, loss or damage to devices – especially in high-risk environments such as public transport or shopping malls – poses a practical challenge for students. Such incidents can impose financial and logistical burdens, particularly for those relying on school-issued devices. While students may adopt strategies like avoiding the use of devices in high-risk locations to mitigate these risks, such approaches may not be ideal solutions. Students should take more responsibility for securing their devices, for example, by using tracking apps or not leaving their devices unattended. Institutions could also consider offering affordable insurance plans or providing durable equipment for school-issued devices.

Addressing these challenges is critical to creating a supportive ecosystem for mobile learning in medical education. By mitigating these challenges through institutional support, professional accountability, and clear communication with patients, medical schools can create an environment in which students can safely and confidently integrate mobile technologies into their learning and clinical practice.

Based on these interpretations, the following section discusses the broader implications of the findings, focusing on their theoretical, practical, methodological, and research-related significance.

5.4 Implications of the Study

Four types of implications – theoretical, practical, methodological, and future research – stemming from the findings of the study are discussed in this section.

5.4.1 Theoretical Implications

This study has theoretical implications for both learning theories and technology adoption models, particularly in the context of mobile learning in undergraduate medical education. The findings show how established theories and models, which were originally developed outside of medical education and mobile learning contexts, can be effectively applied and adapted to explain students' learning behaviours and technology usage in clinical and academic settings.

The study drew on eight established educational theories, as presented in Section 2.1.1, to explain students' learning behaviours in mobile learning environments. These theories collectively offered insights into how students process information, interact socially, regulate their own learning, and engage with learning in authentic contexts.

Although these theories originated from non-medical and non-mobile learning contexts, the findings demonstrate that they are relevant and applicable to mobile learning implementation in undergraduate medical education. This suggests that existing learning theories can be meaningfully extended to mobile learning in clinical education, offering a theoretical foundation for understanding how students engage with mobile technologies in authentic, professional learning environments.

In addition to educational theories, this study utilised four technology-related theories, models and frameworks –Technology Acceptance Models (TAMs and UTAUT), Activity Theory, and Koole's FRAME model, as described in Sections 2.1.2 and 2.1.3 – to understand how medical students adopt and engage with mobile devices for learning. While each of these models provided valuable perspectives, the findings of this study also reveal areas where these theories could be extended or refined to suit the context of undergraduate medical education.

The results of the study align well with the Technology Acceptance Models, particularly in confirming that perceived usefulness and perceived ease of use remain central to students' decisions to adopt mobile devices. Similarly, the facilitating conditions and social influence described in UTAUT were reflected in students' experiences, especially in relation to institutional support and the encouragement or disapproval of educators. However, the study also shows that technology acceptance in clinical learning is shaped by additional factors that these models do not fully account for. Specifically, students were influenced by the perceptions of patients, concerns about professionalism, and the need to negotiate their role in clinical environments. These are not typically included in TAM or UTAUT but were shown to be critical in this review study. This suggests that traditional models of technology acceptance may need to be expanded to incorporate professional, ethical, and contextual considerations that are unique to healthcare education.

The use of Activity Theory further helped to illuminate how students' mobile device use is embedded in a broader system of social roles, institutional rules, and community norms. The model was useful in showing how learning with mobile devices is not just about individual behaviour but also about navigating complex structures, such as hospital policies, educators' expectations, and patient interactions. The study revealed several tensions in this activity system, such as when policies were unclear or when the clinical culture discouraged students' mobile device use. These tensions disrupted learning and contributed to uncertainty among students. This highlights the usefulness of Activity Theory in identifying contradictions in mobile learning environments and underscores the need for more supportive institutional cultures.

The FRAME model was also valuable in capturing the interactions between devices, learners, and the social environment, which are the core of mobile learning. The findings of the study align well with the model's focus on how device usability, learners' characteristics, and social relationships interact and create mobile learning experiences. In the original FRAME model, interactions take place between learner-learner, learner-instructor, and learner-content. However, in the context of medical education, students' mobile learning is shaped not only by social interactions with peers and educators but also by interactions with patients, institutional expectations, and professional identity formation. Therefore, this study suggests that the FRAME model may benefit from extension, i.e., by including these dimensions that are not fully represented in the original FRAME model to reflect the unique attributes of professional and clinical learning environments.

In summary, this study confirms the relevance of existing learning theories in explaining mobile learning adoption in undergraduate medical education. However, it also highlights the need to contextualise or extend technology-related models to reflect the complexities of learning in professional, high-stakes environments like medicine. By integrating institutional, professional, social, and technological influences, this study provides a foundation for refining current models and developing more context-sensitive frameworks for future research.

5.4.2 Practical Implications

The practical implications of this study extend to multiple stakeholders, including students, educators, patients, and institutions. The practical implication for students is the need to develop strategies to balance the benefits of mobile device use with the challenges they face. These strategies may include raising awareness of ethical issues and communicating the pedagogical purpose of using mobile devices to educators and patients. For educators, the implication is the critical role of faculty training programmes that highlight the pedagogical benefits of mobile devices and promote integration of technology into their teaching practices. For patients, it is essential to implement communication strategies that clearly explain the educational purpose of students using devices in clinical settings. Curriculum developers should establish clear policies and guidelines for the legitimate use of mobile devices to create a conducive learning environment. Institutions should also ensure the availability of technological infrastructure and provide training programmes for students and faculty to address technical and ethical challenges.

5.4.3 Methodological Implications

The findings of this study suggest that in future, researchers conducting qualitative evidence syntheses in medical education may benefit from adopting structured and transparent methods similar to those employed in this study. A clearly defined, theory-informed review process from literature search to reporting can enhance the quality, trustworthiness, and usability of findings. Adopting such an approach may strengthen the role of qualitative systematic literature reviews in guiding educational policy, practice, and research within the field of medical education.

5.4.4 Research Implications (Suggestion for Future Research)

This study identifies five key areas for future research. First, as the study focuses exclusively on undergraduate medical students, future research studies should expand the scope to include postgraduate medical students and explore the use of mobile technology in workplace settings. Second, the findings highlight the critical role of medical educators' and patients' perceptions, suggesting that future research should examine in greater depth how these stakeholders' attitudes and perceptions influence students' mobile learning experiences. Third, although the study centres on mobile devices and applications, the advances in technology present opportunities for future research to explore students' perceptions and experiences with emerging tools like augmented reality (AR), virtual reality (VR) and artificial intelligence (AI). Fourth, addressing two research gaps identified from the scoping searches that were not addressed in this study –mobile learning practices in resource-limited countries and the long-term effects of mobile learning in health professional education – would help to build a more comprehensive and globally relevant understanding of mobile learning adoption in medical education.

Finally, future research should empirically test the two conceptual models proposed in this study to evaluate their applicability and robustness across different settings. This could involve using the same population of undergraduate medical students or extending the models to postgraduate medical learners or other health professions contexts. Such studies would help to validate and refine the frameworks, supporting their broader use in mobile learning research and practice in health profession education.

These four implications of mobile learning implementation in undergraduate medical education are summarised in Table 5.1.

Table 5.1 A Four-quadrant Summary of Theoretical, Practical, Methodological, and Research Implications of Mobile Learning Implementation in Undergraduate Medical Education

Theoretical Implications	**Practical Implications**
- Supports the relevance of existing educational theories (e.g., constructivism, situated learning theory) - Resonates with core constructs of technology adoption models (TAM, UTAUT) - Demonstrate Activity Theory helps to explain the interactions of individual, institutional, social and device -Suggests the FRAME model be extended to include patient perceptions, professionalism and clinical norms	- Students need to develop strategies to manage the benefits vs. challenges of using devices - Educators should receive training programmes to support mobile learning - Patients may benefit from transparent communication explaining the students' educational purpose of device use -Institutions should develop clear mobile device policies and provide infrastructure and support
Methodological Implications	**Research Implications**
-Future researchers in medical education should adopt structured, transparent, and replicable methods in qualitative systematic literature reviews	- Extend research to postgraduate medical students and workplace-based learning using mobile devices -In-depth study of the role of the stakeholders (e.g., educators and patients) perceptions -Investigate new technologies like AR, VR, and AI in mobile learning contexts - Explore mobile learning practices in low-resource settings - Investigate the long-term effects of mobile learning in medical education - Empirically test the proposed conceptual models with the same of different study populations

After the implications that highlight the relevance of the findings are discussed, the next section presents the specific contributions this study makes to theory, methodology, and knowledge in medical education.

5.5 Contributions of the Study

This review study makes significant contributions in three key areas: theoretical, methodological, and knowledge. Each of these contributions is discussed in the following sections.

5.5.1 Theoretical Contributions

This study makes important theoretical contributions to the field of mobile learning in medical education by proposing two conceptual models. The first model is a new framework that provides a structured understanding of students' learning experiences in the use of mobile devices, and the second model extends and refines existing technology adoption theories (TAM and UTAUT) by incorporating new domain-specific factors. These contributions advance the theoretical understanding of mobile learning implementation in medical education and provide a foundation for future research.

The first conceptual model (Figure 4.8) introduces a new theoretical framework for understanding medical students' learning experiences using mobile devices. Unlike existing technology adoption models, which primarily focus on usability and perceived benefits, this model integrates device usability, external and personal influences, perceived benefits, challenges, and coping strategies into a single framework. This holistic perspective provides a comprehensive understanding of how medical students navigate mobile learning in clinical and academic environments.

This model makes a novel contribution by:

- Proposing a new structure for understanding mobile device adoption in medical education;
- Integrating challenges and coping strategies, which are often overlooked in traditional technology adoption models;
- Offering a learning-centred perspective, rather than a technology-centred one, by emphasising how students acquire knowledge and skills and

actively negotiate challenges (e.g., negotiation with educators, patients, and themselves).

The second conceptual model (Figure 5.1) refines and extends TAM and UTAUT by incorporating factors specific to medical education. These context-specific enablers significantly shape mobile learning adoption in medical education, including:

- Personal Positive Beliefs – Students' intrinsic motivation and confidence in mobile learning for facilitating their learning;
- Medical Educators' Positive Attitudes and Encouragement –The role of faculty in validating mobile learning practices;
- Patients' Perceptions –Influence of the clinical environment and patient interactions;
- Institutional Support, Technical Assistance, and Training – The critical role of infrastructure and policy commitment of medical institutions.

These findings extend existing models by highlighting the critical role of social, institutional, and professional factors in mobile learning implementation in medical education.

5.5.2 Methodological Contributions

The study contributes methodologically by demonstrating a systematic and structured approach to conducting a qualitative systematic literature review. It offers a step-by-step framework for developing review questions, defining scope and inclusion criteria, conducting comprehensive literature searches across multiple sources, systematically coding data, appraising the methodological quality of data, synthesising findings thematically, and reporting results by using standardised guidelines. By adopting a rigorous and replicable methodology, this study enhances the transparency and reliability of systematic literature reviews. It serves as a reference for future researchers in medical education research conducting qualitative systematic literature reviews.

5.5.3 Knowledge Contributions

This study makes a significant contribution to knowledge by integrating and synthesising insights from previous research to provide a comprehensive understanding of mobile learning practices in undergraduate medical education. Through a qualitative systematic literature review, the study consolidates evidence on enablers, barriers, and contextual factors that influence students' adoption of mobile technologies in both clinical and academic settings.

In addition, a scoping review conducted during the early phase of the research (outlined in Chapter 2) provided foundational insights into the existing literature landscape. This work was presented as an e-poster at the International Association for Medical Education (AMEE) Conference, held virtually from 27- 31 August 2021, further contributing to the dissemination of knowledge within the medical education community. The e-poster can be accessed by scanning the QR code shown in Figure 5.2.

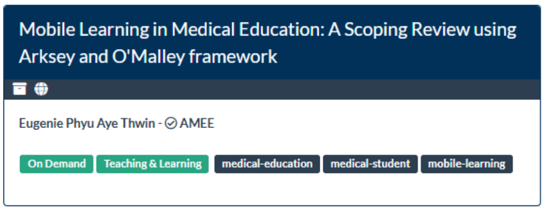

Figure 5.2 An E-Poster Presented at the AMEE Conference 2021

Further dissemination efforts are also planned, targeting key stakeholders within medical education. The findings will be prepared for submission to a peer-reviewed journal focused on health professions education. In addition, selective dissemination will be undertaken by sharing key insights with curriculum leaders, educators, and institutional decision-makers at selected medical schools (e.g., University of Medicine (1), Yangon, Myanmar; UCSI University, Malaysia; Yong Loo Lin School of Medicine, National University of Singapore; School of Medicine, University of Dundee, (UK)). These institutions are purposely chosen due to my prior work experience and familiarity with their faculty members. This approach aims to ensure that the theoretical and practical insights generated by the study inform future policy, professional development, and the implementation of mobile learning strategies in undergraduate medical education.

These three types of contributions of the study discussed in Section 5.5 are illustrated in Table 5.2.

Table 5.2 A Summary of Contributions of the Study

Theoretical Contributions	**Methodological Contributions**	**Knowledge Contributions**
- Proposed two conceptual models for mobile learning in medical education - First model: a framework for understanding students' mobile learning experiences -Second model: extension of TAM and UTAUT, including medical education-specific contextual factors	- Demonstrated a structured and transparent qualitative systematic literature review process - Provided a step-by-step process from review question formulation to reporting -Served as a reference for future qualitative systematic reviews	- Synthesised evidence on students' mobile learning experience in medical education - Identified enablers, barriers, benefits and challenges -Disseminated findings of a scoping search via AMEE conference presentation

In recognising these contributions, it is also important to acknowledge the limitations of the study.

5.6 Limitations of the Study

As no research is perfect, this study has identified six types of limitations (Figure 5.3). The first five limitations are related to research methodology, while the last limitation is concerned with my research experience.

Figure 5.3 Six Types of Limitations of the Study

5.6.1 Limitations of a Single Researcher Approach

The study is an assessed assignment for partial fulfilment of the PhD degree requirements, and the review is expected to be an individual student work. The first limitation, therefore, is that it was conducted independently of a formal review process, particularly in searching, screening, and selecting studies, as well as in data extraction and quality assessment. This limitation was addressed by cross-checking the screening process, data extraction, and methodological quality assessment, with the researcher acting as both the first and second reviewers to ensure consistency and accuracy.

5.6.2 Limitations of the Literature Search

The second limitation relates to the literature search. Although the literature search was undertaken as comprehensively as possible, some relevant papers may still have been missed, and challenges exist in locating unpublished literature, such as dissertations and theses. Adopting supplementary literature search strategies may help to mitigate this limitation by identifying additional relevant studies that may not appear in initial database searches.

5.6.3 Variations in the Methodological Quality and Reporting of the Findings of Studies

The third limitation is the variation in the methodological quality of the studies and the inconsistent reporting of findings. Line-by-line detailed coding has helped to capture themes and insights across studies, regardless of their methodological quality.

5.6.4 Challenges in Data Analysis and Synthesis

The fourth limitation concerns the synthesis process in data analysis. The number of codes extracted from the selected papers was substantial, and data synthesis was time-consuming despite the use of software. Consulting YouTube videos on qualitative data analysis provided practical tips and techniques for managing large datasets and streamlining the synthesis process.

5.6.5 Exclusions of Studies Not Written in English

The fifth limitation of the study is the exclusion of papers not written in the English language. Such papers may contain significant evidence that could have supported the findings of this review. This limitation might have been mitigated if a team with members fluent in other languages had conducted the review. However, as this review was conducted individually, it is necessary to acknowledge this language constraint as a potential limitation.

5.6.6 Limited Experience in Conducting Systematic Reviews

The last limitation is the researcher's own research experience in conducting systematic reviews. As the researcher has been trained in quantitative research for primary studies, conducting a qualitative systematic review has been a challenge. However, attending relevant training courses and workshops in systematic reviews (Appendix AA) helped the researcher develop the foundational skills necessary for conducting qualitative systematic reviews, including strategies for coding and data synthesis.

In light of the limitations discussed, the chapter concludes with a summary that synthesises the key points of the discussion and sets the stage for the concluding chapter of the thesis.

5.7 Chapter Summary

This chapter compares this study with other systematic reviews, along with a comprehensive discussion of the key findings of the review, as well as its implications, contributions, and limitations.

The next chapter consolidates the key findings of this review, reflecting on their implications for practice and future research on mobile learning implementation in medical education.

Chapter 6: Conclusion

This chapter concludes the thesis by summarising how the study addressed the research gaps identified and contributed to the field of mobile learning in undergraduate medical education. It revisits the study's aim, highlights key findings, reflects on the researcher's personal journey, and outlines the broader implications and significance of the study.

6.1 Restating the Aim of the Study

This study has explored undergraduate medical students' experiences of using mobile devices for learning across both preclinical and clinical education. The study applied a qualitative systematic literature review methodology and synthesised findings from 30 primary qualitative and mixed-methods research studies.

6.2 Summary of Key Findings and How the Study Has Addressed Research Gaps

This study has addressed key research gaps identified during the initial scoping review related to mobile learning in undergraduate medical education.

The review identifies key contextual factors that influence mobile device use, including the attitudes of educators and patients, institutional support, students' personal beliefs, and their level of technological confidence. These findings help to fill the gap related to underexplored factors that shape mobile learning experiences.

The findings show that students recognise and take advantage of the usability features of mobile devices, such as portability, connectivity, and multifunctionality, to support knowledge acquisition, skills development, and patient care. By explaining how mobile devices support learning in both preclinical and clinical settings, the study addresses the gap regarding the mechanisms through which mobile devices benefit students.

Despite these benefits, students also face certain challenges, particularly in clinical environments. These include negative perceptions from educators and patients, as well as concerns around professionalism, ethics, and privacy.

The study highlights how students adopt various strategies to manage these challenges, thereby addressing the gap related to the limited discussion of how such barriers may be overcome in practice.

In addition to addressing these knowledge gaps, this study responds to the population gap by focusing specifically on undergraduate medical students. It also contributes to closing the methodological gap by applying a qualitative evidence synthesis approach, which is an area previously underrepresented in mobile learning research. Finally, although the review does not evaluate the theoretical frameworks related to mobile learning in primary studies, it applies relevant educational and technology-related theories to interpret the findings, thereby addressing the theoretical gap related to explaining mobile learning through established theoretical lenses.

In summary, this review effectively responds to key research gaps identified during the scoping search. It contributes new insights into how and why mobile devices are used for learning in undergraduate medical education.

6.3 Implications and Contributions of the Study

The study has important implications for and contributions to knowledge, theory, practice, methodology, and future research. In terms of knowledge, it provides a comprehensive synthesis of factors influencing mobile learning in undergraduate medical education. Theoretically, it demonstrates the relevance of established learning theories in understanding mobile learning in medical education. It also proposes two conceptual models. The first model captures students' mobile learning journeys, and the other extends technology acceptance models by adding medical education-specific factors. Practically, the findings provide practical guidance for medical educators, students, patients, and institutions on how to implement and support mobile learning in medical education practice effectively. Methodologically, it demonstrates a structured, transparent approach to conducting a qualitative systematic literature review, serving as a reference for future researchers. For future research, the study suggests expanding the scope to include postgraduate medical students in workplace settings using mobile devices, testing the proposed models, and exploring emerging technologies.

6.4 Strengths and Limitations of the Study

This study has several strengths, including its focused population (undergraduate medical students), comprehensive search strategy, inclusion of qualitative and mixed-methods studies, critical appraisal using standardised tools, and use of thematic synthesis. The application of relevant theories also adds analytical depth.

However, certain limitations must also be acknowledged. The review was conducted by a single researcher and was limited to studies published in English. Additionally, although the review provides conceptual insights, it is based on secondary data and does not offer real-time observations of students' experiences.

6.5 Personal Reflection on My Role as a Researcher

Conducting a systematic review independently provided me with valuable learning experiences. First, conducting a systematic literature review gave me the opportunity to engage with existing literature without the need to recruit participants. Second, this advantage allowed for flexibility in managing time around personal and social commitments. Third, this approach also allowed me to explore diverse research methodologies, offering insights into their application and limitations. Fourth, critically appraising published studies enhanced my analytical skills, enabling me to identify the strengths and weaknesses of existing research. Finally, this process has improved my understanding of evidence-based practices and strengthened my skills to conduct systematic reviews, laying a foundation for future research endeavours.

As a final remark, I am pleased to announce the completion of my thesis, a journey that has spanned six years. Throughout my PhD studies, I faced significant challenges, including political instability in my home country, the COVID-19 pandemic, migration across countries, and a career transition. Despite these hardships, perseverance and dedication have brought me to this final milestone.

6.6 Chapter Summary

This chapter concludes the thesis by summarising how the study addressed existing research gaps and contributed new knowledge, frameworks, and methodological guidance to the field of mobile learning in medical education. Through a systematic and theory-informed synthesis of qualitative evidence, the study has enhanced our understanding of how mobile devices shape students' learning experiences and how various contextual factors influence their use. The insights generated by this study lay the foundation for future research, institutional policy development, and the more effective integration of mobile technology in undergraduate medical curricula.

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Appendix A: Definitions of Research Gaps (Miles, 2017)

	Type of Research Gap	Definition
1.	Knowledge gap	Desired knowledge may not exist in literature.
2.	Population gap	Research is not addressed to certain underserved populations.
3.	Methodological gap	A variation of research methods is required to generate new insights into a particular phenomenon.
4.	Theoretical gap	There is a lack of theory to be applied and generate new insights.

Appendix B: Reference Reading of Learning Theories and Theories of Mobile Learning

1. ABC of Behaviour Change Theories (Michie et al., 2014)
2. Learning Theories Simplified (Bates, 2019)
3. Understanding and Using Educational Theories (Aubrey & Riley, 2019c)
4. The Super Quick Guide to Learning Theories & Teaching Approaches (Goldhawk, 2023a)
5. AMEE Guide No. 52: Situativity Theory (Durning & Artino, 2011)
6. AMEE Guide No. 58: Self-Regulation Theory (Sandars & Cleary, 2011)
7. AMEE Guide No. 59: Self-Determination Theory (ten Cate et al., 2011)
8. AMEE Guide No. 63: Experiential Learning (Yardley et al., 2012)
9. AMEE Guide No. 83: Adult Learning Theories (Taylor & Hamdy, 2013)
10. AMEE Guide No. 86: Cognitive Load Theory (Young et al., 2014)
11. Handbook of Mobile Learning (Berge & Muilenburg, 2013)
12. Theorising and Implementing Mobile Learning (Kearney et al., 2020b)

Appendix C: A Summary of Critical Analysis of Learning Theories Relevant to Mobile Learning

	Learning Theories	Strengths	Weaknesses	Relevance to Mobile Learning
1	Behaviourism	It is applicable to learning, which involves memorising and recalling facts.	It neglects the internal cognitive processes involved in deeper learning.	Mobile applications such as quizzes can reinforce knowledge acquisition through feedback and repetition.
2	Cognitivism	It is applicable for learning tasks that require students' active engagement, knowledge structuring, retention and retrieval of information.	It ignores the social and cultural aspects of learning.	Mobile learning applications that use multimedia elements or interactive interfaces enhance memory retention and comprehension.
3	Constructivism	It is particularly valuable for fostering critical thinking and problem-solving skills.	It requires significant guidance to ensure that students construct an accurate understanding.	Case-based learning via WhatsApp messenger can enhance students' diagnostic reasoning skills by facilitating the construction of knowledge from

	Learning Theories	Strengths	Weaknesses	Relevance to Mobile Learning
				authentic clinical cases presented through the app.
4	Situated learning theory	It emphasises authentic, real-world contexts, making it particularly suitable for clinical training.	It requires structured facilitation to ensure learning objectives are met.	Real-time access to patient data through mobile devices during clinical rounds enables situated learning.
5	Sociocultural Theory	It highlights the importance of social, cultural and collaborative dimensions in shaping cognitive development.	The theory may fail to recognise individual learning and self-regulation activities.	Mobile learning applications such as WhatsApp can facilitate collaboration, discussion, and group problem-solving activities that are aligned with sociocultural theory.
6	Self-directed Learning Theory	It emphasises learner autonomy, encouraging individuals to identify their learning needs, set goals, and evaluate their progress.	Some students may lack intrinsic motivation or the ability to self-regulate their learning effectively.	Mobile learning supports SDL by providing access to a wide range of resources, enabling learners to tailor their learning experience to their preferences and pace.

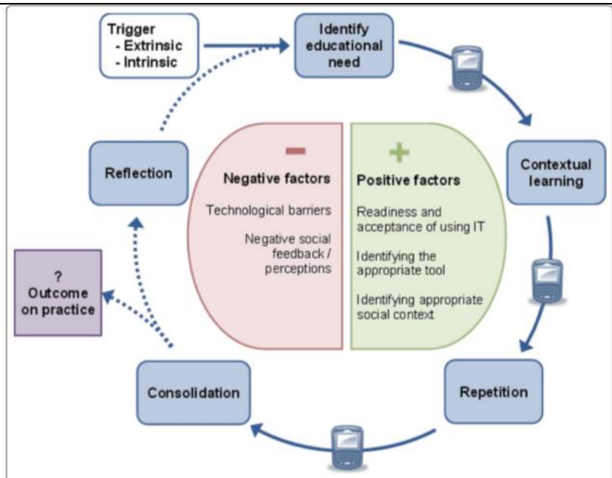
	Learning Theories	Strengths	Weaknesses	Relevance to Mobile Learning
7.	Self-regulated Learning Theory	It emphasises a cyclical process of self-regulation, consisting of goal-setting, self-monitoring of performance, and reflection.	Although it concerns self-regulation, the guidance of instructors is usually required in the process.	Mobile devices, such as tablets, can facilitate a self-regulated learning process.
8	Conversation Theory	It focuses on the role of dialogue in constructing shared understanding and fostering critical thinking and collaborative learning.	In asynchronous mobile learning environments, immediate interaction among learners is not possible.	Mobile learning platforms that allow synchronous interactions allow students to construct knowledge collaboratively.

Appendix D: The Scoping Review Matrix of 42 Empirical Studies

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
Boruff and Storie (2014), Canada (BYOD)	- What is the extent to which medical trainees and faculty use their mobile devices when answering clinical questions and finding medical information? - What are the facilitators and barriers to using mobile devices to find information related to medical studies and clinical work? How do health libraries support mobile users' clinical information needs?	1210 participants of medical students, residents, graduate students, faculty members	An online survey (the questionnaire is available, and it is pretested for face validity)	- 3rd 4th year medical students and residents used their devices more often - Information searching on mobile devices (finding drug information, performing clinical calculations, taking notes, searching for journal articles and reading journal articles - Use of medical resources and apps - Barriers (wireless access, knowing what resources were available, lack of time, understanding how to use the resources, technology problems, complicated installation process, screen size, technical limitations) - Facilitators (the speed and convenience of access)
Chase et al. (2018), UK	- Aim (to evaluate the impact of m-learning devices provided to support	275 medical students	Pre and post-use online questionnaire survey (the	- M-learning has a positive effect on students' perceived efficiency of working. - Experiences of use depend on pre-existing positive opinions about devices and some expected limitations.

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
(device supplied by the school)	placement-based learning by gathering feedback. - Objectives - (1) to identify the attitudes of the students and the perceived reaction of surrounding clinicians and patients towards the use of m learning devices in clinical learning settings - (2) to identify students' perceived impacts of m learning devices as an adjunct to learning in clinical settings - (3) to identify whether m learning devices have an impact on the reported length or efficiency of students' studying hours		questionnaire is available)	- Students are more likely to use the device in downtime than as part of their clinical learning. - Internet access as a limitation

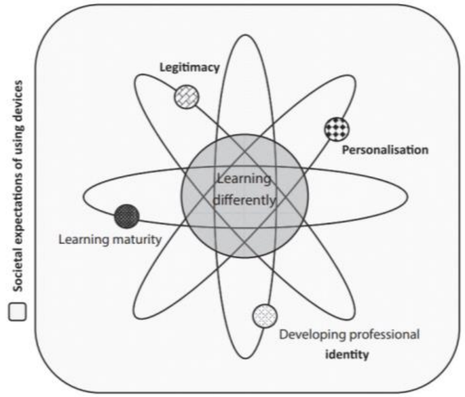
Author (year), country	RQ or aim of the study	Participants	Method	Key themes
	(4) to identify any significant limitation to the use of devices in healthcare education			
Clarke et al. (2019), Ireland (the device supplied by the school)	- To explore students' choices and their use of different devices in their first year of clinical attachment - To explore learners' experiences of using devices in clinical settings	279 medical students	- A mixed-methods approach (the design is not mentioned) An online survey followed by semi-structured interviews (the questions are not available)	- Constant use of online info to support their clinical learning - Three major categories - (1) connection and devices (diverse personal ownership of technology and how this is applied to source educational materials - (2) Influence and interaction with patients - (3) Influence and interaction with faculty - Two major themes - (1) devices are ideal for bedside care - (2) appropriate and inappropriate use of devices

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
Davies et al. (2012), UK (device supplied by the school)	To develop a CF to understand how the med students used the tech, how it enabled them to learn and what theoretical underpinning supported the learning	387 medical students (years 3,4 and 5)	A mixed-methods - Survey - Focus groups - Usage tracking data (Design is not mentioned) Four ways in which learning was enabled emerged from the focus group analysis... 1. Timely access to key facts -learning in context. 2. Consolidation of knowledge through repetition 3. A supplement rather than a replacement 4. Making use of wasted time."	 **Figure 1** Illustration of a model for mobile learning in the clinical setting showing influence of positive and negative contextual factors.

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
Ellaway et al. (2014), Canada (device supplied by the school)	To describe student behaviours, perceptions and attitudes towards mobile devices	101 medical students from year 1 to year 4	- A mixed methods study (the design is not mentioned) - Observation and focus group discussion lead to the development of the instrument (the questionnaire is available)	- Themes emerged are 1) different learners use their mobile devices differently 2) learners' use of mobile devices depends on their devices' affordances 3) learners' use of mobile devices aligns with the context 4) mobile devices are used to augment but not to replace laptops 5) learners only use some features of their mobile devices 6) learners want more control in mobile device selection 7) learners have concerns about using mobile devices 8) there is a hidden curriculum for mobile device use 9) the mobile device is a symbol as well as a tool 10) learners use multiple sources of support
Fan et al. (2016), Australia (BYOD)	To examine the types of Web 2.0 tools and mobile devices used and the reasons for the adoption	- Medical students (years 4 and 5) - Clinical teachers - Admin staff - Academics - Researchers	- A mixed-methods study (the design is not mentioned) - An online questionnaire (the questionnaire is available) and semi-structured interviews (interview questions are available)	- Wide use of mobile devices and Web 2.0 tools - purposes for adoption of the devices and Web 2.0 tools (quick and easy access to information, reliability, interoperability and connectivity and improved workflow and communication - barriers and challenges (time to learn new technologies, trustworthiness of information, dispersed information, selection of technology, reliability and interoperability of technology, security, information overload, disruption and interference with deep learning and effective and efficient professional practice)
Fralick et al. (2017), Canada (BYOD)	To determine whether medical apps improve knowledge of	- 62 residents and senior medical students	- Pre-post control study	- A control group using the app has a higher knowledge score compared to those that did not use the app. - About 90% of users found that the app is easy to navigate and useful.

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
	prescribing antibiotics			
Friederichs et al. (2014), Germany (device supplied by the school)	To compare the usability of mobile devices and a computer in searching the literature	120 medical students (3rd year)	- A randomized study - A control group use a computer - Experimental groups use iPod and iPad A questionnaire survey (the questionnaire is available)	- Mobility of the iPod and iPad is a significant advantage over the computer - The computer is rated superior to these devices in performing effective literature searches at the bedside - iPad is more satisfied with screen size - mobile devices at the bedside for literature searches are not suitable, but mobility has a substantial advantage
Gavino et al. (2013), Philippines (BYOD)	To describe information-seeking trends of physicians and medical students in terms of clinical health information needs, technological resources available and preferred knowledge sources when faced with medical questions	146 participants, of which 91% are doctors, 3% are interns, and 5% are medical students	- A survey using both paper and online questionnaire A questionnaire is available	- A basic mobile phone is the most used device at home and work - SMS, email, instant messaging and MMS are the most commonly used messaging tools at home and work - A primary source of information is a formulary for medication questions and colleagues for diagnostic dilemmas - PubMed for therapy and management questions

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
(Green et al., 2015), UK (device supplied by the school)	- To determine students' self-reported learning efficacy - To determine potential barriers To determine the acceptance of a M-learning scheme	278 medical students (year 4 and 5)	- A mixed methods study (design is not mentioned) A quantitative survey (the questionnaire is not available) followed by focus group discussions	- Enhanced students' learning experience during clinical attachment as they can use apps such as BNF Oxford textbook of clinical medicine, use for instant references - Portability of the smartphones - Better organize time by having mobile access to timetables and emails (time-saving) - Variation in the acceptance of smartphones
Jebraeily et al. (2017), Iran (BYOD)	- To describe common smartphone apps used To identify barriers to using them	508 medical students	- A paper-based questionnaire survey (the questionnaire is not available) Validity and reliability are mentioned in Cronbach alpha	- About 80% of students owned smartphones - The most commonly used apps are identified - Barriers (lack of accreditation of medical apps by valid health institutions, lack of support and update of applications by the developers, lack of adequate skills to use apps
Johnson et al. (2015), USA (BYOD)	To describe the use of smartphones by physicians and medical students	34 faculty, 80 residents and 94 medical students	An online survey (the questionnaire is not available)	- Different patterns of use in different settings - Most use the device while on break - Few use while with patients and during procedures - Three factors in considering the use of the device (degree of relevance to patient care, the appropriateness of behaviour in front of patients, and the issue of how disruptive that behaviour may be)
Joynes and Fuller (2016), UK	To explore students' and educators' views on the impact of mobile learning	- Medical students (all 5 years)	- Focus group discussion incorporating visual methodologies with students	- Four themes emerged (Learning maturity, Learning differently, Just-in-time learning, Learning legitimately

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
(device supplied by the school)	resources on placement learning experiences	Clinical teaching staff, including those who experienced the mobile programme as students	Semi-structured interviews with clinical teaching staff	 **Figure 1.** A conceptual framework for how use of mobile resources can shape learning behaviours. -
Khalifian et al. (2013), USA (BYOD)	To evaluate four popular search modalities used for daily clinical questions	6 medical students (year 3)	Satisfaction score for each modality from 1 to 5, where 1 is the lower and 5 is the higher quality	- Google is a preferred method for questions related to basic disease processes and multimedia resources (Caution should be exercised when using Google in front of patients) - Medscape is the most appealing app due to its broad scope of content and educational features.
Khamis et al. (2018), Saudi (BYOD)	To describe the uses, skills and preferences of IT in medical students	176 medical students (year 4 and 5)	A cross-sectional online survey (the questionnaire is not available)	- Most students prefer mobile devices and a moderate amount of IT in education - High academic value of Google, YouTube and PubMed - Technology helps work faster and makes learning creative
Lau and Kolli (2016), USA	To describe the usage of apps and	86 medical students	A paper-based questionnaire survey	- A large number of apps are used in internal medicine posting. - Less used in surgery, OBGY clerkships

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
(BYOD)	the benefits of using them		(the questionnaire is not available)	Benefits (accessibility and interactivity)
Law et al. (2018) USA (BYOD)	To describe the types of mobile devices students use in their clinical clerkship and their perception	125 medical students during general surgery clinical clerkship	An online survey (the questionnaire is available)	- Most students owned a smartphone, tablet or both - About 60% spend > 11 hours per week learning on a device for educational purposes - Most students preferred using technology, but some have concerns about decreased faculty/class interaction.
Loredo et al. (2018), Brazil (BYOD)	- To evaluate the use of smartphones in the educational context and Internet addiction To relate the usage of smartphone and Internet addiction with superficial and deep learning	710 medical students (divide into pre-clinical-yr 1 & 2, clinical yr 3& 4 and clerkships yr 5 & 6	- A cross-sectional survey (the questionnaire is not available) - Internet Addiction Test developed by Young in 1998 Revised two-factor Study Process Questionnaire developed by Briggs for surface and deep learning	- Almost all students have a smartphone - Uses of smartphones (lectures, classes and meetings) - Less than 50% of students used smartphones for more than 10 minutes for educational purposes - Almost 95% used smartphones in the classroom for noneducational activities such as social media and searching for general information - 68% are problematic Internet users - The frequency of smartphone use and higher Internet addiction were correlated to a higher level of surface learning and a lower level of deep learning.
Masters and Rawahi (2012), Oman	To describe - activities and frequency of	129 medical students (year 6)	A survey using a paper-based questionnaire	- Less usage of medical applications such as clinical guidelines and medical reference tools - Screen size, cost, limited memory and battery, and lack of institutional support as barriers

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
(BYOD)	usage of mobile devices - advantages and barriers when using mobile devices			Time-saving, ease of access and use as advantages
Nuss et al. (2014), USA (device supplied by the school)				
Patel et al. (2018), USA (BYOD)	To understand the perception of professionalism using smartphones	- 123 medical students 73 faculty	An online survey using five case scenarios to rate the behaviour of the clinician using a 5-point Likert scale	Faculty were more likely to find behaviour unprofessional compared to students.
Payne et al. (2012), UK (BYOD)	To describe medical students and junior doctors - Ownership of smartphones Usage of apps (types and frequency of usage)	257 medical students and 131 junior doctors	An online survey using a questionnaire (separate for doctors and students) The questionnaire was tested for validity and reliability but did not mention the values.	- About 80% of both students and doctors owned the smartphones - The majority of them owned 1-5 apps - Students used disease diagnosis/management and drug reference apps - Doctors use clinical score/calculator apps - Apps usage time is 1-30 minutes for students and 1-20 minutes for doctors

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
			Both questionnaires are available.	
Pimmer et al. (2013), Nepal (BYOD)	- To what extent does the adoption of tools (in the form of new ICT) lead to new and adapted learning activities for undergraduate students and residents in resource-constrained environments? To what extent does the adoption of tools (in the form of new ICT) lead to contradictions and changes in rules, communities and divisions of labour in the respective activity systems?	- Medical students (both undergraduate and postgraduate students) - Faculty	- A multiple case study methodology - The semi-structured interview of 8 focus groups of 4-8 participants in each group and a total of 43 Activity theory as a theoretical framework	- Search for ad-hoc information, documentation, and sharing of images and videos, as well as educational engagement in social network sites, as new and adapted tool-mediated activities. - Altered rules, regulations, and cultural norms, changes and extension of communities, division of labour: towards learner-centredness as contradictions - Suggestion for further research 1. Expand the geographical and cultural scope 2. Increase the methodological breadth and depth (quantitative survey to reach more participants, participatory observations and ethnological approaches to produce a more detailed analysis of the activities. 3. Theoretically triangulate the findings (e.g. using theories of mobile learning and informal/non-formal learning to enhance and broaden the theoretical basis. - Examine changes over a longer period to account for long-term development.

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
Pyörälä et al. (2019), Finland (the device supplied by the school)	- To explore students' perceptions of the use of mobile devices and digital note-taking practices - What are the students' most important self-reported study uses of mobile devices? - How did the note-taking practices change over the study years? - What are the students' perceptions of the best practices of note taking with mobile devices?	- 124 medical and 52 dental students	- An action research study - A longitudinal follow-up - An online survey - Focus group discussion (the questions are available)	- The note is the most frequently and consistently reported study use - While taking notes, students processed the new info and personalised the digital learning materials by making comments, underlining, marking images and drawing - Students organise the notes in their personalised digital library for retention - Students face resistance and ambivalence to mobile device usage in their clinical postings
Quant et al. (2016), USA (BYOD)	- To describe - the usage, reliability and popularity of mobile medical apps - perceptions of students on app usage affect the quality of patient-provider interaction	731 medical students	- An online survey (the questionnaire is not available)	- Most thought medical apps enhance clinical knowledge and are as reliable as textbooks - Medical apps save time, improve patient care and improve diagnostic accuracy - About half of the students believed that the use of apps in front of colleagues and patients makes them less competent - They are hesitant to use them out of fear of appearing less engaged

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
Rashid-Doubell et al. (2016), Middle East (BYOD)	- To describe the experiences of students using mobile devices in a clinical setting while learning and interacting with clinical teachers, patients and each other To identify challenges that facilitated or impeded the use of devices in the hospital	6 medical students	- Interpretative phenomenology using semi-structured interviews (an interview guide is not available)	- Three main themes have emerged. 1) Learning: building knowledge and understanding, information gathering, distraction 2) Professional identity: professional identity with the patient, professional identity with the clinical teacher, professional self-identity - Transitioning from medical students to the doctor: the change process, clinical skill acquisition, negotiating relationships
Robinson and Burk (2013), USA (BYOD)	To describe the use of tablet computers in terms of frequency and apps	Medical students from 148 AAMC-accredited medical schools	- An online survey (the questionnaire is not available)	- 3rd year students had the highest tablet computer usage - The Apple iPad is the most popular, followed by Android tablets - One or more times daily usage in about 25% of respondents - The most commonly reported uses are accessing medical reference applications, e-books and board study - Use of apps by 3rd-year students are for reference, USMLE study, clerkship materials, e-books, patient education, EMR access and online social networking
Robinson et al. (2013), UK (BYOD)	To describe the ownership, usage and attitudes of using smartphones	361 medical students from 3rd, 4th and 5th year	- A cross-sectional study - A survey (both paper-based and online questionnaire)	- 59% owned smartphones, and 37% reported the device supported their learning - Positive attitude towards smartphones as educational aids - Cost as a barrier - Potential for unprofessional behaviour, dependence upon smartphones and distraction as negative consequences

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
			- The questionnaire is available	
Sahanaa and Mishra (2018), India (BYOD)	To describe students' perception of using an app as a data collection tool	41 medical students	- A cross-sectional questionnaire survey	- Students enjoyed the paperless method of data collection and entry - The app was easy to install, user-friendly, save time in data collection and data entry
Sandholzer et al. (2015), Germany (BYOD)	To determine predictors of students' self-reported adoption of a smartphone app for general practice	305 medical students	- A survey using a paper questionnaire	- Multivariate logistic regression identified four predictors for the adoption of the app 1) Gender (being female) 2) A higher perceived benefit of the app 3) A higher personal interest in new technologies - A higher perceived impact of previous experiences on smartphone adoption
Sandholzer et al. (2016), Germany (BYOD)	To explore medical students' perception of general practitioner apps for training and subsequent work as a physician	305 medical students (year 4)	- A paper-based cross-sectional survey (the questionnaire is not available)	- The app has a higher potential than textbooks - Expect subsequent use as a physician for looking up info for diagnostic, therapy and prediction, access to electronic patient files, communication and networking, organization of medical training, and online monitoring of patients. - Considerations to use the app in their practice for accessing electronic patient files, networking with colleagues and telemedicine
Scott et al. (2015), Australia (BYOD)	- How do medical students and physicians use mobile devices to learn in the clinical setting? - What is the comparison between	- 236 medical students 109 physicians	- A mixed-methods explanatory sequential design - A paper-based survey to students and physicians (the questionnaire is not available)	- 90% of students and physicians owned mobile devices - Uses of devices (information verification, organization and communication - Challenges (Internet access difficulties)

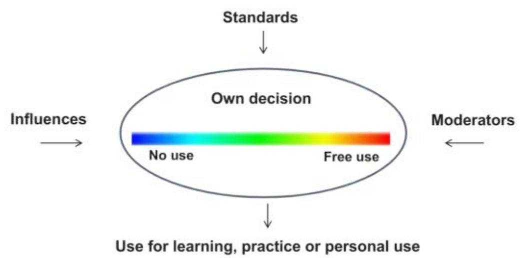
<table>
<tr><th>Author (year), country</th><th>RQ or aim of the study</th><th>Participants</th><th>Method</th><th>Key themes</th></tr>
<tr><td></td><td>students' and physicians' use?
- What are medical students', physicians', patients' and cares' attitudes about others' use?
- What are the ethical, privacy and security implications?</td><td></td><td>- Focus group discussions with students and physicians
- A short survey with patients and carers</td><td>
Table 3: Use of mobile devices (percentages represent responses on a 5-point Likert scale to options "strongly agree" or "agree," not "neutral," "disagree" or "strongly disagree")
<table>
<tr><th>Survey item</th><th>Students (%)</th><th>Physicians (%)</th><th>Chi-square (χ^2)</th><th>Comparison (p Value)</th></tr>
<tr><td>Use of a mobile device to</td><td></td><td></td><td></td><td></td></tr>
<tr><td>4.1 Improve learning</td><td>90.64</td><td>77.78</td><td>10.54</td><td>$p = .001$</td></tr>
<tr><td>4.2 Improve clinical knowledge and skills</td><td>84.68</td><td>71.30</td><td>8.43</td><td>$p = .004$</td></tr>
<tr><td>4.3 Improve basic science knowledge and skills</td><td>84.68</td><td>62.96</td><td>20.23</td><td>$p < .0001$</td></tr>
<tr><td>4.4 Improve timetabling or organisation</td><td>82.98</td><td>84.26</td><td>0.09</td><td>$p = .77$</td></tr>
<tr><td>4.5 Communicate</td><td>80.87</td><td>85.05</td><td>0.87</td><td>$p = .35$</td></tr>
<tr><td>Best uses</td><td></td><td></td><td></td><td></td></tr>
<tr><td>5.1 Access drug information</td><td>91.19</td><td>81.31</td><td>6.74</td><td>$p = .01$</td></tr>
<tr><td>5.2 Access treatment information</td><td>90.75</td><td>75.70</td><td>13.62</td><td>$p = .0002$</td></tr>
<tr><td>5.3 Access up-to-date information</td><td>83.63</td><td>77.57</td><td>1.78</td><td>$p = .18$</td></tr>
<tr><td>5.4 Confirm information I knew</td><td>81.06</td><td>65.09</td><td>10.09</td><td>$p = .002$</td></tr>
<tr><td>5.5 Access calendar or "to do" lists</td><td>68.28</td><td>81.31</td><td>6.18</td><td>$p = .01$</td></tr>
<tr><td>5.6 Access communication facilities</td><td>70.72</td><td>79.25</td><td>2.68</td><td>$p = .10$</td></tr>
<tr><td>Worst uses</td><td></td><td></td><td></td><td></td></tr>
<tr><td>6.1 Technical difficulties</td><td>50.88</td><td>50.94</td><td>0.00</td><td>$p = .99$</td></tr>
<tr><td>6.2 Internet access difficulties</td><td>84.14</td><td>74.53</td><td>4.35</td><td>$p = .04$</td></tr>
<tr><td>6.3 Difficult to use</td><td>9.73</td><td>7.55</td><td>0.42</td><td>$p = .52$</td></tr>
<tr><td>6.4 Screen too small</td><td>25.11</td><td>32.08</td><td>1.77</td><td>$p = .18$</td></tr>
<tr><td>6.5 It distracts me</td><td>20.18</td><td>20.95</td><td>0.03</td><td>$p = .87$</td></tr>
<tr><td>6.6 Unsure of tutors'/clinicians' reaction</td><td>77.53</td><td>25.96</td><td>79.98</td><td>$p < .0001$</td></tr>
<tr><td>6.7 Unsure of patients'/carers' reaction</td><td>77.97</td><td>32.69</td><td>63.28</td><td>$p < .0001$</td></tr>
</table>
- Individual decision-making making the use of mobile devices
- Two themes emerged (Distraction and benefits of mobile devices)


Figure 1: Individual decision making around use of mobile devices
-</td></tr>
<tr><td>Shah et al. (2016), Pakistan</td><td>- To assess the awareness of medical apps and academic</td><td>- 545 medical students</td><td>- A paper-based questionnaire survey</td><td>- Most students own smartphones
- About 40% used medical apps
- About 25% are aware of medical apps but did not use
- About 30% used e-books, but about 70% did not use them.</td></tr>
</table>

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
(BYOD)	use of smartphones			- Students use their smartphones as telecommunication rather than a gadget to improve medical knowledge.
Sheikhtaheri and Kermani (2018), Iran (BYOD)	- To investigate the use of mobile apps among medical and nursing students	- 194 medical students and 178 nursing students	- A survey (the questionnaire is not available)	- The most commonly used apps among medical students are medical dictionaries, drug apps, medical calculators and anatomical atlases.
Shenouda et al (2018), UK (BYOD)	- To explore the role of the smartphone for final year medical students and foundation year trainee doctors in terms of how and why they are using their phones for work and for learning and what issues arise from using the phone	- 7 medical students and 7 doctors	- A qualitative study using interviews and focus group discussion	- Uses of smartphones (prescribing practices, instant messaging allowing coordination of both work and learning opportunities across place and time) - Occasional use of clinical photographs - Concerns about public and colleague perceptions - Medical schools and healthcare institutions should seek to integrate such use into core curricula and training to enable safe and effective use and further ease the transition to foundation training.
Tran et al. (2014), Canada (BYOD)	- To explore the uses of personal smartphones by medical students during their clinical rotations - to describe the perceived impact on the confidentiality of	218 medical students (4th year)	- A paper-based survey - The questionnaire is developed by conducting semi-structured interviews with 7 students, literature review	- Almost all of the respondents owned smartphones, and most were iPhone - Uses of smartphones in clinical rotations (communication with medical team members about patient-related matters as well as non-patient-related matters) - About 70% had password protection on their phone - The disruptive nature of smartphones (about half had answered or made a call, texted or emailed during patient encounters - Communicating patients' personal health information (about 80% never used their phone to text or email identifiable patient info to colleagues.

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
	personal health information and professionalism.		and expert feedback. - The questionnaire is available.	- Attitudes about using personal mobile phones in clinical settings (more efficient clinical work and better patient care - Preparedness for using personal smartphones in a clinical environment (the school curriculum educated students on appropriate and inappropriate ways of using personal mobile phones for communicating patient information. - The threat to patient confidentiality posed by the use of unsecured communication devices such as smartphones
Twiss-Brooks et al. (2017), USA (BYOD)	To describe how students search and use information in their daily activities, especially in clinical settings	86 medical students (3^{rd} year)	Semi-structured interviews using thematic and content analysis	- Information resources (a variety of info resources for clinically relevant info) - The technology used (smartphones, desktop computers and tablet devices - Spaces (a variety of spaces, selection of space depends on noise levels, proximity to clerkship location, availability of computers, the strength of wireless access and ability to interact with others, convenience
Waldmann and Weckbecker (2013), Germany (BYOD)	To evaluate the usefulness of the Primary Care Guideline app in Family Medicine posting	14 medical students (final year)	Likert scale and free-text comments	- An additional learning aid - Used during the waiting period, before, during and after lectures - The challenge is that not all students have a smartphone
Wallace et al. (2012), Canada (BYOD)	To describe medical students, residents and faculty's mobile devices - Patterns of usage - Advantages - Challenges	18 participants (10 students, 7 residents and 1 faculty member) for interviews (Interview protocol)	A mixed-method study (An exploratory sequential design)	- Information management, communication and time management are the main uses - Portability, flexibility, access to multimedia and the ability to look up information quickly are advantages - Superficial learning, not understanding how to find good learning resources, distraction, inappropriate use and concerns about access and privacy as challenges - Future use will be increased

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
	- Anticipated future uses	213 participants (76 students, 65 residents and 41 faculty members) for the online survey (The questionnaire)		
Whipple et al. (2012), USA (BYOD)	To describe medical students' mobile devices - Possession - Usage in a normal day - Security - Privacy - Mobile applications	67 medical students (year 3)	An online survey using the MDQ questionnaire (the questionnaire is available)	- Voice calls, SMS, Internet, email are most common uses - About half of the participants never physically or electronically locked their phones - Privacy concerns such as emailing patient information intact (66.7%), posting de-identified information on YouTube (45.2%) and FB (42.2%)
Witt et al. (2016), Botswana (device supplied by the school)	to describe the use of smart devices (tablets) and the perceptions of students on their learning environment	82 medical students (year 3 and 4)	- A mixed-methods study (the design is not mentioned) - Quantitative data (frequency and usage of medical and communication apps - Qualitative data (focus group discussion) Interview questions are	- The most commonly used medical and communication apps are identified - Accessibility of information (consistent and constant access to medical info, portability of the device, but inadequate or unavailable Internet access sometimes) - Tablet utility in medical education and clinical care (looking up medical info such as drug doses during ward rounds) - Training and technical support for the use of the device (suggest repeat sessions with smaller group sizes) - Factors limiting tablet use (limited or lack of Internet access, security concerns, technical issues, negative perceptions from preceptors and patients, software and hardware issues

Author (year), country	RQ or aim of the study	Participants	Method	Key themes
			available in Table 2	
Youm and Wiechmann (2015), USA (device supplied by the school)	To describe the use of iPads and the perceptions of students	103 medical students (3rd year)	A survey (the delivery mode is not mentioned, and the questionnaire is not available)	- Positive perceptions - Uses (reading or writing emails, searching clinical information online and studying for exams) - Use of apps (few apps - Benefits (access to EMR during rounds, the ability to study during downtime, and quick or on-the-go access to information - Challenges (Wi-Fi access

Appendix E: The Search History for Previous Systematic Reviews Using MEDLINE Complete

Search	Search Query	Filters Applied	Results
S1	TI (mobile learning or mlearning or m-learning or mobile devices) AND TI (medical education or health professional education) AND TI (systematic review or meta analysis or qualitative systematic review)		4
S2	AB (mobile learning or mlearning or m-learning or mobile devices) AND AB (medical education or health professional education) AND AB (systematic review or meta analysis or qualitative systematic review)		40
S1 OR S2	S1 OR S2	English language, Academic Journals,	39
		Narrowed by Subject Major Headings (mobile applications, medical education, distance education, cell phone, medical students, anatomy, augmented reality, clinical clerkship, clinical competence, handheld computers, continuing education, graduate medical education, internship and residency, professional practice)	19

	Search ID#	Search Terms	Search Options	Actions
☐	S5	S1 OR S2	**Limiters** - English Language **Narrow by SubjectMajor:** - professional practice **Narrow by SubjectMajor:** - internship and residency **Narrow by SubjectMajor:** - education, medical, graduate **Narrow by SubjectMajor:** - education, continuing **Narrow by SubjectMajor:** - computers, handheld **Narrow by SubjectMajor:** - clinical competence **Narrow by SubjectMajor:** - clinical clerkship **Narrow by SubjectMajor:** - augmented reality **Narrow by SubjectMajor:** - anatomy **Narrow by SubjectMajor:** - students, medical **Narrow by SubjectMajor:** - cell phone **Narrow by SubjectMajor:** - education, distance **Narrow by SubjectMajor:** - education, medical **Narrow by SubjectMajor:** - mobile applications **Search modes** - Find all my search terms	View Results (19) View Details Edit
☐	S4	S1 OR S2	**Limiters** - English Language **Search modes** - Find all my search terms	View Results (39) View Details Edit
☐	S3	S1 OR S2	**Search modes** - Find all my search terms	View Results (40) View Details Edit
☐	S2	AB (mobile learning or mlearning or m-learning or mobile devices) AND AB (medical education or health professional education) AND AB (systematic review or meta analysis or qualitative systematic review)	**Search modes** - Find all my search terms	View Results (40) View Details Edit
☐	S1	TI (mobile learning or mlearning or m-learning or mobile devices) AND TI (medical education or health professional education) AND TI (systematic review or meta analysis or qualitative systematic review)	**Search modes** - Find all my search terms	View Results (4) View Details Edit

Appendix F: The General Characteristics of Nine Systematic Reviews

Authors and year of publication	Type of systematic review	Review questions	Study population	Types of intervention	Control groups	Pre-defined Outcomes	Findings	Conclusion	Contribution	Identified Research gaps	My critique
Bajpai et al. (2019)	A quantitative systematic review	To identify, map, and evaluate the use of learning theories in digital education	Pre and post-registration health professionals	(1) online-offline interventions (2) mobile digital education (mobile phones, tablets, PDAs and other handheld devices) (3) digital simulation-based interventions (VR, AR, VPs, game-based)	Traditional learning	Identification of learning theories for acquiring 1. Knowledge 2. Skills 3. Performance	242 studies were included. 1/4 of the included studies used single or multiple learning theories. PBL, social learning theory and multimedia learning theories were most commonly reported.	A significant association between the application of learning theory, validity of measurement instruments, and the statistical significance of primary outcomes in digital education interventions	Proposed a Theory-Technology Alignment Framework to design and implement digital education programmes	A lack of using pedagogical frameworks and learning theories in designing and implementing digital education interventions	This review evaluated learning theories used in the primary studies. It did not evaluate the effectiveness of digital education. Only 1/4 of the identified studies were sampled for the review. This ¼ sampling was based on the previous study.
Brusamento et al. (2019)	A quantitative systematic review	To evaluate the effectiveness of digital education among pediatric post-registration professionals	Post-registration professional in paediatrics	Digital education (online-offline, mobile learning, gaming, virtual, high-fidelity mannequins) vs traditional or no learning intervention	Traditional learning	Primary outcomes 1. Knowledge 2. Skills 3. Attitudes Secondary outcomes 1. Satisfaction 2. changes in clinical practice 3. economic aspects 4. changes in accessibility and availability to education 5. untoward effects	20 RCTs with 1382 participants High-fidelity mannequins were associated with higher skill scores compared to low-fidelity mannequins.	Digital education for post-registration health professionals in paediatrics was either as effective or more effective than traditional learning for outcomes such as skill, knowledge, attitude, and satisfaction.	Highlighting the potential of high-fidelity mannequins and computer-based education in improving skills and knowledge.	(1) Limited evidence on outcomes like attitude, satisfaction, costs, and adverse effects of digital education interventions; (2) The scarcity of data from low- and middle-income countries	The review evaluated mLearning from multiple perspectives to provide a more comprehensive understanding of its effectiveness by including primary and secondary outcomes.

Authors and year of publication	Type of systematic review	Review questions	Study population	Types of intervention	Control groups	Pre-defined Outcomes	Findings	Conclusion	Contribution	Identified Research gaps	My critique
Chandran et al. (2022)	A quantitative systematic review	To evaluate the effectiveness of smartphone applications in improving the knowledge and skills of health professions students	Medical, dental, nursing, allied health undergrad and postgrad students	Offline & online mobile applications	Did not explicitly mention the control group	1. Knowledge 2. Skills	52 studies with 4057 participants 15 studies with 962 participants showed improved knowledge scores 19 studies reported improved skills	Mobile applications as effective adjunct tools in improving knowledge and skills	Mobile apps can be used in preclinical and clinical subjects as adjunct learning tools.	The effectiveness of mobile applications, especially in low- and middle-income countries, was evaluated because the majority of the included studies were conducted in developed countries.	While the review included both qualitative and quantitative analyses, it did not provide a clear rationale for the inclusion of the qualitative component. The quantitative meta-analysis could have potentially been sufficient to evaluate the effectiveness of mobile applications in medical education, but the authors may have aimed to provide a more comprehensive understanding by incorporating the qualitative findings as well.
Dunleavy et al. (2019)	A quantitative systematic review	To evaluate the effectiveness of mlearning in improving knowledge, skills, attitude, and satisfaction	Pre and post-registration health professionals	mlearning interventions through handheld mobile devices or blended learning vs. traditional or other forms of digital learning	Traditional learning	Primary outcomes 1. Knowledge 2. Skills 3. Attitudes 4. Satisfaction Secondary outcomes 1. changes in clinical practice 2. economic aspects 3. changes in accessibility and availability to education 4. untoward effects	29 studies with 3175 learners mlearning improved knowledge and skills Inconclusive findings for attitude and satisfaction	mlearning is as effective as traditional learning or possibly more effective	The pedagogical benefits of mlearning in increasing knowledge and skills of health professions students	(1) a lack of research on the impact of mlearning in low and middle-income countries (2) a lack of research on the impact of mlearning on patient outcomes and changes in clinical practice (3) a lack of theoretical framework guiding the instructional design of mlearning interventions	The review evaluated mLearning from multiple perspectives to provide a more comprehensive understanding of its effectiveness by including primary and secondary outcomes.

Authors and year of publication	Type of systematic review	Review questions	Study population	Types of intervention	Control groups	Pre-defined Outcomes	Findings	Conclusion	Contribution	Identified Research gaps	My critique
Koohestani et al. (2018)	A quantitative systematic review	To synthesise the educational effects of mobile learning among health professions students	Health professions students	Mobile learning intervention	Traditional teaching methods	Kirkpatrick's outcome levels	21 studies included Three themes emerged (1) improvement in clinical competency and confidence (2) acquisition and enhancing theoretical knowledge (3) positive attitude and perception of mobile learning	Positive response and attitudes towards mobile learning	Mobile learning can positively affect the knowledge, skills, and attitudes of health professions students	(1) Evaluating the long-term effects of mobile learning intervention (2) evaluating the effects of confounding factors like prior knowledge, skills, organisation culture, support provided to mobile learning	Using Kirkpatrick's hierarchy for defining outcomes Quality assessment of included studies by BEME Guide Although experimental studies were included, meta-analysis was not performed. Instead, descriptions of the studies' characteristics are performed.
Kyaw et al. (2019)	A quantitative systematic review	To evaluate the effectiveness of digital education among medical students for communication skills development	Medical students	Digital education (online learning, virtual patient, video-assisted oral feedback)	Traditional learning (didactic lectures, oral feedback, role play)	Knowledge Skills Attitude	12 studies with 2101 students Low-quality evidence that digital education is as effective as traditional learning in communication skills development Blended digital education is as effective as traditional learning	Digital education, either standalone or blended, improved communication skills training	Synthesising evidence for digital education in improving communication skills among medical students	(1) a lack of long-term effectiveness data (2) a lack of studies conducted in low and middle-income countries	The inclusion and reporting of knowledge and attitude outcomes were not the primary focus as per the stated objective. This deviation from the main aim may have diluted the depth of the analysis and synthesis of the communication skills outcome.

Authors and year of publication	Type of systematic review	Review questions	Study population	Types of intervention	Control groups	Pre-defined Outcomes	Findings	Conclusion	Contribution	Identified Research gaps	My critique
Lall et al. (2019)	A qualitative systematic review	To synthesise findings from qualitative or mixed methods studies to provide factors influencing mlearning for medical and nursing education	Medical and nursing (did not mention whether undergrad or postgrad or both)	Mobile learning using mobile devices	The review was qualitative rather than using a quantitative experimental design, so there was no explicit description of the control groups	The review explored the factors that influenced the implementation of mLearning interventions from a qualitative standpoint to uncover the perspectives of learners and other key actors with experience in mLearning strategies. Particular attention is paid to perceptions of implementation processes	47 studies were included 1. Device Usability: The efficiency and portability of mobile devices, but also concerns about device vigilance and poor functionality, such as small screens 2. Social Technology: Social interactions and relationships between learners, educators, and patients, raising issues of professionalism and practice boundaries 3. Interaction Learning: Facilitated interactions and collaborative learning among students, as well as between students and educators. To organize their learning and engage in reflective practices 4. mlearning Processes: A shift towards more student-centred and collaborative learning 5. mlearning in Clinical Contexts: Required adequate institutional infrastructure, resources, and technical support, as well as training and guidance for both learners and educators	Mobile devices enable interactions between learners, peers, teachers, and learning content. Need institutional support, procedural guidance, training and maintenance services	A valuable contribution to the understanding of mLearning implementation, offering a nuanced, contextual perspective that can inform the design and deployment of mobile technologies to support the education of healthcare professionals	1. Lack of studies exploring ethical concerns related to patient privacy and data security 2. Insufficient detail on the educational purposes and learning theories underlying the mLearning 3. Lack of studies exploring mLearning experiences in university settings, as opposed to clinical settings	The use of Framework analysis may lead to the forced fitting of themes into the framework.

Authors and year of publication	Type of systematic review	Review questions	Study population	Types of intervention	Control groups	Pre-defined Outcomes	Findings	Conclusion	Contribution	Identified Research gaps	My critique
Maudsley et al. (2019)	A mixed-methods systematic review	What works best for health professions students using mobile devices in clinical settings	Health professions students	Use of mobile devices	Did not explicitly mention the control group	Kirkpatrick's outcome levels	Mobile devices support health professions students in various aspects such as assessment, communication, clinical decision-making, logbook/note-taking, and accessing information. Informal and hidden curricula concerns included disapproval, confidentiality, privacy, security, distraction, and mixed messages about policy.	Mobile devices provide powerful educational support on clinical placements, particularly aiding student transitions, metalearning, and care contribution. However, explicit policy addressing concerns about informal and hidden curricula is essential to tackle	The review highlights how these informal and hidden curricula can undermine students' use of mobile devices to support their learning, even when the devices have the potential to provide powerful educational support. Identifying and addressing these complex socio-cultural factors is crucial for effectively integrating mobile devices into clinical education. Without understanding and tackling the informal and hidden curricula, the full educational potential of mobile devices may not be realized.	The a need for more rigorous, relevant, and systematic research that addresses the complex sociocultural factors influencing mobile device use and explores their potential to support student learning and clinical practice,	Kirkpatrick's outcome 4 levels are used. Maxwell's dimensions for quality assessment of the studies
Mi et al. (2016)	A mixed-methods systematic review	To investigate the types of mobile devices used by health professions students, the resources and tools accessed via mobile devices, and the reasons for using these devices to access resources and tools.	Health professions students	Mobile devices	Did not mention the control group	As it was a qualitative systematic review, outcomes were not predefined	The diverse ways in which health professions students used mobile devices to access information resources, support patient care, enhance learning, and improve resident education while also identifying significant challenges that need to be addressed	Despite drawbacks, the rapid development of mobile technologies will offer new opportunities for learning design and lifelong learning habits.	Providing a comprehensive overview of mobile device use, identifying both the benefits and challenges, and highlighting the implications for health sciences libraries	A lack of studies to investigate long-term effectiveness of mobile learning	The review did not clearly mention how the findings from the quantitative studies were analysed for qualitative evidence.

Appendix G: The Methodological Characteristics of Nine Systematic Reviews

Authors and year of publication	Protocol registration	Types of included studies	Database Sources	Supplementary Searches	Study Selection (Inclusion criteria)	Data Extraction	Quality Appraisal	Data Analysis	Reporting	Members checking of study screening, data extraction	Assessment of the overall quality of the review	My critique
Bajpai et al. (2019)	Not mention	RCTs published between 2007 and 2016 Total records identifed = 874 RCTs	1. MEDLINE 2. CINAHL 3. EMBASE 4. PsycINFO 5. ERIC 6. Cochrane Central Register for trails 7. Web of Science	Not mention	Yes	Use of a pilot-tested data extraction form	Not mention	Mostly descriptive (Learning theories vs. general characteristics; Learning theories vs. types of intervention	Not mention or use the PRISMA.	Yes	Not mention	It is a systematic literature review. Although RCTs are included in the review, their effectiveness was not evaluated. Instead, it mainly described the inclusion of learning theories in the included studies.
Brusamento et al. (2019)	Yes at Prospero	RCTs published between 1990 and 2017 Total records identified = 30,532	1. MEDLINE 2. CINAHL 3. EMBASE 4. PsycINFO 5. ERIC 6. Cochrane Central Register for trails 7. Web of Science	Yes - Reference lists -Grey literature	Yes	Use a data extraction form	Assessment of Risk of Bias	Cochrane methodology Meta-analysis Pooled effect size	Use of the PRISMA	Yes	Yes (GRADE criteria)	It is a quantitative systematic review with meta-analysis to evaluate the effectiveness of the interventions.
Chandran et al. (2022)	Yes at Prospero	RCTs, quasi-experimental intervention cohort, cross-sectional Published between 2011 and 2020 Total records identified = 4,116	1. PubMed 2. Scopus 3. Cochrane Library	Yes Reference lists	Yes	Use a data extraction form	Assessment of Risk of Bias	Cochrane methodology Meta-analysis Pooled effect size	Use of the PRISMA	Yes	Not mention	It is a quantitative systematic review following the Cochrane methodology

Authors and year of publication	Protocol registration	Types of included studies	Database Sources	Supplementary Searches	Study Selection (Inclusion criteria)	Data Extraction	Quality Appraisal	Data Analysis	Reporting	Members checking of study screening, data extraction	Assessment of the overall quality of the review	My critique
Dunleavy et al. (2019)	Yes at Prospero	RCTs published between 1990 and 2017 Total records identified = 30,532	1. MEDLINE 2. CINAHL 3. EMBASE 4. PsycINFO 5. ERIC 6. Cochrane Central Register for trails 7. Web of Science	Yes - Reference lists -Grey literature	Yes	Use a data extraction form	Assessment of Risk of Bias (Yes)	Cochrane methodology Meta-analysis Pooled effect size	Use of the PRISMA	Yes	Yes (GRADE criteria)	It is a quantitative systematic review following the Cochrane methodology
Koohestani et al. (2018)	Not mention	Experimental studies published between 2007 and 2017 Total records identified = 1,109	1. PubMed/ MEDLINE 2. CINHAL 3. Embased 4. Web of Science 5. PsycINFO 6. ERIC 7. Cochrane Library 8. Google Scholar	Yes -Reference lists	Yes	Use a data extraction form	Yes (A tool used for BEME review)	Narrative descriptions and interpretation within included papers (Meta-analysis was not performed due to the heterogeneity of the study designs, tools, and outcomes)	Use of the PRISMA	Not mention	Not mention	It is a systematic literature review that focuses on the description of the characteristics of the studies. Although experimental studies were included, meta-analysis was not performed. Instead, descriptive analysis was conducted.
Kyaw et al. (2019)	Yes at Prospero	RCTs published between 1990 and 2018 Total records identified = 44,054	1. MEDLINE 2. CINAHL 3. EMBASE 4. PsycINFO 5. ERIC 6. Cochrane Central Register for trails 7. Web of Science	Yes -Grey literature	Yes	Use a data extraction form	Assessment of Risk of Bias	Meta-analysis The pooled effect size	Use of the PRISMA	Yes	Yes (GRADE criteria)	It is a quantitative systematic review following the Cochrane methodology

Authors and year of publication	Protocol registration	Types of included studies	Database Sources	Supplementary Searches	Study Selection (Inclusion criteria)	Data Extraction	Quality Appraisal	Data Analysis	Reporting	Members checking of study screening, data extraction	Assessment of the overall quality of the review	My critique
Lall et al. (2019)	Yes at Prospero	Qualitative and mixed-methods studies published between 1995 and 2017 Total records identified = 1,946	1. MEDLINE 2. CINHAL 3. EMBASE 4. PsycINFO 5. ERIC 6. Web of Science 7. International Clinical Trials	No	Yes	Use a data extraction form	Quality Assessment Tool used in previous studies	Framework analysis using the FRAME model	Use of the PRISMA	Yes	Not mention	It is a qualitative systematic review using Framework analysis. The use of Framework analysis may lead to the forced fitting of themes into the framework.
Maudsley et al. (2019)	Not mention	Quantitative, qualitative and mixed methods studies published between 1988 and 2015 Total records identified= 2,279	1. MEDLINE 2. CINAHL 3. ERIC 4.PsyINFO 5. Scopus 6. Web of Science 7. Cochrane Central	Yes -Reference lists - Key journals -Key proceedings	Yes	Use of a pilot-tested data extraction form	Maxwell's dimensions for quality assessment (Effectiveness, efficacy, equity, acceptability, accessibility, appropriateness)	Thematic analysis	Use of the PRISMA	Yes	Not mention	It is a Best Evidence Medical Education Systematic Review
Mi et al. (2016)	Not mention	Quantitative, Qualitative, and mix-methods published between 2010 and 2015 Total records identified=4,358	1. MEDLINE 2. CINAHL 3. EMBASE 4. Scopus 5. Web of Science 6. ERIC 7. PsyINFO 8. Google Scholar 9. Proquest dissertations and theses	Yes -Reference lists	Yes	Use a data extraction form	Not mention	Description of included studies' characteristics	Use of the PRISMA	Yes	Not mention	It is a systematic literature review that focuses on the description only.

Appendix H: A Summary of Inclusion and Exclusion Criteria for Selection of Studies

Criteria	Inclusion	Exclusion
Population	Undergraduate medical students, either alone or in combination with other healthcare professions, provided that the qualitative data for them can be extracted separately.	Faculty, postgraduate medical students, doctors, and other health professional students (if qualitative data cannot be separated).
Intervention	Use of mobile devices (smartphones, iPads, and tablets).	Use of desktop computers, laptops, PDAs, and other electronic devices.
Phenomenon of Interest	Experiences of students in using mobile devices for their learning activities	Studies do not focus on students' experiences in using mobile devices in education or address unrelated technological aspects.
Context	Academic settings (medical schools, hospitals and clinics) Non-academic settings (homes, hostels, and public commutes) if used for learning.	Recreational environments (game centres, movie theatres).
Methodologies	Qualitative research methodologies (phenomenology, ethnography, and grounded theory). Mixed methods methodology with clearly defined qualitative components.	Quantitative research methodologies (RCTs, cluster RCTs, experimental studies).
Data Collection Methods	Focus group discussions, interviews (individual or group, structured, semistructured or	Surveys.

	unstructured), and observation.	
Data Analysis Methods	Thematic analysis of qualitative data	Descriptive and inferential (e.g., mean, median, mode, standard deviation, statistical tests).
Language	English	Non-English languages
Time	2010-2022	Before 2010 and after 2022

Appendix I: Search Strings using Free Text Keywords and MeSH with Boolean Operators used for MEDLINE Complete

Study population (Student type)	Intervention (Mobile devices)	Phenomenon of Interest
1. MM Education, Medical	8. MM Cell Phone	28. MM Attitude
2. MM Education, Medical, Undergraduate	9. MM Mobile Applications	29. MM Behaviour
3. MM Student, Medical	10. MM Smartphone	30. MM Information Seeking Behaviour
S1 1 OR 2 OR 3	S4 8 OR 9 OR 10	31. MH Perception
4. medical N3 student*	11. iPad*	32. MH Knowledge
5. medical N3 education	12. android*	33. MM Learning
6. medical learner*	13. mobile phone*	34. MM Personal Satisfaction
7. medical trainee*	14. smartphone*	35. MM Health Knowledge, Attitudes, Practice
S2 TI, AB (4 OR 5…7)	15. smartphone *	S7 28 OR 29….35
S3 S1 OR S2	16. cell phone*	36. attitude*
	17. cellphone*	37. behavio?r*
	18. iPhone*	38. perception*
	19. mobile app*	39. knowledge
	20. mobile device*	40. skill*
	21. mobile learn*	41. learning
	22. mlearn*	42. outcome*
	23. m-learn*	43. implication*
	24. mobile technolog*	44. education N3 benefit*
	25. tablet* N3 computer*	S8 TI, AB (36 OR 37 … 44)
	26. tablet* N3 mobile*	S9 S7 OR S8

27. mobile N3 device*

S5 TI, AB (11 or 12 …

27)

S6 S4 OR S5

S10 = S3 AND S6 AND S9

Legends

MM= Major Concept in MeSH

TI= Title

AB= Abstract

S= Set

Appendix J: Search Strings for Different Databases

Search Strings for MEDLINE Complete and CINAHL Databases through EBSCOHost

S1	(MM "Education, Medical") OR (MM "Education, Medical, Undergraduate") OR (MM "Students, Medical")
S2	TI medical N3 education OR AB medical N3 education
S3	TI medical N3 student* OR AB medical N3 student*
S4	TI ("medical learner*" OR "medical trainee*") OR AB ("medical learner*" OR "medical trainee*")
S5	S1 OR S2 OR S3 OR S4
S6	(MM "Cell Phone") OR (MM "Mobile Applications") OR (MM "Smartphone")
S7	TI (tablet N3 computer OR tablet N3 mobile OR mobile N3 device) OR AB (tablet N3 computer OR tablet N3 mobile OR mobile N3 device)
S8	TI ("ipad*" OR "android*" OR "mobile phone*" OR "smart phone*" OR "smartphone*" OR "cellphone*" OR "cell phone*" OR "iphone*" OR "mobile app*" OR "mobile device*" OR "mobile learn*" OR "mlearn*" OR "m-learn*" OR “mobile technolog*) OR AB ("ipad*" OR "android*" OR "mobile phone*" OR "smart phone*" OR "smartphone*" OR "cellphone*" OR "cell phone*" OR "iphone*" OR "mobile app*" OR "mobile device*" OR "mobile learn*" OR "mlearn*" OR "m-learn*" OR “mobile technolog*)
S9	S6 OR S6 OR S7 OR S8
S10	(MM "Attitude") OR (MM "Behavior") OR (MM "Information Seeking Behavior") OR (MH "Perception") OR (MH "Knowledge") OR (MM "Learning") OR (MM "Personal Satisfaction")
S11	TI education* N3 benefit* OR AB education* N3 benefit*
S12	TI ("attitude*" OR "behavio?r*" OR "perception*" OR "knowledge" OR "skill*" OR "learning" OR "outcome*" OR "implication*") OR AB ("attitude*" OR "behavio?r*" OR "perception*" OR "knowledge" OR "skill*" OR "learning" OR "outcome*" OR "implication*")
S13	S10 OR S11 OR S12
S14	S5 AND S9 AND S13

Search Strings for Embase through the OVID Platform

S1 ("medical N3 student*" or "medical N3 education" or "medical learner*" or "medical trainee*").mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word]

S2 ("Education, Medical" or "Education, Medical, Undergraduate" or "Student, Medical").mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word]

S3 S1 OR S2

S4 ("ipad*" or "android*" or "mobile phone*" or "smartphone*" or "smartphone *" or "cell phone*" or "cellphone*" or "iphone*" or "mobile app*" or "mobile device*" or "mobile learn*" or "mlearn*" or "m-learn*" or "mobile technolog*" or "tablet* N3 computer*" or "tablet* N3 mobile*" or "mobile N3 device*").mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word]

S5 ("Cell Phone" or "Mobile Applications" or "Smartphone").mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word]

S6 S4 OR S5

S7 ("attitude*" or "behavio?r*" or "perception*" or "knowledge" or "skill*" or "learning" or "outcome*" or "implication*" or "education N3 benefit*").mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word]

S8 ("Attitude" or "Behavior" or "Information Seeking Behavior" or "Perception" or "knowledge" or "Learning" or "Personal satisfaction" or "Health Knowledge, Attitudes, Practice").mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word]

S9 S7 OR S8

S10 S3 AND S6 AND S9

Search Strings for ERIC, PsycINFO, and British Education Index Databases through EBSCOHost

S1 TI medical N3 education OR AB medical N3 education

S2 TI medical N3 student* OR AB medical N3 student*

S3 TI ("medical learner*" OR "medical trainee*") OR AB ("medical learner*" OR "medical trainee*")

S4 S1 OR S2 OR S3

S5 TI (tablet N3 computer OR tablet N3 mobile OR mobile N3 device) OR AB (tablet N3 computer OR tablet N3 mobile OR mobile N3 device)

S6 TI ("ipad*" OR "android*" OR "mobile phone*" OR "smart phone*" OR "smartphone*" OR "cellphone*" OR "cell phone*" OR "iphone*" OR "mobile app*" OR "mobile device*" OR "mobile learn*" OR "mlearn*" OR "m-learn*" OR “mobile technolog*) OR AB ("ipad*" OR "android*" OR "mobile phone*" OR "smart phone*" OR "smartphone*" OR "cellphone*" OR "cell phone*" OR "iphone*" OR "mobile app*" OR "mobile device*" OR "mobile learn*" OR "mlearn*" OR "m-learn*" OR “mobile technolog*)

S7 S5 OR S6

S8 TI education* N3 benefit* OR AB education* N3 benefit*

S9 TI ("attitude*" OR "behavio?r*" OR "perception*" OR "knowledge" OR "skill*" OR "learning" OR "outcome*" OR "implication*") OR AB ("attitude*" OR "behavio?r*" OR "perception*" OR "knowledge" OR "skill*" OR "learning" OR "outcome*" OR "implication*")

S10 S8 OR S9

S11 S4 AND S7 AND S10

Search Strings for Scopus Database

(TITLE-ABS-KEY ("attitude" OR "behaviour*" OR "perception*" "knowledge" "skill*" OR "learning" OR "outcome*" OR "implication*" OR "education benefit*") AND TITLE-ABS-KEY ("ipad*" OR "android*" OR "mobile phone*" OR "smartphone*" OR "smartphone*" OR "cell phone*" OR "cellphone*" OR "iphone*" OR "mobile app*" OR "mobile device*" OR "mobile learn*" OR "mlearn*" OR "m-learn*" OR "mobile technolog*" OR "tablet* computer*" OR "tablet* mobile*" OR "mobile device*") AND TITLE-ABS-KEY ("medical student*" OR "medical education" OR "medical learner*" OR "medical trainee*")) AND (LIMIT-TO (SUBJAREA , "MEDI")) AND (LIMIT-TO (LANGUAGE , "English"))

Search Strings for Web of Science Database through Clarivate Platform

S1	TI ("medical learner*" OR "medical trainee*" OR “medical education” OR “medical student*”) OR AB ("medical learner*" OR "medical trainee*" OR “medical education” OR “medical student*”)
S2	TI ("ipad*" OR "android*" OR "mobile phone*" OR "smart phone*" OR "smartphone*" OR "cellphone*" OR "cell phone*" OR "iphone*" OR "mobile app*" OR "mobile device*" OR "mobile learn*" OR "mlearn*" OR "m-learn*" OR “mobile technolog*) OR AB ("ipad*" OR "android*" OR "mobile phone*" OR "smart phone*" OR "smartphone*" OR "cellphone*" OR "cell phone*" OR "iphone*" OR "mobile app*" OR "mobile device*" OR "mobile learn*" OR "mlearn*" OR "m-learn*" OR “mobile technolog*)
S3	TI ("attitude*" OR "behavio?r*" OR "perception*" OR "knowledge" OR "skill*" OR "learning" OR "outcome*" OR "implication*") OR AB ("attitude*" OR "behavio?r*" OR "perception*" OR "knowledge" OR "skill*" OR "learning" OR "outcome*" OR "implication*")
S4	S1 AND S2 AND S3

Search Strings for Cochrane Library

Title Abstract Keyword (medical student) AND Title Abstract Keyword (mobile learning)
(Word variations have been searched)

Search Strings for Google Scholar through Publish or Perish Software WinPosix (x64) edition.

Keywords: "mobile learning" AND "medical education"

Appendix K: The Record-Keeping Forms of Database Searches

1.	Name of database	MEDLINE Complete
2.	Database Platform	EBSCOhost through Lancaster University Library Databases
3.	Date of Database Coverage	2010-2022
4.	Date searched	8 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	MeSH and Keywords search within the Title and Abstract field using Boolean operators of AND, OR
8.	Hits (Number of records retrieved by the strategy)	596
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl
10.	Exported file type to EndNote 20	.RIS Formatted File

1.	Name of database	CINAHL
2.	Database Platform	EBSCOhost through Lancaster University Library Databases
3.	Date of Database Coverage	2010-2022
4.	Date searched	28 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	MeSH and Keywords search within the Title and Abstract field using Boolean operators of AND, OR
8.	Hits (Number of records retrieved by the strategy)	241
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl
10.	Exported file type to EndNote 20	.RIS Formatted File

1.	Name of database	EMBASE
2.	Database Platform	OVID through Lancaster University Library Databases
3.	Date of Database Coverage	2010-2022
4.	Date searched	29 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	MeSH and Keywords search within the Title and Abstract field using Boolean operators of AND, OR
8.	Hits (Number of records retrieved by the strategy)	54
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl

10.	Exported file type to EndNote 20	.RIS Formatted File

1.	Name of database	Cochrane Library
2.	Database Platform	Through the University of Dundee
3.	Date of Database Coverage	2010-2022
4.	Date searched	28 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	Title Abstract Keyword of mobile learning AND medical students
8.	Hits (Number of records retrieved by the strategy)	217
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl
10.	Exported file type to EndNote 20	.RIS Formatted File

1.	Name of database	ERIC
2.	Database Platform	EBSCOhost through Lancaster University
3.	Date of Database Coverage	2010-2022
4.	Date searched	8 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	Keywords search within the Title and Abstract field using Boolean operators of AND, OR
8.	Hits (Number of records retrieved by the strategy)	37
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl

10.	Exported file type to EndNote 20	.RIS Formatted File
1.	Name of database	British Education Index
2.	Database Platform	EBSCOhost through Lancaster University
3.	Date of Database Coverage	2010-2022
4.	Date searched	29 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	Keywords search within the Title and Abstract field using Boolean operators of AND, OR
8.	Hits (Number of records retrieved by the strategy)	33
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl
10.	Exported file type to EndNote 20	.RIS Formatted File

1.	Name of database	PsycINFO
2.	Database Platform	EBSCOhost through Lancaster University
3.	Date of Database Coverage	2010-2022
4.	Date searched	8 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	Keywords search within the Title and Abstract field using Boolean operators of AND, OR
8.	Hits (Number of records retrieved by the strategy)	83
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl

10.	Exported file type to EndNote 20	.RIS Formatted File

1.	Name of database	Web of Science
2.	Database Platform	EBSCOhost through Lancaster University
3.	Date of Database Coverage	2010-2022
4.	Date searched	8 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	Keywords search within the Title and Abstract field using Boolean operators of AND, OR
8.	Hits (Number of records retrieved by the strategy)	114
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl
10.	Exported file type to EndNote 20	.RIS Formatted File

1.	Name of database	SCOPUS
2.	Database Platform	EBSCOhost through Lancaster University
3.	Date of Database Coverage	2010-2022
4.	Date searched	29 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	Search within the Title, Abstract and Keyword fields using Boolean operators of AND, OR
8.	Hits (Number of records retrieved by the strategy)	70
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl

10.	Exported file type to EndNote 20	.RIS Formatted File

1.	Name of database	Google Scholar
2.	Database Platform	Publish or Perish 8.2.3944.8118
3.	Date of Database Coverage	2010-2022
4.	Date searched	29 May 2022
5.	Search by	Eugenie Thwin
6.	Strategy	Keywords search mobile learning AND medical education
8.	Hits (Number of records retrieved by the strategy)	84
9.	Save file name	10 databases 29 May 2022 MyEndNote Library. enl
10.	Exported file type to EndNote 20	.RIS Formatted File

Appendix L: A Quality Appraisal Tool (Lall et al., 2019; Rees et al., 2011)

Dimensions	Methodological Quality Criteria	Ratings			
		Low	Medium	High	Comment
Trustworthiness of findings	1. Were steps taken to increase rigour in sampling?				
	2. Were steps taken to increase rigour in data collection?				
	3. Were steps taken to increase rigour in data analysis?				
Usefulness of findings	1. Were the findings of the study supported by the data?				
	2. What were the findings of the study in terms of breadth and depth?				
	3. To what extent do the findings of the study privilege the perspectives of participants in the study?				

Appendix M: An Ethical Application Form

Ethic form.pdf

Appendix N: An Ethical Approval and Participants' Consent for the Included Studies

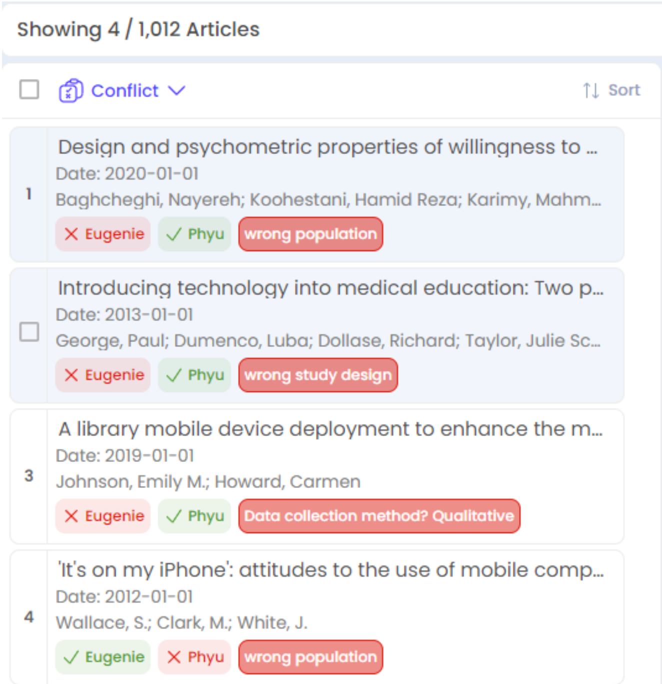
Authors of the Studies	An Ethical Approval	Participants' Consent
Algeria et al. (2014)	Yes	Yes
Clarke et al. (2019)	Yes	Yes
Doherty et al. (2015)	Yes	Yes
Ellaway et al. (2014)	Yes	Yes
Fan et al. (2016)	Yes	Yes
George et al. (2013)	Yes	Yes
Green et al. (2015)	Yes	Yes
Grover et al. (2020)	Yes	Yes
Harmon (2015)	Yes	Yes
Harrison et al. (2019)	Yes	Yes
Johnson et al. (2019)	Yes	Yes
Joynes and Fuller (2016)	Yes	Yes
Küçük et al. (2016)	Yes	Yes
Mansouri et al. (2020)	Yes	Yes
Nuss et al. (2014)	Yes	Yes
O'donovan and Maruthappu (2015)	Yes	Yes
Oo et al. (2022)	Yes	Yes
Pimmer et al. (2012)	Yes	Yes
Pimmer et al. (2013)	Yes	Yes
Raiman et al. (2017)	Not mention	Yes
Rashid-Doubell et al. (2017)	Yes	Yes
Robertson and Fowler (2017)	Yes	Yes
Scott et al. (2017)	Yes	Yes
Shenouda et al. (2017)	Yes	Yes
Sulley (2018)	Yes	Yes
Thomas (2021)	Not mention	Yes
Twiss-Brooks et al. (2017)	Yes	Yes

Authors of the Studies	An Ethical Approval	Participants' Consent
Wallace et al. (2012)	Yes	Yes
Witt et al. (2016)	Yes	Yes
Wu et al. (2013)	Yes	Yes

Appendix O: Number of Records Retrieved from Ten Databases

	Databases	Number of records
1.	MEDLINE Complete	596
2.	EMBASE	54
3.	CINAHL	241
4.	Cochrane Library (Trials)	217
5.	ERIC	37
6.	British Education Index	33
7.	PsycINFO	83
8.	Web of Science	114
9.	Google Scholar	84
10.	Scopus	70
	Total	1,529
	Duplicates	517
	Records to be screened	1,012

Appendix P: Four Conflicted Records Among Two Screening Processes



- The first article by Baghcheghi et al. (2020) was excluded by Eugenie and included by Phyu. Upon retrieving and reviewing the full paper, it was clear that the study population consisted of nursing and allied health students, not medical students. Consequently, this study was excluded.
- The second article by George et al. (2013) was excluded by Eugenie and included by Phyu. A thorough review of its full text revealed that, although it claimed to use a mixed methods approach, the results section exclusively described the quantitative findings. Therefore, it was also excluded.
- The third study by Johnson and Howard (2019) was excluded by Eugenie and included by Phyu. The full text of the paper showed that the texts in the learning journals were thematically analysed with a qualitative description. Therefore, this study was included.
- Lastly, the study by Wallace et al. (2012) was included by Eugenie and excluded by Phyu. Its full text indicated that the study population included medical students, residents, and faculty. However, the qualitative data for medical students could be extracted separately. Therefore, it was decided to be included.

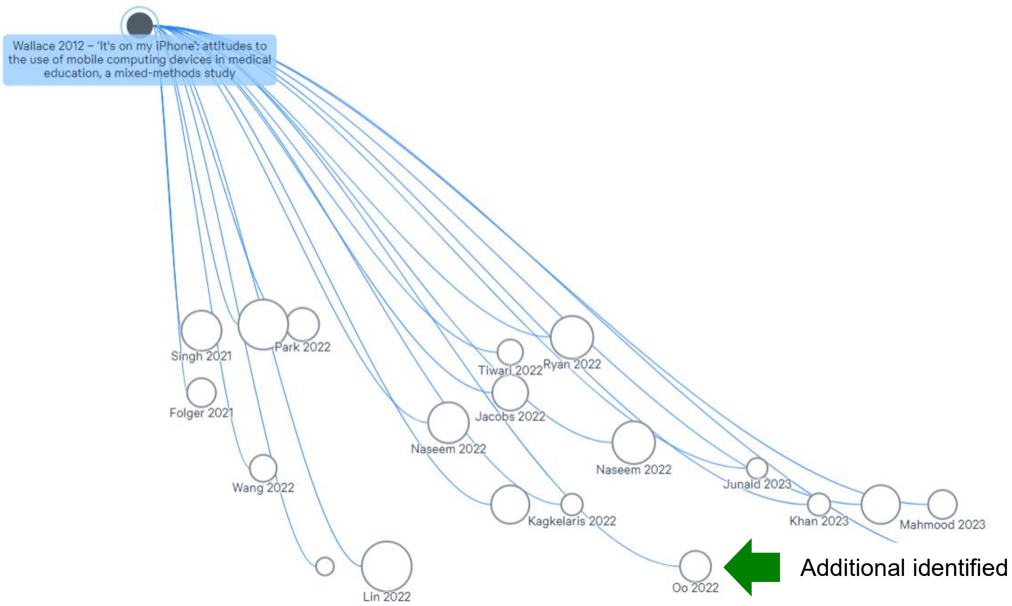
Appendix Q: Results of Supplementary Searches

Search Strategies	Data Sources		Additional Papers	Notes
Checking Reference List	References of 23 included studies	812 references	2	Scanning of reference lists electronically
	References of 9 systematic reviews	533 references	1	Scanning of reference list electronically
Forward citation tracking	Authors with the highest citations from the included studies	Wallace et al. (2012)	1	Litmaps Pro software is used
Hand Searching	E-journals from Lancaster University Library OneSearch	Six high-impact medical education journals	0	Search within the respective journals using keywords
Authors searching	Three authors with high contributions to mobile learning in medical education	Ellaway, Pimmer, and Wallace	0	Litmaps Pro software is used
Searching grey literature	Theses and dissertations	Topics related to mobile learning in medical or health professions education	2	Proquest from Lancaster University is used
	Blogs	Academy of Medical Educators (AoME)	1	AoME 2021 Conference
Additional relevant studies identified			7	

Appendix R: Supplementary Search Strategies and Results

A total of 812 references from 23 included empirical studies (Appendix S), and 533 references from nine systematic reviews (Appendix T) were electronically scanned. During this scanning process, three additional relevant studies were identified.

In addition to checking the reference lists of included papers, forward citation tracking was performed using the Litmaps Pro software (https://www.litmaps.com/). Among the 23 studies identified from electronic database searches, a study by Wallace et al. (2012) received the highest number of citations, with 425 citations. Given its high relevance to the topic of this study, it was considered a key paper, and further studies were explored citing them, as illustrated in Figure 4.2. From this forward citation tracking, one additional relevant article (Oo et al., 2022) was identified.



Key journals in medical education, recommended by the Medical Education Subject Guide at the University of Dundee (https://libguides.dundee.ac.uk/medicaleducation/journal_databases) were searched using two keywords: “medical education OR medical students” and “mobile learning OR mobile devices OR mobile applications” through E-journals in OneSearch of Lancaster University. These journals included Academic Medicine, BMC Medical Education, Clinical Teacher, Medical Education, Medical Teacher, and Advances in Health Science Education. However, no additional relevant articles were retrieved.

From the 23 included studies, three authors were identified as having significantly contributed to research on mobile learning in medical education: Ellaway, Pimmer, and Wallace. Using Litmaps Pro software, other papers by these authors were searched, and no additional relevant paper was identified.

The Proquest database from Lancaster University Library was used to search for theses or dissertations related to the topic, and two relevant theses were identified.

Appendix S: Number of References from 23 Studies from Electronic Database Searching

	Authors and Year of Publication	Number of References
1.	Alegría et al. (2014)	22
2.	Clarke et al. (2019)	36
3.	Ellaway et al. (2014)	34
4.	George et al. (2013)	19
5.	Green et al. (2015)	21
6.	Grover et al. (2020)	19
7.	Harrison et al. (2019)	29
8.	Johnson & Carmen (2019)	60
9.	Joynes et al. (2016)	24
10.	Küçük et al. (2016)	105
11.	Mansouri et al. (2020)	31
12.	Nuss et al. (2014)	19
13.	O'donovan and Maruthappu (2015)	28
14.	Pimmer et al. (2012)	38
15.	Pimmer et al. (2013)	54
16.	Raiman et al. (2017)	16
17.	Rashid-Doubell et al. (2016)	37
18.	Robertson and Fowler (2017)	34
19.	Scott et al. (2015)	51
20.	Shenouda et al. (2018)	58
21.	Twiss-Brooks et al. (2017)	16
22.	Wallace et al. (2012)	31
23.	Witt et al. (2016)	30
	Total references	812

Appendix T: Number of References from Nine Systematic Reviews

	Authors and Year of Publication	Number of References
1.	Bajpai et al. (2019)	49
2.	Brusamento et al. (2019)	62
3.	Chandran et al. (2022)	70
4.	Dunleavy et al. (2019)	60
5.	Koohestani et al. (2018)	43
6.	Kyaw et al. (2019)	40
7.	Lall et al. (2019)	79
8.	Maudsley et al. (2019)	89
9.	Mi et al. (2016)	41
	Total References	533

Appendix U: Descriptive Data Extraction Table for the 30 Included Studies

Data Extraction
(Mixed Methods anc

Appendix V: The Methodological Quality Assessment of the 30 Included Studies

Algeria et al. (2014)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. Clear sampling process but a small sample size.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. Well-defined, consistent data collection process, with efforts to ensure thoroughness by conducting two focus groups during and prior to the end of the clerkship programme.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. Triangulation and structured data analysis by using a focus group analysis framework increased rigour in data analysis.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are well-supported by the collected data.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. Good depth but limited breadth due to the focus on one data collection tool and one setting.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. Findings privilege participant perspectives effectively.

Clarke et al. (2019)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. The study includes a representative survey sample but has a low response rate, and limited detail on how non-responders were accounted for may affect the rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The combination of survey methods and iterative refinement of interview questions adds rigour to the data collection process.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. The use of systematic coding, double-coding, and respondent validation enhances the rigour of the data analysis.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The study presents findings that are clearly supported by the data collected through both methods.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study provides good depth on specific aspects of device use but has limitations in terms of broader generalisability.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively privileges participants' perspectives through detailed qualitative insights and representative survey findings.

Doherty et al. (2015)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. The study covers multiple programmes, but the use of convenience sampling reduces the rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The methodologically sound data collection process, including semi-structured interviews, adds rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. The use of grounded theory and triangulation between facilitator and student data adds substantial rigour to the data analysis.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are well-supported by rich qualitative data from both students and facilitators.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The depth of analysis is strong, but the scope and sample size limit the breadth.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The perspectives of participants are central to the findings, and their views are well-represented.

Ellaway et al. (2014)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. All students in a particular intake were invited, but the low survey response rate from senior students affected rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. A well-designed, mixed-methods data collection process with clear efforts to improve data quality.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. Comprehensive, multi-method data analysis with thematic coding and triangulation.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Findings are clearly derived from the qualitative and quantitative data.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. Good depth of insight, but the scope is limited to a specific context and institution.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. Participants' perspectives are central to the study's conclusions.

Fan et al. (2016)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. While the sample size and response rate are commendable, the imbalance between student and staff participation in interviews limits the depth of data collection from all relevant groups.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The combination of qualitative and quantitative methods, along with structured analysis, demonstrates strong data collection rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. The constructivist grounded theory approach to data analysis ensures rigour and reliability.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The study provides evidence to support its conclusions.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. Good breadth but limited depth in understanding the students' experiences because no student participated in the interviews.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: Medium. The perspectives of educators are well-represented, but student voices are underexplored in the qualitative phase.

George et al. (2013)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. While the sample size is substantial, the moderate response rate for the survey may affect the generalisability of the findings. However, random sampling for two focus groups may increase the rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The use of mixed methods enhances the rigour of the data collection process.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. The study uses appropriate statistical methods and triangulation between data sources, strengthening the analysis process.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are well-supported by data collected through multiple methods.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study provides good depth in exploring iPad use in specific contexts but lacks broader generalisability across different programs.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study privileges the perspectives of participants, particularly in the qualitative findings from focus groups.

Green et al. (2015)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. The response rate for the survey is acceptable, but voluntary participation in focus groups limits the sample's representativeness.

b) *Were the steps taken to increase rigour in data collection?*

Rating: Medium. The data collection process is sound overall, but the small size of 15 students for the focus groups reduces the rigour of the qualitative component.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. Appropriate statistical methods were used, and deductive-inductive thematic analysis was used for qualitative data.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are generally well-supported by data.

b**)** *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study provides a broad range of findings, but the depth is somewhat lacking due to the small focus group size and focus on one institution.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively integrates participants' perspectives, especially through the qualitative data.

Grover et al. (2020)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. While the sample size is adequate and the participation rate is high, there is insufficient detail on the sampling process for pre- and post-intervention comparison.

b*) Were the steps taken to increase rigour in data collection?*

Rating: High. The study employs a robust, mixed-methods approach.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. While the statistical analysis is sound, the limited information on performing thematic analysis weakens data analysis.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are clearly supported by the data, with consistent evidence across both quantitative and qualitative analyses.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. While the depth of analysis on the chosen topic is strong, the breadth of the study is limited due to the focus on a single subject area and small sample.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively integrates and privileges participants' perspectives, particularly through the FGD data.

Harmon (2015)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Low. The small sample sizes limit the study's ability to generalise findings.

b) *Were the steps taken to increase rigour in data collection?*

Rating: Medium. Data collection methods are appropriate, but there is a potential observer bias.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. While the use of TAM strengthens the quantitative analysis, qualitative analysis lacks transparency in how to analyse qualitative data.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: Medium. While the findings align with the data, small sample sizes and potential biases reduce the robustness of the conclusions.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study provides valuable insights but lacks breadth due to the small sample and specific focus on a single block at one institution.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively centres the perspectives of participants, although observer bias is a concern.

Harrison et al. (2019)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: High. The very high participation rate ensures that the sample is representative.

b) *Were the steps taken to increase rigour in data collection?*

Rating: Medium. The mixed-methods approach adds strength, but a lack of detailed information on focus group procedures reduces the rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. While appropriate methods were used, the lack of transparency around the validation of qualitative data analysis reduces the rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are strongly supported by the data, with consistent themes emerging from both quantitative and qualitative analyses.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. While the study provides good depth in its exploration of influencing factors, its breadth is limited by focusing on one institution and setting.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study privileges participants' perspectives by highlighting their personal experiences and decision-making processes.

Johnson and Howard (2019)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Low. The small sample size and lack of a detailed sampling strategy reduce the rigour of the sampling process.

b) *Were the steps taken to increase rigour in data collection?*
Rating: Medium. While the mixed-methods approach adds strength, the lack of validation for the SLJs and some reliability issues in the survey weaken the rigour of data collection.
c) *Were the steps taken to increase rigour in data analysis?*
Rating: Medium. The thematic analysis process is sound, but issues with the reliability of quantitative data reduce the overall rigour of the analysis.
2. Usefulness of Findings
a**)** *Were the findings of the study supported by the data?*
Rating: Medium. While the data support the findings, the small sample size and some data reliability issues limit their robustness.
b) *What were the findings of the study in terms of breadth and depth?*
Rating: Medium. The study offers good depth but limited breadth due to the small sample size and the focus on one specific programme.
c) *To what extent do the findings privilege the perspectives of participants in the study?*
Rating: High. The study effectively centres participants' perspectives, particularly through the qualitative reflections in the SLJs.

Joynes and Fuller (2016)
1. Trustworthiness of Findings
a) *Were the steps taken to increase rigour in sampling?*
Rating: Medium. While the sample size is adequate, more details on sampling procedures for focus groups would increase the rigour.
b) *Were the steps taken to increase rigour in data collection?*
Rating: High. Focus groups, aided by visual research methods in the form of process maps and semi-structured interviews, increase rigour in data collection.
c) *Were the steps taken to increase rigour in data analysis?*
Rating: Medium. The analysis process using an inductive approach is sound, but there is insufficient information, such as inter-coder reliability checks.
2. Usefulness of Findings
a) *Were the findings of the study supported by the data?*
Rating: High. The data clearly support the findings, though more educator perspectives could strengthen the results.

b) *What were the findings of the study in terms of breadth and depth?*
Rating: Medium. While the study offers valuable depth in its findings, the focus on a single programme at one institution limits the breadth and generalizability of the conclusions.
c) *To what extent do the findings privilege the perspectives of participants in the study?*
Rating: High. The study effectively privileges participant perspectives, particularly through the qualitative focus groups and interviews.

Küçük et al. (2016)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*
Rating: Medium. Random sampling and matching improve rigour, but more information on participant diversity would strengthen it.
b) *Were the steps taken to increase rigour in data collection?*
Rating: Medium. The validated tools add strength, but more detail on the interview process would enhance rigour.
c) *Were the steps taken to increase rigour in data analysis?*
Rating: Medium. The quantitative analysis is rigorous, but the lack of detail on the thematic analysis of qualitative data reduces the overall rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*
Rating: High. Both quantitative and qualitative data strongly support the results.
b) *What were the findings of the study in terms of breadth and depth?*
Rating: Medium. The study provides strong depth but is limited in scope, focusing on one university and one topic.
c) *To what extent do the findings privilege the perspectives of participants in the study?*
Rating: High. The study effectively integrates participant perspectives, especially through the qualitative interview data.

Mansouri et al. (2020)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. Purposive sampling is suitable for the study's goals, but the small sample size weakens the rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: Medium. The use of semi-structured interviews is a strength, but the absence of piloting or validation of interview protocols limits the rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. The analysis is thorough and includes member checks, but the absence of formal inter-rater reliability measures reduces the rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Qualitative data from multiple sources strongly support the findings.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study offers valuable depth but is limited in breadth due to its focus on a single institution and specific cohort.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively centres on participant perspectives, particularly through its focus group approach.

Nuss et al. (2014)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. While the sample represents the full cohort, it is institution-specific and lacks diversity details, which limits broader applicability.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The mixed methods study, using multiple, complementary data collection methods, is a strong point, though more detail on piloting or validation of tools could improve rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. While the use of inductive analysis is appropriate, the lack of detail on inter-rater reliability weakens the overall rigour of the analysis.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Robust data across multiple data sources clearly support the findings.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study provides strong depth but lacks breadth, as it focuses on a narrow population and context.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study places participants' perspectives at the centre of the analysis, giving a clear voice to the student's experiences.

Odonovan et al. (2015)

1. Trustworthiness of Findings

a*) Were the steps taken to increase rigour in sampling?*

Rating: Low. The small sample size and non-randomised selection weaken the rigour of sampling.

b) *Were the steps taken to increase rigour in data collection?*

Rating: Medium. The use of multiple data sources strengthens the study, but the absence of validation or piloting of the questionnaires and interviews reduces the overall rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. The statistical methods are appropriate, but the lack of formal validation for qualitative analysis weakens the rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are well-supported by both quantitative and qualitative data, although the small sample size limits generalisability.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study provides good depth in exploring the technology and educational outcomes, but the narrow scope limits broader applicability.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively captures and integrates participant perspectives through qualitative methods.

Oo et al. (2022)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. The sample is diverse within the institution, but the small size and lack of broader representativeness limit the rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. While the survey was validated, more information about the FGDs would enhance the rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. The analysis methods are appropriate, but the absence of inter-rater reliability checks reduces rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are well-supported by robust data from multiple sources.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. While the depth is strong, the study's scope is narrow as it focuses on one institution.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study centres participant perspectives effectively, particularly through qualitative findings.

Pimmer et al. (2012)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. While the sample is balanced across private and public institutions by including both educators and students, the purposive sampling may limit the rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: Medium. The use of focus groups strengthens rigour, but including informal talks as one of the data collection methods decreases its rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. The inductive thematic analysis is appropriate, and gaining consensus among researchers increases the rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The study's findings are well-supported by the data collected from multiple sources.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study provides strong depth but is limited in breadth due to its focus on a specific setting and platform.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study incorporates and privileges the perspectives of participants, particularly through qualitative findings.

Pimmer et al. (2013)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. The sampling strategy ensured diversity, but the purposive sampling may reduce the rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The use of an interview guide for the semi-structured interviews increases the rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. The thematic coding process was rigorous by including members checking, gaining consensus and involving participants to comment on the findings.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are robust and well-supported by data from multiple qualitative sources.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study provides valuable insights into mobile learning in resource-constrained environments but is limited in scope and generalisability.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively captures and privileges the perspectives of participants, particularly through its qualitative approach.

Raiman et al. (2017)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. The sample is small and only includes one particular clinical rotation group.

b) *Were the steps taken to increase rigour in data collection?*

Rating: Medium. The structured interview approach and collection of WhatsApp messages are used.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. The analysis using both quantitative and qualitative methods is appropriate, but there is no information about inter-coder reliability checks.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Both quantitative and qualitative data strongly support the findings.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study provides valuable depth but is limited in breadth by its small sample size and narrow focus.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively integrates and reflects participants' perspectives, particularly through qualitative methods.

Rashid-Doubell et al. (2016)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: High. The use of interpretative phenomenological analysis (IPA) does not impose sample size. Therefore, a small sample size does not affect the rigour of sampling.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The individual in-depth semi-structured interviews using an interview guide increase the rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. The use of IPA is appropriate, as using line-by-lining coding, member checking, and gaining consensus among researchers increases the rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are well-supported by the data collected from the interviews.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The depth of the findings is strong, but the limited scope in a single institution reduces the breadth.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study successfully captures and privileges the perspectives of the participants.

Roberston and Fowler (2017)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. The voluntary nature of participation in the study may reduce the rigour of sampling.

b*) Were the steps taken to increase rigour in data collection?*

Rating: Medium. While focus groups are a suitable method for qualitative exploration, no description of using the interview guide reduces rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. The use of thematic analysis is appropriate, but no description of member checking and gaining consensus may reduce the rigour of the analysis.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Qualitative data from multiple focus groups strongly support the findings.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study offers valuable depth but is limited in breadth due to its narrow focus on a specific cohort and institution.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study successfully captures and privileges the perspectives of participants, particularly through qualitative methods.

Scott et al. (2015)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: High. The large and diverse sample provides robust representation, though more transparency on patient selection would enhance rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The use of mixed-methods sequential explanatory design and development of instruments by stakeholders adds strong rigour to the data collection.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. The triangulation of quantitative and qualitative findings and reporting of integrated data strengthen the rigour of data analysis.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Diverse and comprehensive data from multiple participant groups clearly support the conclusions.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. While the study provides a thorough analysis, its generalisability is limited by a specific setting.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. Participants' perspectives are central to the findings, contributing significantly to the study's value.

Shenouda et al. (2018)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. While the study includes participants with varying levels of experience, the use of convenience sampling may have affected the diversity of perspectives.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The use of both focus groups and interviews increases rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. The use of detailed transcription, thematic analysis, and cross-case analysis enhances the rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Qualitative data from both interviews and focus groups strongly support the findings.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study offers valuable insights into smartphone use during the transition to foundation training, but its findings are confined to one NHS trust.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study successfully captures and privileges the perspectives of its participants.

Sulley (2018)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: High. The sampling strategy was broad and representative, though response bias remains a concern.

b) *Were the steps taken to increase rigour in data collection?*

Rating: Medium. The study used multiple data collection methods, but the lack of piloting or validation of instruments limits the rigour.

c*) Were the steps taken to increase rigour in data analysis?*

Rating: Medium. The analysis methods are suitable, but the absence of inter-rater reliability checks reduces the rigour of the qualitative analysis.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are well-supported by the data from multiple methods and models.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study offers both breadth and depth in exploring m-health use across several institutions, although its focus is limited to one country**.**

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively captures and privileges participants' perspectives through its use of mixed methods and multiple stakeholder groups.

Thomas (2021)

Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium**.** While the study targeted relevant groups (students and educators), the small sample size and limited participation from senior educators affected the representativeness of the findings.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High**.** Despite the small sample size, the use of semi-structured interviews across two rounds and the inclusion of different participant groups (students, fellows, and educators) strengthens the rigour of data collection.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High**.** The rigorous analysis process, including the use of phenomenological methods and cohort analysis, ensures that the findings are well-grounded in the data.

2) Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High**.** The study provides well-supported conclusions based on the data collected from both rounds of interviews.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium**.** The study provides good insights into the changing perceptions of mobile learning, but the small sample size and single-institution focus limit the breadth and depth of the findings.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: Medium. While the study privileges educators' and students' perspectives, the imbalance in participation and the over-representation of senior educators may limit the comprehensiveness of student perspectives.

Twiss-Brooks et al. (2017)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. The sample size is sufficient for qualitative research, but the use of convenience sampling limits the overall representativeness and rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The data collection methods are appropriate and provide rich insights.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. The content and thematic analysis methods are suitable, but the absence of inter-rater reliability checks reduces the overall rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. The findings are well-supported by rich qualitative data from diverse participants.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study offers substantial depth but is limited to one institution, which affects the breadth.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively captures and privileges participants' perspectives through the ethnographic method.

Wallace et al. (2012)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. The sample is sizable and diverse, but the use of convenience sampling and the low response rate limit the rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The combination of online surveys and semi-structured interview methods adds rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: Medium. The thematic analysis was appropriate, but a lack of information on inter-rater reliability checks weakens the rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Comprehensive qualitative and quantitative data strongly support the findings.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. While the study provides detailed insights into multiple factors, its scope is limited to one medical school, reducing broader applicability.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively captures and privileges participants' perspectives through its mixed-methods approach.

Witt et al. (2016)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: Medium. While the sample is of a reasonable size, convenience sampling introduces bias and reduces the rigour.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The use of mixed methods is a strength and increases the rigour.

c) *Were the steps taken to increase rigour in data analysis?*

Rating: High. Appropriate analysis methods for both quantitative and qualitative data were used, and inter-coder checks increased the rigour of the analysis.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Data from both quantitative and qualitative sources strongly back the findings.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study covers a wide range of topics but lacks depth due to its limited scope in one specific location.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study effectively centres on the experiences and perspectives of participants, particularly through its qualitative component.

Wu et al. (2013)

1. Trustworthiness of Findings

a) *Were the steps taken to increase rigour in sampling?*

Rating: High. The sampling approach was robust and designed to ensure diversity.

b) *Were the steps taken to increase rigour in data collection?*

Rating: High. The mixed-methods approach and variety of data sources increase the rigour.

c)*Were the steps taken to increase rigour in data analysis?*

Rating: High. The deductive approach and applying a conceptual framework increases the rigour.

2. Usefulness of Findings

a) *Were the findings of the study supported by the data?*

Rating: High. Comprehensive data from interviews, observations, and email analysis strongly support the findings.

b) *What were the findings of the study in terms of breadth and depth?*

Rating: Medium. The study offers both breadth and depth in exploring smartphone use, though its focus on a specific context limits broader applicability.

c) *To what extent do the findings privilege the perspectives of participants in the study?*

Rating: High. The study successfully centres on participants' perspectives through the use of qualitative methods and triangulation of multiple data sources.

Appendix W: A Summary Table of Quality Appraisal of the Included Studies

	Trustworthiness of Findings				Usefulness of Findings			
Study reference no.	Sampling	Data collection	Analysis	*Overall rating*	Findings supported by the data	Breadth and depth achieved in the findings	Perspectives privileged	*Overall rating*
Algeria et al. (2014)	Medium	High	High	***High***	High	Medium	High	***High***
Clarke et al. (2019)	Medium	High	High	***High***	High	Medium	High	***High***
Doherty et al. (2015)	Medium	High	High	***High***	High	Medium	High	***High***
Ellaway et al. (2014)	Medium	High	High	***High***	High	Medium	High	***High***
Fan et al. (2016)	Medium	High	High	***High***	High	Medium	Medium	*Medium*
George et al. (2013)	Medium	High	High	***High***	High	Medium	High	***High***
Green et al.(2015)	Medium	Medium	High	*Medium*	High	Medium	High	***High***
Grover et al. (2020)	Medium	High	Medium	*Medium*	High	Medium	High	***High***
Harmon (2015)	Low	Medium	Medium	*Medium*	Medium	Medium	High	*Medium*
Harrison et al. (2019)	High	Medium	Medium	*Medium*	High	Medium	High	***High***
Johnson and Howard (2019)	Low	Medium	Medium	*Medium*	Medium	Medium	High	*Medium*
Joynes and Fuller (2016)	Medium	High	Medium	*Medium*	High	Medium	High	***High***
Küçük et al. (2016)	Medium	Medium	Medium	*Medium*	High	Medium	High	***High***
Mansouri et al. (2020)	Medium	Medium	Medium	*Medium*	High	Medium	High	***High***
Nuss et al. (2014)	Medium	High	Medium	*Medium*	High	Medium	High	***High***
Odonovan and Maruthappu (2015)	Low	Medium	Medium	*Medium*	High	Medium	High	***High***

	Trustworthiness of Findings				Usefulness of Findings			
Study reference no.	Sampling	Data collection	Analysis	*Overall rating*	Findings supported by the data	Breadth and depth achieved in the findings	Perspectives privileged	*Overall rating*
Oo et al. (2022)	Medium	High	Medium	Medium	High	Medium	High	***High***
Pimmer et al. (2012)	Medium	Medium	High	*Medium*	High	Medium	High	***High***
Pimmer et al. (2013)	Medium	High	High	***High***	High	Medium	High	***High***
Raiman et al. (2017)	Medium	Medium	Medium	*Medium*	High	Medium	High	***High***
Rashid-Doubell (2016)	High	High	High	***High***	High	Medium	High	***High***
Robertson and Fowler (2017)	Medium	Medium	Medium	*Medium*	High	Medium	High	***High***
Scott et al. (2015)	High	High	High	***High***	High	Medium	High	***High***
Shenouda et al. (2018)	Medium	High	High	***High***	High	Medium	High	***High***
Sulley (2018)	High	Medium	Medium	*Medium*	High	Medium	High	***High***
Thomas (2021)	Medium	High	High	***High***	High	Medium	Medium	*Medium*
Twiss-Brooks et al (2017)	Medium	High	Medium	*Medium*	High	Medium	High	***High***
Wallace et al. (2012)	Medium	High	Medium	*Medium*	High	Medium	High	***High***
Witt et al. (2016)	Medium	High	High	***High***	High	Medium	High	***High***
Wu et al. (2013)	High	High	High	***High***	High	Medium	High	***High***

Appendix X: Initial Coding of 499 Codes, A Codebook and Coded Segments of the final set of Codes from 30 Studies

Initial Coding of 499 codes.docx

A Codebook of final set.docx

Summaries with Coded Segments of

Appendix Y: The Number of Studies Contributing to the Six Descriptive Themes

	Themes	The number of studies contributing to themes	The authors of the studies
1	External Factors Affecting Device Usage (External factors influencing students' use of devices)	17	Alegría et al. (2014), Clarke et al. (2019), Ellaway et al. (2014), Fan et al. (2016), Green et al. (2015), Harrison et al. (2019), Joynes and Fuller (2016), Oo et al. (2022), Pimmer et al. (2013), Rashid-Doubell et al. (2016), Scott et al.(2015), Sulley (2018), Shenouda et al. (2018), Thomas (2021), Twiss-Brooks et al (2017), Witt et al. (2016)
2	Personal Factors Affecting Device Usage (Personal factors of students influencing their use of devices)	17	Alegría et al. (2014), Clarke et al. (2019), Doherty et al. (2015), Ellaway et al. (2014), Harmon (2015), Harrison et al. (2019), Johnson and Howard (2019), Joynes and Fuller (2016), Mansouri et al. (2020), Nuss et al. (2014), Raiman et al. (2017), Rashid-Doubell et al. (2016), Scott et al. (2015), Shenouda et al. (2018), Thomas (2021), Wallace et al. (2012), Witt et al. (2016)
3	Usability of Mobile Devices in Medical Education (The functional features of mobile devices in relation to students' learning)	17	Alegría et al. (2014), Clarke et al. (2019), Doherty et al. (2015), Ellaway et al. (2014), Fan et al. (2016), George et al. (2013), Green et al. (2015), Harrison et al. (2019), Nuss et al. (2014), Pimmer et al. (2013), Oo et al. (2022), Raiman et al. (2017), Shenouda et al. (2018), Sulley (2018), Twiss-Brooks et al. (2017), Witt et al. (2016), Wu et al. (2013)
4	Benefits of Mobile Technology in Medical Education (Pedagogical benefits and improved patient care by using mobile devices in medical education)	19	Alegría et al. (2014), Clarke et al. (2019), Green et al. (2015), Grover et al. (2017), Harmon (2015), Joynes & Fuller (2016), Küçük et al. (2016), Mansouri et al. (2020), Nuss et al. (2014), O' donovan and Maruthappu (2015), Pimmer et al. (2012), Pimmer et al. (2013), Raiman et al. (2018), Rashid-Doubell et al. (2016), Sulley (2018), Thomas (2021), Twiss-Brooks et al. (2017), Wallace et al. (2012), Witt et al. (2016)
5	Challenges Encountered in Using Mobile Devices (Challenges students face in using mobile devices)	12	Doherty et al. (2015), Ellaway et al. (2014), Fan et al. (2016), George et al. (2013), Grover et al. (2020), Harrison et al. (2019), Oo et al. (2022), Rashid-Doubell et al. (2016), Robertson and Fowler (2017), Scott et al. (2015), Sulley (2018), Wallace et al. (2012)

	Themes	The number of studies contributing to themes	The authors of the studies
6	Strategies to Overcome Challenges (The strategies students adopt to negotiate their device usage to mitigate the challenges)	8	Alegría et al. (2014), Clarke et al. (2019), Ellaway et al. (2014), Green et al. (2015), Harrison et al. (2019), Rashid-Doubell et al. (2016), Shenouda et al. (2019), Witt et al. (2016)

Appendix Z: The Number of Studies Contributing to the Sub-Themes

	Themes	Sub-themes	The number of studies contributing to sub-themes	The authors of the sub-themes
1	External Factors Affecting Device Usage (External factors influencing students' use of devices)	Institutional Factors (The guidelines, support, and cultural factors of medical schools and hospitals)	6	Clarke et al. (2019), Harrison et al. (2019), Joynes and Fuller (2016), Rashid-Doubell et al. (2016), Scott et al. (2015), Thomas (2021)
		Factors Related to Medical Educators (Attitudes, behaviours, guidance and technological literacy of medical educators)	14	Alegría et al. (2014), Ellaway et al. (2014), Fan et al. (2016), Green et al. (2015), Harrison et al. (2019), Joynes and Fuller (2016), Oo et al. (2022), Pimmer et al. (2013), Rashid-Doubell et al. (2016), Scott et al.(2015), Sulley (2018), Thomas (2021), Twiss-Brooks et al (2017), Witt et al. (2016)
		Perceptions of Patients (Attitudes and behaviours of patients towards students' use of devices)	6	Clarke et al. (2019), Green et al. (2015), Harrison et al. (2019), Johnson and Howard (2019), Rashid-Doubell et al. (2016), Shenouda et al. (2018)
		Influence of peers and families (Support and suggestions of peers and families for students' use of devices)	3	Ellaway et al. (2014), Sulley (2018), Thomas (2022).
2	Personal Factors Affecting Device Usage (Personal factors of students influencing their use of devices)	Personal Beliefs and Perceptions of Using Mobile Devices in Educational and Clinical Contexts (Students' beliefs and perceptions on the use	12	Clarke et al. (2019), Ellaway et al. (2014), Harmon (2015), Harrison et al. (2019), Johnson and Howard (2019), Mansouri et al. (2020), Raiman et al. (2017), Rashid-Doubell et al. (2016), Scott et al. (2015), Shenouda et al. (2018),

	Themes	Sub-themes	The number of studies contributing to sub-themes	The authors of the sub-themes
		of devices for their learning)		Wallace et al. (2012), Witt et al. (2016).
		Emotional Factors (Impacts of students' emotions on their use of devices)	2	Oo et al. (2022), Rashid-Doubell et al. (2016).
		Technological Experience (Students' prior technological experience on the use of devices)	8	Alegría et al. (2014), Clarke et al. (2019), Doherty et al. (2015), Joynes and Fuller (2016), Nuss et al. (2014), Rashid-Doubell et al. (2016), Thomas (2021), Witt et al. (2016)
		Individual Learning Needs (The influence of students' specific learning needs on their motivation to adopt mobile devices)	2	Joynes and Fuller (2016), Nuss et al. (2014).
3	Usability of Mobile Devices in Medical Education (The functional features of mobile devices in relation to students' learning)	Connectivity (The capability of a device to connect with the Internet, various networks and other devices)	2	Clarke et al. (2019), Sulley (2018)
		Portability (The physical characteristics of devices, such as weight and size, that allow users to carry them from one place to another easily)	7	Ellaway et al. (2014), Green et al. (2015), Harrison et al. (2019), Oo et al. (2022), Sulley (2018), Twiss-Brooks et al. (2017), Witt et al. (2016)

	Themes	Sub-themes	The number of studies contributing to sub-themes	The authors of the sub-themes
		Multifunctionality (The multifunctionality of mobile devices allows them to serve various roles, such as a camera, voice recorder, calendar, and note-taking)	13	Alegría et al. (2014), Doherty et al. (2015), Ellaway et al. (2014), Fan et al. (2016), George et al. (2013), Harrison et al. (2019), Nuss et al. (2014), Pimmer et al. (2013), Raiman et al. (2017), Shenouda et al. (2018), Sulley (2018), Witt et al. (2016), Wu et al. (2013)
		Environmental Friendliness (Environmental benefits of using mobile devices)	3	Alegría et al. (2014), Doherty et al. (2015), George et al. (2013)
4	Benefits of Mobile Technology in Medical Education (Pedagogical benefits and improved patient care by using mobile devices in medical education)	Enhanced Learning (The diverse ways in which mobile technology enhances students' learning experiences)	19	Alegría et al. (2014), Clarke et al. (2019), Green et al. (2015), Grover et al. (2017), Harmon (2015), Joynes & Fuller (2016), Küçük et al. (2016), Mansouri et al. (2020), Nuss et al. (2014), O' donovan and Maruthappu (2015), Pimmer et al. (2012), Pimmer et al. (2013), Raiman et al. (2018), Rashid-Doubell et al. (2016), Sulley (2018), Thomas (2021), Twiss-Brooks et al. (2017), Wallace et al. (2012), Witt et al. (2016)
		Just-in-time Learning	7	Green et al. (2015), Joynes and Fuller (2016), Pimmer et al. (2013), Rashid-Doubell et al. (2016), Sulley (2018), Wallace et al. (2012), Witt et al. (2016)
		Self-regulated Learning	6	Alegría et al. (2014), Nuss et al. (2014), Witt et al. (2016)
		Self-directed Learning	3	Harmon (2015), Küçük et al. (2016), Mansouri et al. (2020)
		Collaborative Learning	5	Grover et al. (2017), O' donovan and Maruthappu (2015), Raiman et al. (2018), Sulley (2018), Thomas (2021)

	Themes	Sub-themes	The number of studies contributing to sub-themes	The authors of the sub-themes
		Informal Learning	6	Alegría et al. (2014), Harmon (2015), Küçük et al. (2016), Mansouri et al. (2020), Nuss et al. (2014), Witt et al. (2016)
		Improved Patient Care (The role of mobile technology in improving patient care)	11	Alegría et al. (2014), Ellaway et al. (2014), Fan et al. (2016), Harrison et al. (2019), Johnson and Howard (2019), Joynes and Fuller (2016), Nuss et al. (2014), Rashid-Doubell et al. (2016), Shenouda et al. (2018), Sulley (2018), Witt et al. (2016)
		Obtaining Patient Information	8	Alegría et al. (2014), Ellaway et al. (2014), Fan et al. (2016), Harrison et al. (2019), Johnson and Howard (2019), Nuss et al. (2014), Sulley (2018), Witt et al. (2016)
		Checking Clinical Skills Performance	1	Rashid-Doubell et al. (2016)
		Making Informed Therapeutic Decisions	5	Alegría et al. (2014), Joynes and Fuller (2016), Nuss et al. (2014), Shenouda et al. (2018), Witt et al. (2016)
		Providing Patient Education, Counselling, and Communication and Collaboration with a Healthcare Team	6	Alegría et al. (2014), Clarke et al. (2015), Ellaway et al. (2014), Harrison et al. (2019), Joynes and Fuller (2016), Witt et al. (2016)
		Development of Soft Skills (The role of mobile technology in developing essential soft skills among medical students)	5	Clarke et al. (2019), Green et al. (2015), Oo et al. (2022), Scott et al. (2015), Wallace et al. (2012)
		Organisational and Time Management Skills	4	Clarke et al. (2019), Green et al. (2015), Scott et al. (2015), Wallace et al. (2012)

	Themes	Sub-themes	The number of studies contributing to sub-themes	The authors of the sub-themes
		Interpersonal Skills	1	Oo et al. (2022)
		Academic Writing Skills	1	Oo et al. (2022)
5	Challenges Encountered in Using Mobile Devices (Challenges students face in using mobile devices)	Disruption to Learning (The negative impacts of mobile devices affecting students' learning)	12	Doherty et al. (2015), Ellaway et al. (2014), Fan et al. (2016), George et al. (2013), Grover et al. (2020), Harrison et al. (2019), Oo et al. (2022), Rashid-Doubell et al. (2016), Robertson and Fowler (2017), Scott et al. (2015), Sulley (2018), Wallace et al. (2012)
		Information Overload and Superficial Learning	6	Doherty et al. (2015), Fan et al. (2016), Harrison et al. (2019), Scott et al. (2015), Sulley (2018), Wallace et al. (2012)
		Missing Learning Opportunities	2	Harrison et al. (2019) and Robertson and Fowler (2017)
		Distraction in Education and Clinical Settings	9	Ellaway et al. (2014), George et al. (2013), Grover et al. (2020), Harrison et al. (2019), Oo et al. (2022), Rashid-Doubell et al. (2016), Scott et al. (2015), Sulley (2018), Wallace et al. (2012)
		Impacts on Professionalism (The negative impacts of mobile technology on students' professional practice)	3	Harrison et al. (2019), Shenouda et al. (2018), Wallace et al. (2012).
		Limitation of Devices (The limitations of device usage negatively	11	Alegría et al. (2014), Ellaway et al. (2014), Green et al. (2015), Grover et al. (2020), Harrison et al. (2019), O'donovan and

	Themes	Sub-themes	The number of studies contributing to sub-themes	The authors of the sub-themes
		impact students' professional practice)		Maruthappu (2015), Twiss-Brooks et al. (2017), Shenouda et al. (2018), Sulley (2018), Thomas (2021), Witt et al. (2016)
		Barriers related to physical features of mobile devices	7	Alegría et al. (2014), Green et al. (2015), Harrison et al. (2019), O'donovan and Maruthappu (2015), Twiss-Brooks et al. (2017), Sulley (2018), Witt et al. (2016)
		Overdependence on mobile devices	3	Ellaway et al. (2014), Shenouda et al. (2018), Thomas (2021)
		Security concerns with mobile devices	4	Alegría et al. (2014), Green et al. (2015), Sulley (2018), Witt et al. (2016).
		Technical and connectivity barriers	6	Ellaway et al. (2014), Green et al. (2015), Grover et al. (2020), O'donovan and Maruthappu (2015), Sulley (2018), Witt et al. (2016).
6	Strategies to Overcome Challenges (The strategies students adopt to negotiate their device usage to mitigate the challenges)	Strategies for optimising educator-student dynamics in device usage (The strategies students adopt to negotiate with educators to optimise their learning experiences)	4	Clarke et al. (2019), Ellaway et al. (2014), Harrison et al. (2019), Rashid-Doubell et al. (2016)
		Strategies for optimising device use acceptance among patients (The strategies students adopt to negotiate with patients to optimise their learning experiences)	4	Green et al. (2015), Harrison et al. (2019), Shenouda et al. (2019), Witt et al. (2016)

	Themes	Sub-themes	The number of studies contributing to sub-themes	The authors of the sub-themes
		Strategies for optimising device use in clinical contexts (The strategies students adopt themselves to optimise their learning experiences using mobile devices)	4	Alegría et al. (2014), Harrison et al. (2019), Rashid-Doubell et al. (2016), Shenouda et al. (2019)

Appendix AA: Completion Certificates of Training Courses on Systematic Reviews, Scoping Reviews, Realist Synthesis and Qualitative Evidence Synthesis

	Name of the Course	Course Provider	Period	Certificate of Attendance
1.	Comprehensive Systematic Review Training Programme	Joanna Briggs Institute (JBI), University of Adelaide, Australia	20-24 July 2020	JBI Systematic Review Certificate.p
2.	Realist Review and Realist Evaluation Course	Department of Continuing Education, University of Oxford, United Kingdom	8 November to 10 December 2021	Oxford Realist Review Certificate.p
3.	Realist Research and Evaluation Intensive Programme	Charles Darwin University, Australia	8 March to 5 May 2022	Australia Realist Review Certificate.p
4.	Scoping Review Workshop	Joanna Briggs Institute (JBI), University of Adelaide, Australia	22 August 2023	JBI Scoping Review Certificate.pdf
5.	Searching the Evidence Base for Mixed Methods Review Course	Leeds Institue of Health Sciences, University of Leeds, United Kingdom	21, 25, 27 March 2024	Leeds Certificate.pdf
6.	Evidence Synthesis of Qualitative Research in Europe	University of Sheffield, United Kingdom	18, 19, 26 September 2024	QES Certificate.pdf

Appendix AB: A Certificate of Academic Proofreading

Gerard Hearne M.A.

Academic Proofreading

15 April 2025

To whom it may concern:

I hereby certify that I have proofread a doctoral thesis, entitled 'Experiences of Undergraduate Medical Students in the Use of Smartphones, iPads, and Tablets for Learning during their Preclinical and Clinical Years of Training: A Qualitative Systematic Literature Review' (word count approx. 48,000, exc. references), by Eugenie Phyu Aye Thwin, for basic errors in grammar, punctuation, spelling, consistency and typographical mistakes.

Gerard Hearne

email: gerardhearne@gmail.com
website: proofreading.education

Appendix AC: Software and Tools Used in the Study

1. MAXQDA software version 24.5.1 for data analysis
2. Litmap Pros for citation tracking
3. Rayyan for screening of papers
4. EndNote 20 as reference management software
5. Grammarly for spelling and grammar checking
5. Miro for drawing diagrams
6. PowerPoint slides templates purchased from ArteRamgopal.com and used under the regular license
7. Pictures are Creative Common Licences pictures.

Appendix AD: List of Abbreviations

Abbreviations	Full Term	First Use (Page Number)
3D	Three-dimensional	16
AI	Artificial intelligence	182
AMEE	International Association for Medical Education	186
AoME	Academy of Medical Education	80
APA	American Psychological Association	10
App	Application	16
Apps	Applications	4
AR	Augmented Reality	182
AT	Activity Theory	22
BNF	British National Formulary	96
BYOD	Bring Your Own Device	30
CBL	Case-based Learning	17
CD-ROM	Compact Disc Read-only Memory	35
CINAHL	Cumulative Index to Nursing and Allied Health Literature	39
ECG	Electrocardiogram	106
EHR	Electronic Health Records	18
EMBASE	Excerpta Medica Database	39
ERIC	Education Information Resources Centre	39
FRAME Model	Framework for the Rational Analysis of Mobile Education	27

Abbreviations	Full Term	First Use (Page Number)
GRADE	Grading of Recommendations, Assessment, Development and Evaluation	42
IPA	Interpretative Phenomenological Analysis	287
mAR	Mobile Augmented Reality	16
MEDLINE	Medical Literature Analysis and Retrieval System Complete	29
MeSH	Medical Subject Heading	62
NHS	National Health Service	127
OSCE	Objective Structured Clinical Examination	127
PBL	Problem-based Learning	17
PDA	Personal Digital Assistant	3
PDF	Portable Document Format	69
PEOU	Perceived Ease of Use	23
PICO	Population, Intervention, Control, and Outcomes	67
PICo	Population, Phenomenon of Interest, Context	48
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analysis	41
PU	Perceived Usefulness	23
RCTs	Randomised Controlled Trials	40
SDL	Self-directed Learning	19
SIM	Subscriber Identity Module	147

Abbreviations	Full Term	First Use (Page Number)
SRL	Self-regulated Learning	19
SLJ	Structured Learning Journals	280
TAM	Technology Acceptance Models	21
UK	United Kingdom	7
USA	United States of America	7
USMLE	United States Medical Licensing Examination	120
UTAUT	Unified Theory of Acceptance and Use of Technology	21
VR	Virtual Reality	182
Wi-Fi	The high-speed wireless transmission of data over a relatively short distance (Oxford English Dictionary)	4
ZPD	Zone of Proximal Development	18

Appendix AE: A Short Biography