Challenges in promoting sustainable use of mobile technologies in developing medical terminology for doctor trainees

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Abstract

Mobile technologies offer second language learners opportunities to make use of multimodal learning resources, communicate collaboratively and develop their self-regulated learning skills. However, in medical education, the sustainable use of mobiles in the support of learning terminology for second language doctor trainees has not been widely investigated. Guided by the literature on vocabulary learning strategies and taxonomy of vocabulary knowledge, this study interviewed 22 Indian students studying at a national medical university in mainland China, to explore their preferred ways of learning medical vocabulary with mobile devices and the justifications behind their choices. The results indicated two types of challenges that prevented the sustainable use of mobiles in learning medical vocabulary. First, *social* and *affective* learning strategies were rarely applied with the assistance of mobile devices or applications, and current mobile technologies mostly supported the use of *cognitive* and *metacognitive* learning strategies. Secondly, the opportunities for learners to develop their *productive* vocabulary knowledge have been reported to be much fewer than when it comes to *receptive* vocabulary knowledge. To achieve sustainable development of vocabulary learning for L2 medical students, the digital affordances of mobile technologies should be designed and integrated with the curriculum in medical education.

Keywords: mobile technologies, vocabulary learning strategies, vocabulary knowledge, medical education

Introduction

Mobile-assisted language learning has received increasing attention from researchers and practitioners, and mobile language learning applications were revealed to be among the most commonly used, together with other online platforms such as games, social networking sites, and learning management systems (Mortazavi et al., 2021; Rafiq et al., 2021). There are seven types of potential benefits of using mobile learning technologies in the development of vocabulary knowledge for second language learners: (1) ubiquitous

learning (Bradley, 2015); (2) availability of feedback and suggestions (Hasegawa et al., 2015); (3) capabilities of presenting multimodal information (Chen et al., 2021; Lai & Chang, 2021); (4) promotion of collaborative learning and creation of online learning communities (Liu et al., 2022); (5) opportunities for active knowledge making (Yeh et al., 2020); (6) metacognition (Chen et al., 2021); (7) differentiated learning, rather than learning at the same pace (Chen et al., 2019).

However, for L2 medical students, the impact of mobile-assisted technologies on their sustainable learning in medical terminology has not been extensively investigated. Medical students' preferences for specific e-affordances of mobile technologies and their long-term effectiveness remain underexplored. Presumably, the stated advantages of mobile learning technologies - including assistance in maintaining learning communities, promoting active knowledge-making, and encouraging greater use of self-directed learning strategies - are believed to increase learners' willingness and engagement level, and therefore have great potential in achieving their long-term learning goals and sustainability.

This study intends to address this gap in the existing research by investigating the preferred digital affordances used by second language medical students for enhancing their medical vocabulary, with a special reference to the challenges and reasons behind their use of mobile technologies in learning medical terminology.

Literature Review

Concerning the sustainable use of mobile technologies in developing medical terminology for second language learners, four areas have not been widely investigated, including (1) *affective* and *social* learning strategies; (2) *productive* vocabulary knowledge; (3) long-term learning engagement; (4) mobile-assisted terminology learning for medical students.

First of all, to achieve sustainability in vocabulary learning, two crucially important considerations have to do with promoting emotional guidance (Kosmas & Zaphiris, 2020) and social support (Mazman & Usluel, 2010) for second language learners. These two factors, which also play essential roles in promoting learners' engagement, were reported as two key driving forces behind the high completion rate and the low dropout rate for learners in online and blended learning programs without a high level of teacher supervision (Junior, 2020; Mihai et al., 2022; Pavelescu & Petric, 2018).

Notably, students' learning autonomy is promoted with *affective* and *social* vocabulary learning strategies when students use mobile technologies. Learning autonomy refers to students' ability to manage their learning, design personal learning experiences and environments, and engage in their learning processes in personal ways (Scott et al., 2015). Benson (2011) learning autonomy in four dimensions, including (1) location, for which learning took place out of class and students had access to their learning themselves; (2) formality, for which students depended on themselves to proceed with learning; (3) pedagogy, for which students instructed themselves without instructors' teaching; and (4) locus of control, for which self-directed learning was carried out with students' independence. When it comes to the technology-mediated vocabulary learning environment, students with learning autonomy, as active agents, were expected to evaluate the potential affordances of technologies, and then make use of these technologies to meet their learning goals (Liu et al., 2023; Steel & Levy, 2013). Therefore, the use of *social* and

affective vocabulary learning strategies helps L2 learners to raise questions, interact, and share experiences in their online learning environment, which highlights the role of learners, their self-directedness, and cognitive engagement to promote learners' learning autonomy.

However, in the medical education field, there were insufficient studies discussing the effectiveness and sustainability of *social* and *affective* learning strategies in promoting terminology learning. Van and other researchers (2013) developed an online dictionary for overseas-trained medical students to help them deal with communication barriers in their professional fields. Medical terminology was grouped by topics, and students were encouraged to add their content to this interactive dictionary, such as learning tips and translations, so that they could read their peers' comments as part of an active learning community for sharing vocabulary knowledge. The use of this online multilingual dictionary was also found to have a positive effect on their motivation, both improving vocabulary performance, and decreasing anxiety levels. Seidlein and colleagues (2020) conducted other research in medical education, mentioning learners' interest and preference for online student groups when using an interactive gamified e-learning course to make use of medical terminology taught in classrooms. Based on surveys, students reported their overall satisfaction with this online learning tool as a way of meeting their individualized needs.

However, previous studies concluded that *cognitive* and *memory* strategies were the two preferred strategies. Students and even their instructors were revealed to prefer specific techniques, including dictionaries, note-taking, and repetition, rather than imagery or grouping to help them better manage personal vocabulary learning processes (Fan, 2003; Gu & Johnson, 1996; Schmitt, 1997; Vasu & Dhanavel, 2016). A similar pattern was also found in the medical education field where these *cognitive* and *memory* strategies were mentioned frequently. Researchers developed corpus-based medical vocabulary lists, such as morphemes or word parts (prefixes, suffixes, and roots), to help medical students better understand and remember complex terminology with mental linkages to different meaningful groups. Other terminology learning strategies were also applied among medical students to examine efficacy, such as repeated exposure to collocations in reading texts, jigsaws, or retrieval practices. With pre-/post-tests, students' performance in medical vocabulary knowledge was improved and they reported perceived effectiveness towards these cognitive learning approaches. However, other sustainable vocabulary learning practices --- such as the above-mentioned focus on *emotional* and *social* support provision --- were seldom discussed by these medical studies (Fendos, 2021; Le & Miller, 2020; Toomer & Elgort, 2019).

Secondly, it is still rare to explore the link between the use of mobile technologies and second language medical learners' *productive* vocabulary knowledge which also promotes the sustainable development of their vocabulary learning. Mostly being a feature of speaking and writing, *productive* knowledge refers to the linguistic ability to construct and produce words correctly. It was revealed to be effective in developing learners' communicative competency and language learning by organizing productive classroom dialogues, and contributing to their further performance in different social interaction conditions (Li & Hafner, 2022; Van der Veen et al., 2017). In this way, *productive* knowledge required more autonomy on the part of learners and was linked to communicative language learning, promoting learners' skills in accuracy, fluency, and confidence during the learning process, which eventually led to sustainable language

learning in the long term (Hirata & Thompson, 2022; Ilgaz & Eskici, 2018). Regrettably, in the medical education context, only Vorona (2019) discussed different ways to enhance *productive* knowledge of medical Latin terminology, including using information resources on the Internet to develop writing skills, preparing homework with presentations to improve speech-making abilities, and taking interactive courses to encourage medical students' learning.

Other medical papers focused on the development of *receptive* vocabulary knowledge, which included reading and listening skills, and discussed the following three aspects: (1) the development of pronunciation knowledge (Dang, 2020; Müller, 2012) in which the spoken form of medication names and other specialized medical words were received by learners, with the help of audio and videos from games or subject-related TV programs; (2) the recognition of vocabulary spelling (Le & Miller, 2020), where corpus-based medical terminology lists were developed to provide students with written vocabulary knowledge, together with morphemes, to assist their learning processes as reliable re-sources; (3) the retention of meaning (Ainsworth et al., 2007; Brahler & Walker, 2008; Wang et al., 2016), where students were offered mnemonics with images for learning complex Latin and Greek medical terms. They also took pre-/post-tests with multiple-choice or matching questions alongside reading comprehension exercises to examine their mastery of terminological concepts. Regrettably, as discussed before, *productive* vocabulary knowledge was scarcely investigated in previous medical papers as a sustainable aspect for promoting second language learners' terminological development, let alone with the assistance of mobile technologies.

The third unexplored area has to do with second language learners' long-term engagement with medical vocabulary learning, which leads to the sustainable development of language skills and constantly improved proficiency (Mihai et al., 2022). A limited number of papers conducted longitudinal studies to investigate in-service teachers' consistent use of innovation in their language classrooms, and cross-cultural awareness and willingness to change are critical factors in ensuring their training participation sustainability (Gu, 2005; Yan, 2008). However, there was still a lack of clarity on whether second language learners succeeded in maintaining their autonomy in sustainable vocabulary learning over a long period. In medical education, Ainsworth and other colleagues (2007) carried out a two-year research project to examine first-year students' comprehension of veterinary professional words in the absence of a formal terminology course. However, this study emphasized the use of incidental learning offered by a veterinary curriculum, rather than focusing on medical students' sustainable vocabulary development.

Lastly, existing studies in medical education have not addressed the issue of using mobile technologies in developing second language medical students' learning processes. Current studies have tended to center on EFL students and mobile-assisted approaches to investigate their sustainable English vocabulary learning, in which mobile applications and other online platforms, such as games, social networking sites, and learning management systems, were revealed to be used in their daily learning (Mortazavi et al., 2021; Rafiq et al., 2021). With improved *receptive* and *productive* language skills, EFL learners favored the self-paced mode provided by mobile-based accessibility and convenience, and also reported experiencing better learning outcomes and increased motivation to process vocabulary learning with more autonomy.

However, in medical education, there were insufficient studies about mobile-assisted technologies and terminology learning, and each paper discussed a single method, including online dictionaries, tech-based applications, videogames, medical courses, programs, and other resources (Van de Poel et al., 2013; Seidlein et al., 2020; Vorona, 2019; Dang, 2020; Hassan Ja'ashan et al., 2022; Müller, 2012). These mobile-assisted methods were implemented in the online environment to facilitate medical students in remembering terminology. With the help of pre-/post-tests, questionnaires, and interviews, these technologies were revealed to be effective in improving students' vocabulary performance and motivation, and also triggered incidental learning for continuous medical education.

Research Questions

In exploring the sustainable use of mobile technologies in assisting medical vocabulary learning, the topics of second language medical students' learning strategies and vocabulary knowledge have not been investigated comprehensively on a long-term scale. There is also a lack of comprehensive research into *affective* and *social* techniques, and *productive* knowledge in communicative language learning, which contribute to the sustainable development of medical students' terminology learning. To our knowledge, previous studies in medical education have not been guided by the taxonomy of vocabulary learning strategies (Oxford, 1990) and vocabulary knowledge classification (Nation, 2001) as frameworks for guiding data collection and analysis, let alone in-depth interviews to explore medical students' explanations and justifications for their learning experience with the assistance of different mobile technologies.

This study aims to investigate the sustainable use of mobile technologies in developing medical terminology for second language learners, and the following research questions are proposed:
- What are the preferred mobile-assisted vocabulary learning strategies among second language medical students, and why?
- What types of vocabulary knowledge are reportedly learned with the assistance of mobile technologies, and why?

Methodology

Participants and Context

In recent years, Chinese medical universities have been encouraged by the government to incorporate various forms of cross-border programs, and the population of international medical students pursuing their studies in China has increased, with majors including medicine, surgery, and dental surgery (Jiang et al., 2022; Yu et al., 2017). For this study, a medical university in southern China was contacted in 2019, and among 89 international medical students from India, there were 35 junior and senior year volunteers that accepted our invitation to take part in this study as the second language Chinese learners. However, at the onset of COVID-19, they went back to their home country. Finally, 22 medical students remained in regular online contact during 2020 and were able to participate in the interviews.

This study included participants ranging in ages from 20 to 22 years, with a similar ratio of males and females. They had finished two-year Chinese language lessons and achieved the intermediate proficiency level. According to the university's curriculum, they receive Chinese language courses in the first two years to overcome language barriers, and then pursue professional study in the third and fourth years in the field of clinical medicine, with the teaching language being Chinese. They are required to pass medical Chinese examinations before graduation to ensure qualified language proficiency, and then most of them plan to return to India to be local doctors. All of the participants agreed to communicate in English via the social media platform WeChat, while sometimes Chinese was used to describe or refer to specific medical terminology.

Data Collection

Semi-structured interviews were used to collect detailed explanations of these students' experience of learning medical terminology. The interviews were conducted from May to July 2020, yet it was difficult to estimate the interview duration since some of them lasted for a few days because of Internet limitations and participants' unavailability. These medical students were informed that participation was voluntary and the collected data would be anonymous, and they could withdraw at any time without incurring any punishment. The interview prompts were: *To achieve sustainable use of mobile devices in developing your medical vocabulary learning, what is your favorite strategy in the last three years of study? Why?*

Follow-up questions were asked and other forms of data were encouraged to be shared voluntarily with these medical students, both for triangulation and to provide more detailed descriptions of their vocabulary learning strategies and terminology learning processes. The interviews were carried out by typing text messages on the social media networking platform, and other evidence was also collected online, such as photocopies of homework, teaching slides, students' notes from lectures, or screenshots of applications.

Data Coding and Analysis

To answer the first research question, the interview transcripts were coded based on the taxonomy of vocabulary learning strategies (Oxford, 1990) (see Table 1). Based on Oxford (1990)'s classification, *memory* strategies in the mobile-assisted condition refer to information associated with images, sounds, or other mental connections provided by mobile resources, while *cognitive* strategies are about the target language's manipulation for use across mobile platforms, such as social networking sites or applications, to receive or send messages. *Compensation* strategies make use of mobiles to infer reasonably or overcome the limitations of the target languages. *Metacognitive* types are applied by learners to manage, plan or evaluate their medical vocabulary study with mobile technologies, and *social* strategies refer to the online communication function offered by mobiles to talk with other learners or native speakers. Tech-based applications are also used to help users manage their emotions or attitudes, which belong to *affective* strategies. As suggested by the literature on Massive Open Online Courses (MOOCs) and computer-assisted learning (Barak et al., 2016; Zhao & McClure, 2022), *social* and *affective* strategies are more likely to be linked to greater use of learning autonomy strategies and a higher

level of motivation, and therefore may contribute to the sustainable use of mobile devices for the development of medical vocabulary.

Table 1

Coding System of Vocabulary Learning Strategies, Adapted from Oxford (1990)

Strategy	Descriptions
Memory	Information is associated with images, sounds or other mental connections provided by mobile resources.
Cognitive	The target language's manipulation to use mobile platforms, such as social networking sites or applications, to receive or send messages.
Compensation	Mobile technologies are used to infer reasonably or overcome target languages' limitations.
Metacognitive	Learners manage, plan or evaluate their medical vocabulary study with mobile technologies.
Social	Online communication functions are offered by mobiles to talk with other learners or native speakers.
Affective	Technology-based applications are used to help users manage their emotions or attitudes.

To answer the second research question, the coding system was derived from vocabulary knowledge taxonomy (Nation, 2001) (see Table 2). Specifically, the *productive* type refers to the expression of meaning through speaking or writing, to retrieve and produce the appropriate spoken or written word form with the assistance of mobiles. Its counterpart *receptive* knowledge is about perceiving the form of a word while listening or reading to recognize its meaning with mobile uses. Ideally, a higher level of willingness to communicate with other peers is considered to be one of the key predictors of academic success in mobile and long-distance learning environments. Therefore, to some extent, using mobile learning devices to develop more *productive* vocabulary knowledge is more desirable than *receptive* vocabulary knowledge for promoting sustainable development of vocabulary learning.

Table 2

Coding System of Vocabulary Knowledge, Adapted from Nation (2001)

Knowledge type	Descriptions
Receptive	Learners perceive the form of a word while listening or reading to recognize its meaning with mobile uses.
Productive	Learners express word meaning through speaking or writing, to retrieve and produce the appropriate word form with mobiles.

Coding was conducted by the author and the research assistant independently. The discrepancy was resolved through their discussions and re-coding of the interview transcripts, as well as negotiating with the corresponding author (Campbell et al., 2013).

In the coding process, the disagreements lay in two areas. Firstly, though each participant was interviewed to share one terminology learning strategy, some of their descriptions included more than one strategy for using mobile technologies to develop their medical vocabulary knowledge. It was agreed that it should be coded as an additional one to collect medical students' comprehensive strategy use as much as possible, since there were several participants not reporting their mobile-mediated vocabulary learning strategies. A similar condition also happened when a few participants' vocabulary knowledge was coded to include both *receptive* and *productive* types, and it was also agreed that it would be collected as separate evidence for further analysis. Second, some of the participants mentioned their preferences for using dictionaries to search for new words and write down medical terminology precisely, yet they did not indicate whether these dictionaries were paper-based traditional reference books or mobile-based vocabulary applications. It was decided that these descriptions would be taken as referring to digital dictionaries since the interview prompts were about mobile device use, and other learning strategies that these participants shared were all related to mobile technologies.

Results

Findings to Research Question 1

In terms of vocabulary learning strategies with mobile uses, descriptive data (Table 3) suggested that the most preferred technique was the *cognitive* category (N=14) with 67% of participants reported, followed by 4 *metacognitive* strategies (19% of respondents) and 2 *memory* strategies (10% of the participants). In other words, it means that second language medical students mainly use mobile devices and technologies to learn terminology by memorizing, note-taking, and reviewing on an individual basis. Mobile devices are treated as an extension of classroom instructions.

Table 3
Description of Terminology Learning Strategies with Mobile Technologies

Strategy	Count	Percentage
Cognitive	14	67%
Metacognitive	4	19%
Memory	2	10%
Social	1	5%
Compensation	0	0%
Affective	0	0%

However, only one *social* vocabulary learning strategy was mentioned, and there was no *affective* category reported by any medical participants. It suggests that mobile devices fail to help second language medical learners to establish and participate in learning activities within learning communities, with very limited opportunities for peer learning or peer feedback among them. Moreover, mobile technologies have not been used to manage learners' emotional status. Theoretically speaking, these two strategies, i.e. *social* and *affective*, are believed to link to the greater use of learning autonomy and self-directed language learning with mobile uses to achieve sustainability. Therefore, the reported over-reliance from medical students on *cognitive*, *metacognitive,* and *memory* strategies takes the risk of less sustainable development regarding terminology learning.

Moreover, the thematic analysis of transcripts offers more insights into the preference for medical terminology learning strategies with mobile use. For the frequent implementation of *cognitive* and *metacognitive* strategies, the participants used mobile technologies, including online dictionaries, vocabulary applications, medical learning platforms, and the mobile-based note-taking function, to assist their self-learning based on classroom instructions, and to understand new medical terms. In detail, they (1) translated, understood, and reviewed medical terms taught in class by repeating, taking notes, and practicing with the target language's new writing system; and (2) watched multimedia resources, by which they set learning goals and arranged their terminology study processes to achieve purposeful learning.

For example, one interviewee shared screenshots of online lessons (see Figure 1) and another student reflected on terminology learning with medical programs. As can be seen in the following excerpt:

I'm using our Chinese teacher's lesson content and slides. It is good for studying and I'm listing what she says in class…when she teaches, most of the time she tries to teach new words that are not in our textbooks…I note them on my phone and read them three or four times.

I watch a lot of movies. Whenever I have free time I'll watch different movies, because to learn medical Chinese, I think I have to be fluent in local Chinese too. If you don't understand much of the patients' words, it doesn't make sense.

Figure 1
The Screenshots of an Online Medical Lesson
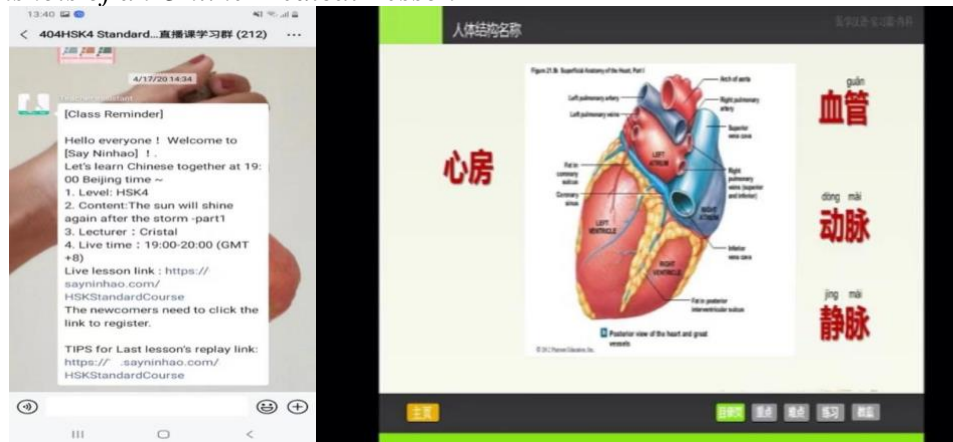
For the category of *social* strategies, one participant reported the use of social networking platforms to communicate with proficient users of the target language and learn medical terminology expressions in the active real-life community. One commented:

I help Chinese friends with their physical problems on WeChat (note: a Chinese social media platform). In this way I practice vocabulary in conversations. I think it is good for my learning.

Findings to Research Question 2

To answer the second research question, Table 4 presents the descriptive data for vocabulary knowledge with mobile usage. It is suggested that *receptive* knowledge (N=15, with 68% of the respondents) was elicited more noticeably than *productive* knowledge (N=7, with 32% of the respondents). Regrettably, the *productive* vocabulary knowledge, which reportedly was less readily obtained, is considered to promote communicative language learning and learners' confidence. As a result, this imbalanced pattern with exceedingly more *receptive* vocabulary knowledge may lead to students' rote memorization and more knowledge internalization, and may pose a threat to their sustainable vocabulary development with mobile usage. In addition, these quantitative results are consistent with the reported vocabulary learning strategies before, with less *productive* knowledge being linked to limited *social* and *affective* strategy use. These medical learners are reluctant to speak out or write down professional words in their daily learning processes, which also indicates their unwillingness to interact with peers or instructors with inadequate autonomy. A similar condition also takes place in extra *receptive* vocabulary knowledge and preferred vocabulary learning strategies of *cognitive* and *metacognitive* types. Participants suggested that their learning experience in listening to and reading medical resources corresponded with their preference for receiving vocabulary information and setting learning goals.

Table 4
Description of Vocabulary Knowledge with Mobile Technologies

Knowledge type	Count	Percentage
Receptive	15	68%
Productive	7	32%

Regarding the qualitative data of vocabulary knowledge with mobile-assisted technologies, students reported more *receptive* vocabulary knowledge obtained during their long-term learning processes. They recalled the form and meaning of medical terminology in two approaches: (1) reading words and texts shown on mobile devices' screens to recognize the written form and conveyed concepts; and (2) listening to subject-specific lessons to understand pronunciation and meaning in a professional context. As two interviewees reported:

I am able to understand 60% to 70% of the characters given in the subtitles of medical programs… I watch lots of times in one episode and if I find it interesting, I will re-watch again during the weekends… I also try to use Baidu (note: a Chinese search engine) to translate some characters I have never seen.

I listen to teachers' lectures online to preview…The teacher makes a presentation of new words and explains the way it has been used. Because certain things are kind of different and hard for us to understand though we are medical students.

Some participants suggested they obtained *productive* vocabulary knowledge by pursuing more opportunities to communicate and practice, based on what they learned through activating those terms in a mobile-assisted environment. They produced professional vocabulary knowledge in two ways: (1) by pronouncing terminologies correctly to express the precise meaning with vocabulary dictionary applications; and (2) by constructing word parts and using the words in original sentences to suit the medical situation, with the help of multimedia resources from instructors. One participant reported the terminology learning experience in a medical laboratory, and another student also provided the notes scanning (see Figure 2) with the assistance of teaching slides, as can be seen in the following excerpt:

When we went to the laboratory for an experiment, we learned some new words with dictionaries. For example, we got forceps and syringes there, and we translated these words into Chinese and repeated them every day…For the first time I read so quietly for understanding and then I will read aloud.

Each Sunday the teacher sends us the PPT, so every Sunday evening I study with the PPT… I write a case report of the patient in the PPT.

Figure 2

The Scanning Picture of a Student's Notes
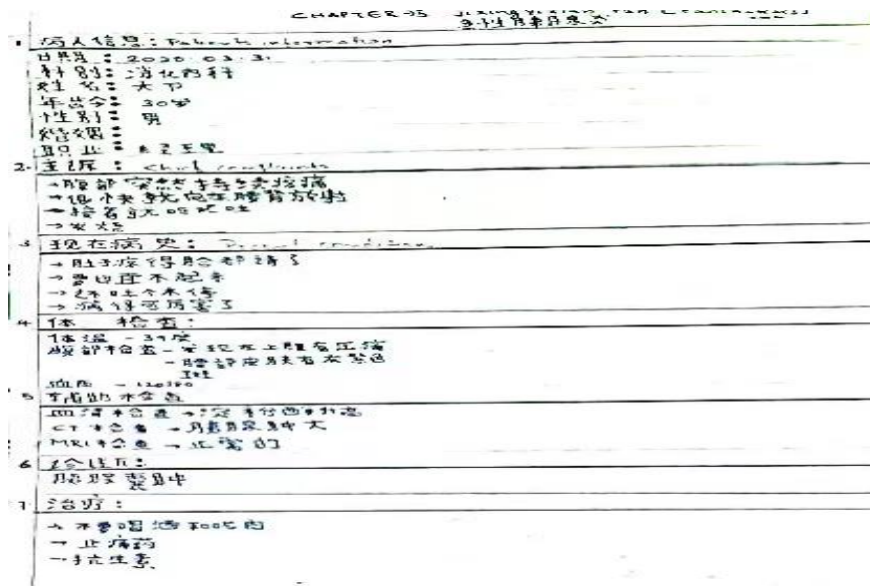
Discussion and Conclusions

The purpose of this study was to explore the sustainable use of mobiles in developing medical learners' terminology learning, in which their vocabulary learning strategies and vocabulary knowledge were examined in their long-term professional higher education study. An empirical study was conducted with semi-structured interviews, and the overall findings revealed the challenges that medical learners encountered and the underlying reasons for further sustainability in the field of medical education.

Preferences for Cognitive and Metacognitive Strategies

Most medical participants reported a great use of *cognitive* and *metacognitive* learning strategies with their mobile devices. They came to understand medical terminology by repeating, translating, reviewing, and managing their learning processes, with the assistance of mobile use, including mobile dictionaries, teaching multimedia resources, social networking, and other mobile-based applications or platforms. The findings suggested that mobile technologies have been treated as self-learning tools and extensions of classroom instructions to supplement students' vocabulary learning and help them develop a better understanding of knowledge acquired in the classroom. The popular cognitive and metacognitive learning strategies, reported by those medical students in this study, can be interpreted from two perspectives. Firstly, more *cognitive* and *metacognitive* strategies were proposed by medical instructors to guide students to learn complex medical terminology. It echoes previous papers in medical education, in which most studies discussed tech-mediated methods from *cognitive* or *metacognitive* dimensions to increase learners' efficiency in remembering terms, such as online dictionaries or different medical word lists (Van de Poel et al., 2013; Le & Miller, 2020). Secondly, current mobile technologies do not undertake the practical functions for users to develop learning communities or satisfy their affective needs to benefit their terminology study, so these medical students failed to receive *social* and *emotional* support. The lack of social and emotional functions in the online learning environment may threaten the possible sustainable use of mobile technologies to support second language medical students in an online or blended learning environment for learning terminology (Bahari, 2022; Puebla et al., 2022). Reynolds and others (2021) also mentioned similar difficulties when learning English vocabulary for medical purposes, such as insufficient communication with teachers, insufficient feedback, and a lack of contextualized professional writing practice to realize personal learning problems, which posed a negative impact on students' learning efficacy.

However, the noticeable preferences for *cognitive* and *metacognitive* strategies pose challenges for the sustainable development of medical vocabulary learning with mobile use, since students are not provided with thriving collaborative learning communities and have to rely on themselves to develop sufficient learning willingness necessary to support their long-term study. Rather than developing ubiquitous learning or making active knowledge, they use mobile technologies only to recall and understand complicated terms, especially when they review vocabulary knowledge in class or search for the pronunciation and meaning of new words. The use of *cognitive* and *metacognitive* strategies helps them receive useful vocabulary messages and finally internalize knowledge; however, they are

still not provided with the support needed to develop a sense of belonging and confidence in their subsequent learning processes, and thereby achieve vocabulary learning sustainability in the mobile-based environment. This finding of students' over-reliance on *cognitive* and *metacognitive* strategies provides a different perspective from previous studies, which suggested more teacher-led instructions to promote students' self-regulation by encouraging them to make use of more *cognitive* and *metacognitive* aspects of learning strategies (Chiang et al., 2021; Ping et al., 2015), while in fact, the increased use of these strategies may not contribute to students' continuous vocabulary learning effectively.

Absence of Social and Affective Strategies

Social vocabulary learning strategies were mentioned by one participant to communicate with native-speaking friends through a social networking platform, while *affective* strategies were not applied by any student to assist their medical terminology learning with mobile technologies. It indicated the unavailability of promoting a learning community where L2 medical students could have developed *social* and *affective* learning strategies with opportunities to support each other reciprocally and emotionally. Possible reasons may include two aspects: (1) students' learning preferences and their teachers' instructions, and (2) unsuccessful functions undertaken by current mobile technologies. For the first reason, because of cultural barriers, these Indian medical students may not have sufficient willingness to interact with their peers or develop positive attitudes when using mobiles to learn medical terms. Past papers suggested that Asian students favored more techniques including dictionaries, repetition and note-taking, and their teachers in these contexts encouraged the use of these strategies, rather than establishing active learning communities or providing emotional support with mobile use (Fan, 2003; Gu & Johnson, 1996; Schmitt, 1997; Vasu & Dhanavel, 2016). The second reason is the scarcity of some mobile-based functions in medical terminology learning, which hinders these medical students from using the technology effortlessly and intuitively. They are reluctant to apply many *social* or *affective* strategies since they cannot receive extra assistance from mobile devices to help them cooperate with other learners or proficient native speakers. They also fail to take emotional temperatures and increase willingness during terminology learning.

The absence of *social* and *affective* learning strategies also leads to challenges in the sustainable development of medical vocabulary learning with mobile technologies. Students do not have online collaborative communities to promote their learning engagement and build up their confidence, which also impedes their sense of belonging and learning autonomy. As Chen (2022) stated, students benefited more from self-directed and engaging experiences in a social dimension while taking activities online, which helped to maintain qualified and lifelong education, thereby ensuring sustainability. Moreover, the strong sense of enjoyment and comfort also improved second language knowledge and students' affective states, leading to self-regulated language learning (Hromalik & Koszalka, 2018). However, these participants failed to apply *affective* strategies in their medical terminology learning processes, which indicated the potential threat to their continuous learning in a mobile-based environment with inadequate emotional support.

Over-obtained Receptive Knowledge

More *receptive* vocabulary knowledge was reportedly obtained by the L2 medical students than *productive* vocabulary knowledge, and these students mostly used mobile technologies to translate, review or take notes when studying medical terminology. In this way, mobile learning technologies were perceived as approaches to learning vocabulary, rather than platforms to use and practice medical vocabulary knowledge. The possible explanation may come from students' preferences for *cognitive* and *metacognitive* strategies as discussed above, and they are accustomed to receiving useful information, such as pronunciation, spelling, or concepts, during which mobile technologies perform as convenient tools for them to search and understand. The insufficient design and functions of mobile devices with installed applications may be another interpretation, since they cannot offer mobile users opportunities to construct and produce vocabulary in original sentences, such as generating user self-made learning materials (Zou & Xie, 2021) or communicating with virtual characters (Ahn & Lee, 2016). The development of more interactive elements in mobile devices is also recommended, to increase second language learners' *productive* knowledge for further learning, including online topic discussion, reflection writing, and multimodal presentation (Li & Hafner, 2022).

The exceeding *receptive* vocabulary knowledge obtained by medical students also poses challenges to the sustainable use of mobile technologies in developing medical terminology for second language learners. These learners turn to mobile devices that act as supplementary tools for instructors' teaching, or an extension of the classroom, to satisfy their learning needs and achieve terminology knowledge internalization (Wang & Shih, 2015). However, they do not have enough autonomy to communicate with their peers, instructors, or even patients, in both real and simulated conditions, or specifically to speak out or write down using medical terms, to develop their long-term and effective vocabulary learning in a mobile-based environment. This finding regarding excessive obtained receptive vocabulary knowledge seems inconsistent with previous papers since some meta-analysis research suggested that current mobile technologies support both *productive* and *receptive* skills to promote learners' vocabulary knowledge in both two types (Mortazavi et al., 2021; Chen et al., 2020; Mahdi, 2018), while participants in this study reported over-whelming achievement specifically in *receptive* vocabulary knowledge in the medical education context.

To achieve sustainable development of vocabulary knowledge for L2 medical students, digital affordances are recommended to be designed and integrated with the curriculum in medical education. For mobile developers, they can increase online medical users' engagement level with more functional and refined designs from the aspects of (1) establishing online communities, (2) meeting emotional needs, and (3) setting simulation-based tasks as sustainable solutions for dealing with the challenges of students' terminology learning. Firstly, mobile devices and their installed applications can make the best use of digital affordances of technologies in building up online active collaborative groups in which students are offered enough opportunities to interact reciprocally (Comas-Quinn, 2009). Meanwhile, peer and teacher feedback should be made available online, both through automated evaluation systems and learning management platforms, to achieve synchronous or asynchronous assessment and future learning suggestions (Dai & Wu, 2021; Godwin-Jone, 2022). Secondly, mobile-based functions for detecting and improving users' emotional conditions can be developed, such as emotion recognition technology, affective tutoring systems, and gamification (Cho & Castañeda, 2019; Wu et al., 2022), to

provide psychological support and lower students' anxiety levels when learning complicated medical terms. Moreover, task-based instructions can be conducted in the mobile-mediated environment to provide medical users with the incentives to apply terminology to online scenarios, which encourages them to adopt professional identities and immerse themselves in simulated medical-related situations (Müller, 2012).

Limitations

By employing the classifications of vocabulary learning strategies and vocabulary knowledge, this study contributed to the medical education field in that it investigated second language medical students' sustainability in learning subject-specific terminology with their mobile devices, to better assist further vocabulary learning and teaching. Because of COVID-19, there were only 22 Indian medical students at a single university who were successfully contacted for online interviews, which might cause bias in the findings. It is suggested that more participants should be recruited for further research, to obtain more reliable results regarding medical students' terminology learning behaviors. Additionally, this study focused on learning strategies and vocabulary knowledge as indicators of sustainability, while the measurement of medical students' vocabulary size or depth may be another consideration for exploring their actual performance when using mobile technologies (Zhao & Ji, 2018; Zeng et al., 2022). Future research can address this limitation by investigating the relationship between medical students' vocabulary learning strategies with their terminology breadth or depth, or even vocabulary knowledge, to grasp a better understanding of their learning processes and outcomes. A longitudinal case study from the student's perspective is also expected, to provide more detailed evidence about students' mobile use and terminology learning in the long term.

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