

Use of Mobile Devices to Access Resources among Health Professions Students: A Systematic Review

Rutgers University has made this article freely available. Please share how this access benefits you.
Your story matters. <https://rucore.libraries.rutgers.edu/rutgers-lib/48851/story/>

This work is an **ACCEPTED MANUSCRIPT (AM)**

This is the author's manuscript for a work that has been accepted for publication. Changes resulting from the publishing process, such as copyediting, final layout, and pagination, may not be reflected in this document. The publisher takes permanent responsibility for the work. Content and layout follow publisher's submission requirements.

Citation for this version and the definitive version are shown below.

Citation to Publisher Version: Mi, Misa, Wu, Wendy, Qiu, Maylene, Zhang, Yingting, Wu, Lin & Li, Jie. (2016). Use of Mobile Devices to Access Resources among Health Professions Students: A Systematic Review. *Medical Reference Services Quarterly* 35(1), 64-82. <https://dx.doi.org/10.1080/02763869.2016.1117290>.

Citation to this Version: Mi, Misa, Wu, Wendy, Qiu, Maylene, Zhang, Yingting, Wu, Lin & Li, Jie. (2016). Use of Mobile Devices to Access Resources among Health Professions Students: A Systematic Review. *Medical Reference Services Quarterly* 35(1), 64-82. Retrieved from [doi:10.7282/T38S4RX7](https://doi.org/10.7282/T38S4RX7).

This is an Accepted Manuscript of an article published by Taylor & Francis in *Medical Reference Services Quarterly* on 21 January 2016, available online: <http://www.tandfonline.com/10.1080/02763869.2016.1117290>.

Terms of Use: Copyright for scholarly resources published in RUcore is retained by the copyright holder. By virtue of its appearance in this open access medium, you are free to use this resource, with proper attribution, in educational and other non-commercial settings. Other uses, such as reproduction or republication, may require the permission of the copyright holder.

Article begins on next page

**Use of Mobile Devices to Access Resources among Health Professions Students: A
Systematic Review**

Misa Mi

Wendy Wu

Maylene Qiu

Yingting Zhang

Lin Wu

Jie Li

ABSTRACT. This systematic review examines types of mobile devices used by health professions students, kinds of resources and tools accessed via mobile devices, and reasons for using the devices to access the resources and tools. The review included 20 studies selected from articles published in English between January 2010 and April 2015, retrieved from PubMed and other sources. Data extracted included participants, study designs, mobile devices used, mobile resources/apps accessed, outcome measures, and advantages of and barriers to using mobile devices. The review indicates significant variability across the studies in terms of research methods, types of mobile programs implemented, resources accessed, and outcomes. There were beneficial effects of using mobile devices to access resources as well as conspicuous challenges or barriers in using mobile devices.

KEYWORDS. Health information resources, health professions students, health professions education, information access, information-seeking behavior, mobile devices, mobile technology, systematic reviews

Author Information

Misa Mi, PhD, MLIS, AHIP (mi@oakland.edu) is Associate Professor & Medical Librarian, Oakland University William Beaumont School of Medicine Library, Oakland University, 2200 North Squirrel Road, Rochester, MI 48309.

Wendy Wu, MS (wendywu@med.wayne.edu) is Information Services Librarian, Shiffman Medical Library, Wayne State University, 320 E. Canfield, Detroit, MI 48201.

Maylene Qiu, MA (qiuk@upenn.edu) is Evidence-Based Healthcare & Clinical Liaison Librarian, Biomedical Library, University of Pennsylvania, 3610 Hamilton Walk, Philadelphia, PA 19104.

Yingting Zhang, MLS, AHIP (yzhang@ca.rutgers.edu) is Information & Education Librarian, RWJ Library of the Health Sciences, Rutgers, The State University of New Jersey, 1 RWJ Place, PO Box 19, New Brunswick, NJ 08903.

Lin Wu, MLIS, AHIP (lwu55@tamu.edu) is Instructional Associate Professor & Pharmacy and South Texas Health Science Campus Librarian, Medical Sciences Library, Texas A&M University, 1010 West Avenue B, Kingsville, TX 78363.

Jie Li, MLS, AHIP (jli@southalabama.edu) is Assistant Director, Collection Management, Biomedical Library, University of South Alabama, 5791 USA Drive, North, Mobile, AL 36688.

INTRODUCTION

The stewardship of high-quality information has always been at the center of a librarian's mission.¹ Libraries are experiencing a shift from information place to information space.²

T. Scott Plutchak contends that librarians are more necessary than ever in helping members of their communities navigate the increasingly complex information space.³

The near ubiquity of mobile devices among clinicians⁴ in the current digital age may contribute to the shift in health sciences libraries. Mobile devices are changing the landscape of health care and e-learning environments. They are being used to extend the human mind's limited capacity to recall and process vast amount of relevant data to support information management, general administration, and clinical practice.⁵ Gaglani and Topol argue that medical schools should make efforts to integrate mobile technologies into their curriculum.⁴ Raman points out that work is necessary to make mobile devices more easily accessible to students and to encourage and enhance the practice of working with mobile technology in nursing education.⁶

Health sciences librarians are quick to spring into action in response to the widespread use of mobile technology. They have been taking various initiatives to incorporate mobile technologies and resources in health professions education by instructing on proper uses of mobile technologies and resources,⁷ connecting health professionals to clinically relevant mobile resources and library services,⁸ designing library websites to meet mobile information needs,⁹ and creating mobile-optimized subject guides to facilitate medical students' access to mobile resources and tools.^{7, 10}

Libraries have made great strides in support of adoption of mobile devices and utilization of mobile resources and applications for different purposes and activities. Health sciences librarians need to continue to advance towards the goals of making mobile devices and resources more easily accessible, incorporating mobile resources in curricula, and developing strategies to address existing concerns and barriers associated with mobile technologies.

In the face of the rapid development of mobile technologies and increased utilization of mobile devices in clinical practice and health professions education, it is essential for health sciences librarians to become cognizant of a variety of resources and tools accessed via mobile devices and to develop awareness of concerns and issues associated with the use of mobile devices. A systematic review was conducted to examine what types of mobile devices were implemented in health professions education, what kinds of mobile resources and tools health professions students accessed and used, and what activities students took while accessing these mobile resources and tools.

Systematic knowledge of the evidence pertinent to these questions would aid health sciences librarians when launching various initiatives such as allocating adequate funding to develop mobile resource collection, developing programs to educate users about mobile apps, embedding mobile devices within existing or future curriculum design and delivery, and developing creative strategies to overcome concerns with or barriers to using mobile devices. In the digital age, libraries are poised to play various roles that will enable them to emerge as institutional change agents.¹¹

METHODS

Data Sources

Databases searched included PubMed, EMBASE, CINAHL, ERIC, Web of Science, Scopus, PsycINFO, Cochrane Library, ProQuest Dissertations & Theses, Academic OneFile, and Google Scholar. Search results were limited to articles published from January 2010 to April 2015. Index terms unique to each database were identified and searched in combination with keywords derived from key concepts of mobile devices, information retrieval, information resources, and health professions students. Search strategies were created and peer-reviewed by a team of librarians. To identify additional studies, the reference lists of included studies were hand-searched. The final PubMed search is available in the Appendix. Search strategies from other databases are available from the authors upon request.

Study Selection

All included studies contained empirical data in published reports investigating the impact of the implementation of mobile devices as an intervention or strategy to facilitate access to resources and mobile apps among health professions students. For the purpose of this review, health professions students are defined as undergraduate medical students, graduate medical students (residents, doctors in training), nursing students, allied health professions students, and students enrolled in other health care-related educational programs. Editorials, comments, general opinion pieces, letters, survey research studies,

and reviews were excluded. Studies without implementing any mobile devices as an approach were also excluded. Two researchers worked independently to screen all retrieved titles and abstracts based on the selection criteria and to select potential article candidates for the systematic review. Following a similar process, the two authors screened all potentially relevant full-text articles and selected articles for the final review. A third researcher served as a tiebreaker to resolve any disagreement if the two researchers could not reach a consensus.

Data Extraction

A standardized data abstraction form was developed and utilized. Fields of data extracted included participants, setting, study design, data collection methods, mobile devices used, duration of intervention, resources/apps accessed, and outcomes from the use of mobile devices in accessing information resources. A qualitative systematic review was conducted due to heterogeneity in the selected studies in terms of study designs, types of mobile devices as interventions, duration of intervention, participants recruited, and data collection methods. Quality of articles was assessed using principles discussed in works on education research.¹²⁻¹⁴

RESULTS

The initial search of all databases and resources yielded 6,086 citations. After removing duplicated citations, excluding articles not meeting the selection criteria, 57 full-text articles were examined, from which 20 articles were selected in the final review.

[PLACE FIGURE 1 HERE]

Legend: FIGURE 1. Flowchart of the literature search and study screening process in a systematic review to identify eligible studies

Study Characteristics

Of the 20 studies, 13 used quantitative research designs; five had mixed methods designs; and two employed qualitative research designs. Of the 13 quantitative research studies, five were one-group pretest-posttest designs, six one-shot case study design, one crossover study design, and one pretest-posttest control group design with random assignment (participants randomly assigned to a control and experimental groups). In the one-group pretest-posttest design, all participants in a single group are exposed to the same conditions: pretest, implementation of an experimental treatment, and posttest; while in the one-shot case study design, an experimental treatment is administered to the single group of participants and only a posttest is used to measure the effect of the treatment. In the crossover study design, two or more experimental treatments are administered one after the other in a specified or random order to the same group of participants.

The five mixed method studies combined qualitative and quantitative approaches into their research methodology. Mixed methods use methodological triangulation that involves the use of both qualitative and quantitative approaches to study the same phenomena within the same study.¹⁵ The mixed methods in the five studies included quantitative methods of pretest-posttest randomized control group design and one-group pretest-posttest design in combination with qualitative methods such as focus group, interview, observation, and narrative report.

A majority of studies (n=17) used questionnaires as data collection methods; six studies included observation, content analysis, usage log, and feedback; five studies employed focus groups; and two studies administered objective performance tests.^{16, 17} Only one study included an interview.¹⁸ None of the selected studies provided any evidence of reliability of the questionnaires administered to participants; only three studies provided information on face and content validity of questionnaires used.^{16, 19} Findings of individual studies reviewed are available at <<http://tinyurl.com/qhseceq>>.

Settings

The majority of the studies (n=15) reported activities related to the application of mobile devices in clinical and primary care settings. Academic setting, such as medical school, library, and classroom, was documented in the other five studies. Since the scope of the systematic review was international, studies from all countries were included. Ten studies were conducted in the United States; four studies were in the UK; and one study each in Australia, Germany, Sweden, Canada, Singapore, and Botswana.

Study Population

Health professions students were the target population of studies selected for the systematic review. Among the 20 studies, seven targeted medical students; eight focused on residents; seven studied nursing students; and five studies included other groups of participants from programs in physiotherapy, midwifery, sports medicine, and residency training. The sample size ranged from 9 to 578.

Types of Mobile Devices Used

Of the 20 studies, eight reported the implementation of the iPad as an intervention or strategy to facilitate students' resources access, enhance learning, aid patient care, and meet other needs. Eleven studies reported the use of other mobile devices including iPod, iPAQ, Smartphone, personal digital assistant (PDA), Netbook, and Kindle e-reader. One used a tablet device that was not specified. The duration of mobile devices in use in the selected studies varied, ranging from two weeks to two years.

Health Information Resources Accessed on Mobile Devices

Mobile devices were mostly utilized as portable tools for quick and easy access to health information resources at the point of need. Of the 20 selected studies, 10 reported the use of and access to evidence-based medicine (EBM) resources via mobile devices. These

resources included pre-appraised EBM resources in three studies, practice guidelines in six studies, and journal articles in six studies. Among the EBM resources were DynaMed, Micromedex, UpToDate, Cochrane Abstracts, and Outlines in Clinical Medicine. The majority of studies (n=16) reported the use of and access to a wide array of health information resources and specialty resources applications appropriately selected for knowledge acquisition and inquiry-based or self-directed learning to enhance health professions students' learning outcomes and patient care experiences at clinical settings. These resources included drug guides, handbooks, manuals, dictionaries, encyclopedias, online textbooks, lab values, nursing procedures, and specialty resources (e.g., internal medicine, radiology, pathology, neurology, neurosurgery). A few others were visual resources of mobile applications such as VisualDX,¹⁸ drawMD,¹⁸ and anatomy atlases.²⁰⁻

23

Learning Resources Accessed on Mobile Devices

Another function of mobile devices was distributing learning resources to support students learning activities. These resources came in the form of question banks, self-assessment applications,^{18, 19, 24} calculators,^{25, 26} multimedia learning resources,^{16, 22, 27} or curriculum-related materials.^{22, 28-30} In a study by Bruce-Low et al., mobile learning devices for students to use (Samsung NC10 Netbook) were loaded with a video of an ECG technique incorporating multiple choice quizzes and interactive exercise.¹⁶ Sharpe and colleagues reported the educational impact of the iPad on resident educational experiences in their entire residency program.²² In their study, an educational and clinical

tool, a Radiology Resident iPad Toolbox, was created to improve resident education and to fit various learning styles of residents as adult learners.²²

Mobile Applications Used for Knowledge Management and Workplace Performance

Other uses of mobile devices included knowledge management^{8, 17, 24} and access to EMRs.^{18, 24, 28} The use of mobile applications to improve learning and enhance workplace performance and communications were also reported in 10 studies. Examples of these applications included a multiplatform journaling app Evernote,²⁴ the iPad “air-play-mirroring” for presentations, FaceTime, Dropbox,²⁸ Skyscape,³¹ Keynote,¹⁷ DocTool Cross Library Search Tool,²¹ PDF Expert for reading and editing PDF files on the iPad, and QuickOffice.¹⁸ In this study, various clinical tools were used to access EMRs (DICOM viewers), make call schedules, and access PACSs and EMRs remotely via Citrix Receiver.²² The Cisco WebEx Meetings video conference application was installed for iPad users to make didactic and case-conference lectures anywhere with an Internet connection, and the ResponseWare application was embedded into the iPad to offer the capability of audience response during resident training events.²²

Patient Care and Clinical Decision Making

Mobile devices were introduced to health professions students as an intervention in 12 studies to improve their patient care experiences and support clinical decisions by means

of quick and easy access to various health information resources, mobile applications, and tools.

Medical Students' Use of Mobile Devices. Third-year medical students reported using the iPad at all stages of patient care (before, during, and after patient encounters).¹⁸ Alegria et al. found that the majority of third-year medical students used tablet computers (iPads) for remote access to patient records, while some students accessed reference information at the point of care.²⁴ The results of the study by Nuss and colleagues suggested that obtaining real-time patient data via the electronic health record was the most frequent way of using the iPad, followed by identifying medical knowledge resources for clinical decision support.¹⁸ The majority of students used the iPad many times daily, and the amount of time spent using the device grew over time.¹⁸

When comparing the use of a PC, smartphone, and tablet computer in conducting a bedside literature search on “Unbound Medline,” a free PubMed app, Friederichs and colleagues noticed in their study that third-year medical students in the PC group found searching more effective than the students in the smartphone or the tablet group. The PC group reported being more eager to try a literature search during their next internship compared with the other two groups, even if all three groups had sufficient technical skills for the bedside literature search and had the same level of confidence in performing a literature search at the bedside.³² Another mobile device, the Kindle reader, was investigated for its benefits to second-year and fourth-year medical students, residents, and preceptors in accessing online textbooks in clinical settings.²⁹ The findings of the study indicated that the e-reader had more uses for educational support than for direct patient care. In comparison with networked computers if available, the e-reader was less

efficient in direct patient care settings due to its slow processor and suboptimal wireless connection.²⁹

Residents' Use of Mobile Devices. In a study by Berkowitz et al., radiology residents looked up relevant anatomy and used diagnostic aids to help them identify pertinent radiographic abnormalities on the iPad.²³ The results of another study showed that neurology residents used the iPad regularly while on inpatient service. They used the tablet to access and update the sign-out list of patients, and to show patients magnetic resonance and computed tomography imaging at the bedside.²⁸ When using the same mobile devices to answer clinical questions, the types of medical applications available for use by residents can affect their performance differently. Goldbach and his associates investigated the effect of mobile resources on first-year residents' performance in answering clinical scenario questions. PubMed4Hh (PubMed for Handheld, a mobile application) and medical applications, both accessible on the smartphone, were compared in terms of information available to correctly answer questions related to clinical scenarios. The medical applications loaded on the mobile devices included Medscape, 5-Minute Consultant, 5-Minute Pediatric Clinical Consult, Drug Facts, Clinical Evidence, and a few others. The findings of the study showed that the residents across four residency programs (internal medicine, pediatrics, emergency medicine, and family medicine) had a significantly higher percentage of correct responses when using the medical apps for questions on drugs, diagnosis/definition, and treatment/management. PubMed4Hh had an advantage over the medical apps only for the epidemiology type of questions.³¹ However, the findings of another study revealed that the majority of trainee doctors, when directly supervised, consulted senior medical staff as the most popular and

frequently sought information source in the workplace followed by their peers and other staff in the medical/nursing team. Online textbooks and journals on the mobile devices were used as a just-in-time information resource in daily clinical practice when other sources were not available or when students were in transition from medical students to first-year trainees. The use of information sources in the workplace was attributable to several factors such as ease and speed of access, perceived reliability of the information source, senior staff's experience, and application of information in context.²¹

Nursing Students' Use of Mobile Devices. Brown and McCrorie noticed in their study that a majority of nursing and midwifery students were able to use the evidence on the iPad to guide clinical and care decision making at the point of care. The students also used the handheld device to answer patient questions promptly about their medication.²⁷ In a study of nursing students' experience with the PDA in a clinical setting, Johansson et al. found that nearly half of the students used the PDA at the patient bedside. The majority of students felt the PDA was very useful, especially in homecare where there was limited information and no computer available to use. The PDA was perceived as being easier to carry out calculations of medicines. It boosted students' confidence, saved their time, increased quality of care and patient safety; it was a useful tool to access information at the point of need.²⁶ Nursing students in another study felt that the iPod touch could help facilitate delivery of nursing care and enhance the confidence of the nurses.¹⁹ Nursing students in a study by Wittmann-Price et al. reported using the smartphone to access information for medication administration, and they reported that the smartphone made it easy and faster for them to provide patient care. In light of the handheld device's positive influence on students' patient care, staff nurses supported the

students' use of the handheld device as a patient care tool.³³ However, Johansson and colleagues noticed that few students were convinced that the PDA filled the same need in hospitals where there were abundant resources such as stationary computers, laptops, paper-based guidelines, and card index available.²⁶ Over half of nursing students in a study by Hudson and Buell did not use the PDA in clinical practice.³⁴ Similarly, a study by Morris and Maynard showed a low utilization of iPads at the clinical setting, primarily due to practical difficulties associated with accessing the Internet and small screen size on the device.³⁵

Mobile Resources to Support Student Learning

Apart from the use of mobile devices to access resources for patient care and clinical decision support, 16 studies reported multiple uses of mobile devices in accessing resources to enhance individual learning activities and improve education. Medical students used mobile devices to access medical knowledge resources and curriculum-related documents,¹⁸ prepare for tests,^{16, 18, 24} and assess and track their learning.²⁴ The handheld device (e.g., Netbook) loaded with multimedia learning materials and quizzes enabled students to gauge their level of understanding and engagement in learning and, thus, significantly improved their test scores.¹⁶ The use of the PDA consolidated learning and reinforced learned knowledge because students could repeatedly look up information. In addition, students accessed information via the PDA to make constructive use of empty time spaces during their downtime.²⁰

Compared with medical students' reaction to mobile devices in supporting learning, nursing students' opinions about mobile devices for learning were mixed. Nursing students and midwifery students in one study reported that the use of the iPad assisted with their learning in the clinical laboratory and accessing information during simulation activities and saved them in printing lecture notes in preparation for the class.²⁷ When nursing students were surveyed about the iPod touch, an overwhelming majority felt it was useful and helpful in their learning.¹⁹ However, nursing students in one study didn't think that the PDA was useful in the classroom as a learning/reference tool.³⁴ They were concerned about themselves being perceived as unprofessional or less socially acceptable with the use of the iPod in patient encounters; they indicated their intention of using the device less at post-implementation than at baseline.²⁵

Various uses of mobile devices by residents were reported in five studies. Radiology residents used the iPad during didactic and case-based conferences,²³ while neurology residents used the iPad "air-play-mirroring" to give educational presentations during or shortly after rounds.²⁸ Gonzalez, Dusick, and Martin examined the use of mobile tablet devices within the context of a competency-based curriculum in a neurosurgery residency program.¹⁷ In their study, neurosurgical residents used tablet computers as a primary tool to access a digital library and mobile resources. One year following the deployment of the tablet computer program, the results of a performance examination (CNS-SNS, a neurological surgery examination) showed a statistically significant improvement in global scoring and improvement in 16 of the 18 individual areas evaluated. The majority of the residents devoted more time to studying outside the hospital due to the introduction of tablet computers and mobile resources.³¹ Sharpe and

colleagues found a positive impact of the implementation of the Radiology iPad Toolbox on radiology residents' education and learning experience.²² More than half of the residents reported that the iPad facilitated their access to educational materials and increased their learning efficiency. In addition, the average total number of hours spent in learning radiology increased after the introduction of the iPad preloaded with the toolbox.²² The impact of the iPad on residents' learning was also reflected in their evaluation of the educational curriculum. There was a statistically significant increase in the global rating of a rotation of anesthesia for orthopedics by residents when they were provided curriculum materials on the iPad. The quality of the curriculum syllabus on the iPad was also rated higher than the print one.³⁰

Benefits of and Challenges in Accessing Resources on Mobile Devices

Among the 20 articles, 14 studies addressed the portability that enabled users to carry the mobile devices to different settings and enhanced a variety of activities including using mobile devices to read learning materials in a classroom setting,^{24, 27} check e-mails during clinical downtime,^{27, 32} make remote diagnosis when a diagnostic workstation was unavailable, and make notes at bedsides during patient encounters.^{17, 24, 27} All selected studies reported the advantage of instant access to a variety of resources via mobile devices, particularly when being away from workstations. Users appreciated the benefit of using mobile devices for quick access to learning materials,^{16, 19, 20, 23-27, 32, 34} immediate access to medical resources,^{17-19, 21, 22, 24, 28, 29, 32, 33, 35} and electronic health records at the point of patient care,^{18, 24, 26, 28} as well as performing quick and simple searches for the

evidence used to answer clinical questions at patient care settings.^{16, 22, 31} Another unique advantage of mobile devices was the availability of specially designed mobile applications discussed in 13 studies.

More than half of the reviewed studies (n=12) addressed technical difficulties that users encountered. These issues included problematic WiFi or Internet connectivity at clinical settings,^{19, 21, 24, 26, 28, 31, 33} slow processing of data,^{19, 21, 30, 33, 34} short battery life,^{29-31, 34} and limited storage capacities of mobile devices.³⁴ The portability of mobile devices came with a trade-off. The small screen size constrained users' ability to navigate^{22, 30, 33} and browse pages.^{18, 22} Due to the small screen size and inconvenience in navigation, mobile devices might not be an ideal tool for students to perform comprehensive web searches.^{19, 33} Furthermore, there was a concern with text entry on mobile devices^{22, 25, 32, 36} using a virtual keyboard,²⁴ and the small size screen inherent in tablet computers.³² Another major concern was the cost associated with ownership of mobile devices^{16, 25, 27, 29-31} and subscription to mobile applications.^{16, 20, 31, 36} Subscriptions to mobile applications, particularly subject content resources, imposed an additional burden to students, not to mention the financial cost incurred for renewing subscriptions. There were other concerns with the use of mobile devices such as preceptor or patient perceptions of student mobile device use in clinical settings as non-clinical activities or being unprofessional^{16, 27, 28, 30-32} and safety/security and consequences associated with a stolen or lost mobile device.^{16, 20, 27, 28, 34, 37}

DISCUSSION

The heterogeneity in research methods in the 20 studies precluded a quantitative systematic review of literature on the use of mobile devices to access resources by health professions students. However, the review sheds light on how medical students, nursing students, residents, and other allied health students in various settings from eight different countries used a variety of mobile devices to access a wide array of resources, mobile applications, and tools for various purposes and activities.

Mobile devices offered students a great opportunity to access and utilize a wide array of information and learning resources and application tools at a time and place when it was convenient. They served as a primary tool for accessing health information resources or locating the evidence to support evidence-based practice or clinical decision making in patient care settings.^{23, 24, 27, 28, 31, 32} They were also used for distributing learning resources and tools to enhance, consolidate, reinforce, or monitor medical and nursing students' learning,^{16, 18-20, 23, 27} and help them study for exams.^{18, 19, 24} The review has generated evidence demonstrating improved resident educational experiences during residency training.^{17, 22, 23} An iPad Toolbox of textbooks, case files, journals, lecture notes, and videos considerably increased residents' learning efficiency;²² the introduction of mobile devices loaded with curriculum-related materials contributed to residents' improved performance in a neurological surgery examination¹⁷ and their positive evaluation of the teaching quality of a rotation.³⁰ Research also reported the use of mobile devices to facilitate remote access to patient records,^{18, 24, 28} patient education,^{27, 28} and knowledge management.^{17, 18, 24}

Beneficial effects of mobile devices were evidenced through studies demonstrating their portability, convenience, and instant access to a wide range of

knowledge-based or learning resources and mobile apps favored by users. However, the findings of the studies suggested several conspicuous challenges or barriers faced by students in using mobile devices, such as unstable WiFi/Internet connections, slow data processing, short battery life, and small screen size. There were other technical, interface, cost, security, and social perception concerns with the use of mobile devices and apps. Several studies reported nursing students' mixed comments on the usability of the PDA in classroom and clinical learning environments,³⁴ a perception that the iPod was less socially desirable in patient encounters,²⁵ a low level of utilization of the iPAQ in a clinical setting,³⁵ and less likelihood of using the iPod following the implementation of the device.²⁵ The existing drawbacks in mobile resources may inhibit their wide use and adoption in specific settings. It is clear that existing technical, contextual, and cost factors merit attention when implementing a mobile program to enhance e-learning and teaching and support clinical practice.

Limitations

While every effort was made to conduct comprehensive literature searches for all relevant articles published during the defined time period and to peer-review strategies or statements for all databases and sources searched, there is likelihood that pertinent articles might be missed. Research shows that more positive results than negative results are more likely to be published in an international, English-language journal³⁸ and that positives studies are three times more likely to be published than negative studies.^{39, 40} The magnitude and direction of a study's results may, to a greater extent, determine the

summary effect of results in a quantitative review or meta-analysis. This is a qualitative systematic review that is subject to limitations of restricting search results to published literature written in English. The limitations could potentially introduce language and publication bias to the review.

Implications for Practice and Future Research

Practice of Librarianship. Mobile technologies, such as tablets (e.g., iPad) and mobile phones, are one of the fastest growing online access platforms. “Mobile technology has transformed library patrons’ expectations of when and where they should be able to access content and services.”⁴¹ Mobile device users have pushed information providers to go mobile.

The qualitative synthesis has immediate implications for health sciences libraries in allocating resources for acquiring mobile devices and applications and taking initiatives to expand library services and programs. The findings of the review point to exciting opportunities for health sciences librarians to launch creative and innovative initiatives to facilitate and accelerate integration of mobile technologies into teaching, learning, patient care, and administrative functions at their home institution. Health sciences librarians are at the forefront of embracing and adopting information and emerging technologies; promoting technology-mediated information management and retrieval; educating evidence-based medicine skills; and facilitating access to and utilization of resources for teaching, learning, patient care, and administrative function.

The following are a few recommendations for using mobile technologies as leverage to elevate health sciences libraries' status and enhancing librarians' roles and functions:

- Develop mobile-friendly websites to optimize access to and use of mobile resources (e.g., health information resources, learning resources, mobile apps) integrated into education curricula and clinical practice/workflow and geared towards specific needs of students (the millennial learners), faculty, and clinicians;
- Design, implement, and evaluate library educational programs to develop skills and expertise in using mobile technologies and various applications to foster self-regulated and lifelong learning of students, faculty, and clinicians;
- Evaluate the relevance and appropriateness of mobile resources and applications in bridging local or context-specific learning and point-of-care information gaps;
- Collaborate with health professions educators in creating or developing a toolbox of mobile resources content to facilitate the use of mobile technologies in enhancing learning, teaching, patient care, and job performance;
- Participate in or lead rigorous research endeavors that incorporate the mixed method design with multiple data collection tools to study outcomes of mobile programs.

Future Research. The review indicates that there is broad variation in how each study was conducted. The single group pretest-posttest design and one-shot case study contributed to the majority of research designs in the selected studies with populations of varying sample sizes. Single-group pretest-posttest studies with participants acting as

their own control are susceptible to numerous validity threats including history, maturation, testing, instrumentation, and so on.¹³ Moreover, there was over reliance on questionnaires as data collection measures of the efficacy of mobile devices in specific or local programs. The results in the qualitative synthesis based on self-reports and perceptions of using different types of mobile devices make it difficult to draw firm conclusions about the impact of mobile devices and also limit valid generalizability to different groups of health professions students across diverse educational programs in various settings. Further empirical research with large sample sizes and mixed research methods and triangulation techniques as demonstrated in two reports^{18, 20} is needed to build up a strong evidence base on the long-term efficacy of mobile technologies incorporated in educational curricula, student learning, patient care, and knowledge management.

The studies reviewed fell short of using standardized outcome measures to assess the impact of mobile device use. There was no evidence of reliability testing for the questionnaires used in 17 studies. Scant evidence of face and content validity was provided in three studies.^{16, 19, 35} Future investigative work on psychometric properties of a subjective and objective mobile technology measurement instrument would contribute to the development of a reliable and valid measurement to assess outcomes of mobile technology integrated into curricula of health professions education beyond the internal, local, or institutional application. The line of research with rigorous methodology design would facilitate cross-institutional research and enhance generalizability of results to health professions students across different programs.

CONCLUSION

Notwithstanding the drawbacks inherent in various types of mobile devices, the rapid development of mobile technologies will give rise to new and creative opportunities to design learning differently, extend learning spaces in real and virtual worlds, and foster a habit of lifelong learning. The findings of the systematic review suggest significant implications for health sciences libraries in allocating resources for acquiring mobile devices and apps and developing specific learning resources and mobile programs integrated into curricula and busy clinical workflow. The future of mobile devices will likely lead to health sciences librarians' expanded role in integrating mobile technology mediated information resources access in health professions education.

Received: August 21, 2015

Revised: September 22, 2015

Accepted: October 18, 2015

REFERENCES

1. "An Interview with Tom Davenport and Larry Prusak, About Their New Book: Working Knowledge: How Organizations Manage What They Know." 2005.
<http://www.brint.com/km/davenport/working.htm>.

2. Lucier, R. E. "Building a Digital Library for the Health Sciences: Information Space Complementing Information Place." *Bulletin of the Medical Library Association* 83, no. 3 (July 1995): 346-350.
3. Plutchak, T. Scott. "Breaking the Barriers of Time and Space: The Dawning of the Great Age of Librarians." *Journal of the Medical Library Association* 100, no. 1 (January 2012): 10-19.
4. Gaglani, Shiv M., and Eric J. Topol. "iMedEd: The Role of Mobile Health Technologies in Medical Education." *Academic Medicine* 89, no. 9 (September 2014): 1207-1209.
5. Su, Kuo-Wei, and Cheng-Li, Liu. "A Mobile Nursing Information System Based on Human-Computer Interaction Design for Improving Quality of Nursing." *Journal of Medical Systems* 36, no. 3 (June 2012): 1139-1153.
6. Raman, Janet. "Mobile Technology in Nursing Education: Where Do We Go from Here? A Review of the Literature." *Nurse Education Today* 35, no. 5 (May 2015): 663-672.
7. Stokes, Alice, Jeanene Light, and Laura L. Haines. "Library Support of Mobile Resources during Clinical Clerkships." *Medical Reference Services Quarterly* 33, no. 2 (April-June 2014): 179-194.
8. Klatt, Carolyn A. "Going Mobile: Free and Easy." *Medical Reference Services Quarterly* 30, no. 1 (January-March 2011): 56-73.
9. Rosario, Jovy-Anne, Marie T. Ascher, and Diana J. Cunningham. "A Study in Usability: Redesigning a Health Sciences Library's Mobile Site." *Medical Reference Services Quarterly* 31, no. 1 (January-March 2012): 1-13.

10. Boruff, Jill T., and Edward Bilodeau. "Creating a Mobile Subject Guide to Improve Access to Point-of-Care Resources for Medical Students: A Case Study." *Journal of the American Medical Association* 100, no. 1 (January 2012): 55-60.
11. Ludwig, Ludwig, and Susan Starr. "Library as Place: Results of a Delphi Study." *Journal of the Medical Library Association* 93, no. 3 (July 2005): 315-326.
12. Gall, Meredith D., Joyce P. Gall, and Walter R. Borg. *Educational Research: An Introduction*. 8th ed. Boston, MA: Pearson Education, 2007.
13. Cook, David A., and Thomas J. Beckman. "Reflections on Experimental Research in Medical Education." *Advances in Health Sciences Education: Theory and Practice* 15, no. 3 (August 2010): 455-64.
14. Gruppen, Larry D. "Improving Medical Education Research." *Teaching and Learning in Medicine* 19, no. 4 (December 2007): 331-335.
15. Tashakkori, Abbas, and Charles Teddlie. *Mixed Methodology: Combining Qualitative and Quantitative Approaches*, Applied Social Research Methods Series. Thousand Oaks, CA: Sage, 1998.
16. Bruce-Low, S. S., S. Burnet, K. Arber, D. Price, L. Webster, and M. Stopforth. "Interactive Mobile Learning: A Pilot Study of a New Approach for Aport Science and Medical Undergraduate Students." *Advances in Physiology Education* 37, no. 4 (December 2013): 292-297.
17. Gonzalez, Nester R., Joshua R. Dusick, and Neil A. Martin. "Effects of Mobile and Digital Support for a Structured, Competency-Based Curriculum in Neurosurgery Residency Education." *Neurosurgery* 71, no. 1 (July 2012): 164-172.

18. Nuss, Michelle A., Janette R. Hill, Ronald M. Cervero, Julie K. Gaines, and Bruce F. Middendorf. "Real-Time Use of the iPad by Third-Year Medical Students for Clinical Decision Support and Learning: A Mixed Methods Study." *Journal of Community Hospital Internal Medicine Perspectives* 4, no. 4 (September 2014). doi: 10.3402/jchimp.v4.25184.
19. Mui, Koh Geok, Phang Chiew Hun, Tang Lee Sung, How Ai Ling, Chioh Mei Suang, and Soo Tina. "Evaluation of the Use of Ipad Touch Drug Guide by Nursing Students." *Singapore Nursing Journal* 41, no. 1 (January-March 2014): 10-14.
20. Davies, Bethany S., Jethin Rafique, Tim R. Vincent, et al. "Mobile Medical Education (MoMED) - How Mobile Information Resources Contribute to Learning for Undergraduate Clinical Students – A Mixed Methods Study." *BMC Medical Education* 12 (January 2012): 1. doi: 10.1186/1472-6920-12-1.
21. Hardyman, Wendy, Alison Bullock, Alice Brown, Sophie Carter-Ingram, and Mark Stacey. "Mobile Technology Supporting Trainee Doctors' Workplace Learning and Patient Care: An Evaluation." *BMC Medical Education* 13 (January 2013): 6. doi: 10.1186/1472-6920-13-6.
22. Sharpe, Emerson E., Michael Kendrick, Colin Strickland, and Gerald D. Dodd. "The Radiology Resident Ipad Toolbox: An Educational and Clinical Tool for Radiology Residents." *Journal of the American College of Radiology* 10, no. 7 (July 2013): 527-532.
23. Berkowitz, Seth J., Justin W. Kung, Ronald L. Eisenberg, Kevin Donohoe, Leo L. Tsai, and Priscilla J. Slanetz. "Resident Ipad Use: Has It Really Changed the

- Game?" *Journal of the American College of Radiology* 11, no. 2 (February 2014): 180-184.
24. Alegria, Dylan Archbold Hufty, Christy Boscardin, Ann Poncelet, Chandler Mayfield, and Maria Wamsley. "Using Tablets to Support Self-Regulated Learning in a Longitudinal Integrated Clerkship." *Medical Education Online* 19 (March 2014). <http://dx.doi.org/10.3402/meo.v19.23638>.
25. Mann, Elizabeth G., Jennifer Mary Medves, and Elizabeth Vandenberg. "Accessing Best Practice Resources Using Mobile Technology in an Undergraduate Nursing Program: A Feasibility Study." *Computers, Informatics, Nursing* 33, no. 3 (March 2015): 122-128.
26. Johansson, Pauline E., Goran I. Petersson, and Gunilla C. Nilsson. "Nursing Students' Experience of Using a Personal Digital Assistant (PDA) in Clinical Practice - an Intervention Study." *Nurse Education Today* 33, no. 10 (October 2013): 1246-1251.
27. Brown, Janie, and Pamela McCrorie. "The iPad: Tablet Technology to Support Nursing and Midwifery Student Learning: An Evaluation in Practice." *Computers, Informatics, Nursing* 33, no. 1 (March 2015): 93-98.
28. George, Pravin, Christopher R. Newey, and Adarsh Bhimraj. "The Tablet Device in Hospital Neurology and in Neurology Graduate Medical Education: A Preliminary Study." *Neurohospitalist* 5, no. 1 (January 2015): 15-21.
29. Shurtz, Suzanne, and Megan von Isenburg. "Exploring e-Readers to Support Clinical Medical Education: Two Case Studies." *Journal of the Medical Library Association* 99, no. 2 (April 2011): 110-117.

30. Tanaka, Pedro Paulo, Kathryn Ashley Hawrylyshyn, and Alex Macario. "Use of Tablet (iPad[®]) as a Tool for Teaching Anesthesiology in an Orthopedic Rotation." *Revista Brasileira de Anestesiologia* 62, no. 2 (March-April 2012): 214-222.
31. Goldbach, Hayley, Aileen Y. Chang, Andrea Kyer, et al. "Evaluation of Generic Medical Information Accessed via Mobile Phones at the Point of Care in Resource-Limited Settings." *Journal of the American Medical Informatics Association* 21, no. 1 (January-February 2014): 37-42.
32. Friederichs, Hendrick, Bernhard Marschall, and Anne Weissenstein. "Practicing Evidence Based Medicine at the Bedside: A Randomized Controlled Pilot Study in Undergraduate Medical Students Assessing the Practicality of Tablets, Smartphones, and Computers in Clinical Life." *BMC Medical Informatics and Decision Making* 14, no. 1 (December 2014): 113. doi: 10.1186/s12911-014-0113-7.
33. Wittmann-Price, Ruth A., Lynn D. Kennedy, and Catherine Godwin. "Use of Personal Phones by Senior Nursing Students to Access Health Care Information during Clinical Education: Staff Nurses' and Students' Perceptions." *Journal of Nursing Education* 51, no. 11 (November 2012): 642-646.
34. Hudson, Kathleen, and Virginia Buell. "Empowering a Safer Practice: PDAs Are Integral Tools for Nursing and Health Care." *Journal Nursing Management* 19, no. 3 (April 2011): 400-406.
35. Morris, Jenny, and Veronica Maynard. "Pilot Study to Test the Use of a Mobile Device in the Clinical Setting to Access Evidence-Based Practice Resources." *Worldviews on Evidence-Based Nursing* 7, no. 4 (December 2010): 205-213.

36. Amerith, Husny. "Using iPads in OT Education." *Advance for Occupational Therapy Practitioners* 29, no. 6 (April 2013): 19. <http://occupational-therapy.advanceweb.com/Archives/Article-Archives/Using-iPads-in-OT-Education.aspx>.
37. Critical Appraisal Skills Programme. "Casp Qualitative Checklist." 2013. <http://www.casp-uk.net/-!casp-tools-checklists/c18f8>.
38. Egger, Matthias, Kay Dickersin, and George Davey Smith. "Problems and Limitations in Conducting Systematic Reviews." In *Systematic Reviews in Health Care: Meta-Analysis in Context*, edited by Matthias Egger, George Davey Smith and Douglas G. Altman, 43-68. London: BMJ, 2001.
39. Stern, Jerome M., and R. John Simes. "Publication Bias: Evidence of Delayed Publication in a Cohort Study of Clinical Research Projects." *British Medical Journal* 315, no. 7109 (September 1997): 640-645.
40. Egger, M., and G. D. Smith. "Bias in Location and Selection of Studies." *British Medical Journal* 316, no. 7124 (January 1998): 61-66.
41. Stansbury, Meris. "6 Trends on the Horizon for Academic Libraries." 2015. <http://www.ecampusnews.com/technologies/trends-horizon-libraries-873/>.