Developing the Evidence Base for M-Learning in Undergraduate Radiology Education

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Developing the Evidence Base for M-Learning in Undergraduate Radiology Education: Identifying Learner Preferences for Mobile Apps

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Abstract

Purpose: There is a lack of evidence for developing radiology mobile apps for medical students. This study identifies the characteristics which students perceive as most valuable to teaching radiology with mobile apps (m-learning).

Methods: An online anonymous survey was administered to second- to fourth-year medical students at a single institution. The survey, which was based on established theoretical framework, collected students' preferred content organization, content presentation, and delivery strategies. The Copeland method was used to rank student preferences and a 2-tailed *t* test was used to determine if student responses were related to their clinical experience, with statistical significance at $P < .05$.

Results: The response rate was 25.6% (163/635). For content organization, image interpretation (66.9%), imaging anatomy (61.3%), and common pathological conditions (50.3%) were selected as the most important. For content presentation, quizzes (49.1%) and case presentations (46.0%) were selected as the most useful. Students with clinical experience rated algorithms as more important ($P < .01$) and quizzes as less important ($P = .03$). For delivery strategies, ease of use (92.6%), navigation (90.8%), and gestural design (74.8%) were deemed the most applicable.

Conclusion: This study documents medical students' preferences for m-learning in radiology. Although learner preferences are not the only feature to consider in the development of educational technology, these provide the initial framework for radiologists wishing to develop and incorporate mobile apps into their teaching.

Résumé

Objectif : Le développement d'applications mobiles en radiologie destinées aux étudiants en médecine a peu été étudié. Cette étude visait à identifier les caractéristiques considérées comme les plus utiles par les étudiants pour l'enseignement de la radiologie au moyen d'applications mobiles.

Méthodes : Un sondage anonyme a été conduit en ligne sur des étudiants en deuxième, troisième ou quatrième année de médecine, dans un seul établissement. Ce sondage, qui s'appuie sur un cadre théorique établi, a recueilli les préférences des étudiants relatives à l'organisation de contenu, la présentation de contenu et les stratégies d'exécution. La méthode de Copeland a été utilisée pour classer les préférences des étudiants. Un test *t* bidirectionnel a servi à déterminer si les réponses des étudiants étaient associées à leur expérience clinique, avec un seuil de signification statistique $P < .05$.

Résultats : Le taux de réponse était de 25,6 % (163/635). Concernant l'organisation de contenu, les caractéristiques les plus importantes sélectionnées étaient l'interprétation de cliché (66,9 %), l'imagerie de l'anatomie (61,3 %) et les états pathologiques courants (50,3 %). Pour la présentation de contenu, les questionnaires (49,1 %) et les présentations de cas (46,0 %) ont été choisis comme les plus utiles. Les étudiants présentant une expérience clinique ont classé les algorithmes comme plus importants ($P < .01$) et les questionnaires comme moins importants ($P = .03$). Concernant les stratégies d'exécution, les caractéristiques jugées les plus applicables étaient la facilité d'utilisation (92,6 %), la navigation (90,8 %) et la conception des saisies gestuelles (74,8 %).

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Conclusion : Cette étude dévoile les préférences des étudiants en médecine en ce qui concerne l'apprentissage de la radiologie sur des applications mobiles. Bien que les préférences des étudiants ne constituent pas le seul paramètre à retenir lors de l'élaboration de technologies pédagogiques, elles apportent un cadre de référence aux radiologistes qui souhaitent développer et incorporer des applications mobiles à leurs méthodes d'enseignement.

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Key Words: Education technology; Undergraduate; Radiology; M-learning; Mobile apps

Technology-enhanced learning has become mainstream in undergraduate medical programs and medical students worldwide rely on online modules, videos, and other electronic resources to complete their training [1]. E-learning is the term used to describe the use of electronic resources (eg, the Internet) for teaching and learning and m-learning, which is a subcategory of e-learning, is the term used to describe the use of mobile applications (apps) for the same purpose [2]. Mobile apps may be used across many devices, including phones and tablets. Masters et al predicted that mobile apps would also become mainstream in medical education, and in 2012, it was reported that 85% of medical students and residents carried a smartphone to use for education [1–4]. The increasing use of mobile apps by medical students presents an opportunity to develop high quality evidence-informed mobile apps to enhance learning [4,5]. A few studies have recently documented improved learning outcomes amongst students who use mobile apps [6,7].

Education technology is essential to teaching radiology, as medical images are dynamic and viewed digitally in clinical practice. As radiology takes an increasingly prominent role in clinical practice, the need for evidence-based medical undergraduate teaching tools in radiology is growing [8,9]. There have been numerous studies documenting the use of e-learning resources in undergraduate radiology education [10–12]. However, the use of m-learning for undergraduate radiology teaching has not been documented in the literature. In 2013, a review of mobile apps in radiology was conducted that did not reveal any available specifically for medical students [13]. With the increasing capability of smartphone technology, there are more possibilities in mobile app development, such as the inclusion of high-quality radiology images. Currently, there is no data on the process of adapting established education technology frameworks to mobile apps or the use of mobile apps for undergraduate radiology teaching.

Student learning preferences in curricula play an important role in learning as student engagement and motivation are linked to improved learning outcomes [14]. However, to be useful to instructional designers, learner preferences must be solicited and incorporated into curricular initiatives in a way that takes into account evidence-informed instructional design methods [15]. Reigeluth et al proposed an instructional design method for teaching with technology which includes consideration for the way in which content is organized (ie, organizational strategies), the way material is

presented (ie, delivery strategies), and the way in which learners interact with the content (ie, management strategies) that can be applied to m-learning in radiology [16]. The aim of this study is to use this theoretical framework to identify the characteristics which medical students perceive as most valuable to teaching radiology with mobile apps.

Methods

Participants

An online survey was administered to the second-, third-, and fourth-year medical students at a large distributed medical school with campuses situated throughout the province prior to the beginning of the 2016/2017 academic year. First-year medical students were excluded, as they do not have exposure to radiology. Second-year students are exposed to 30 hours of didactic radiology teaching; third-year students are exposed to an additional 37 hours of didactic radiology teaching; and fourth-year students are exposed to an additional 4 hours of didactic radiology teaching in addition to the non-structured clinical radiology teaching encountered during core clerkship rotations [17]. Institutional ethics review board approval was waived for this study.

Materials

The survey contained 40 items grouped into 3 main sections based on the framework proposed by Reigeluth et al (Appendix 1) [16]. Sections included the way in which content is organized (ie, organizational strategies), how material is presented (ie, delivery strategies), and the way in which learners interact with the content (ie, management strategies) [16]. The survey also collected respondents' demographic information including age, sex, and year in medical school. In addition, students were asked about their exposure to radiology prior to medical school and experience using mobile apps. Finally, students were asked if they would be willing to pay for a radiology mobile app.

For this study, organizational and delivery strategies focused on content while management strategies focused on technical features. The survey items related to organization strategies were based on the standardized objectives issued by the American and European radiological societies

Figure 1. Importance of various organizational strategies for m-learning. Respondents ranked the importance of these features on a 5-point Likert scale where 1 = not important; 2 = somewhat important; 3 = neutral; 4 = important; 5 = very important. This figure is available in colour online at <http://carjonline.org/>.

[18,19]. Students ranked the perceived importance of these strategies using a 5-point Likert scale where 1 = not important; 2 = somewhat important; 3 = neutral; 4 = important; and 5 = very important. The survey items related to delivery strategies included various instructional media [20]. Students ranked the perceived usefulness of these strategies using a 5-point Likert scale where 1 = not useful; 2 = somewhat useful; 3 = neutral; 4 = useful; and 5 = very useful. Items related to management strategies were adapted from a validated mobile app rating scale (Mobile Application Rating Scale) on a 3-point Likert scale where 1 = not applicable; 2 = somewhat applicable; and 3 = applicable [21,22].

Procedure

An online survey was sent to students through their institutional email listserv in August 2016. The survey remained open for 2 weeks and students received a reminder email after the first week. The survey was anonymous and voluntary. Following collection of the data, statistical analysis was completed using Stata 14 (StataCorp). In order to rank student preferences for technology-enhanced resources, the Copeland score method for ranking was used [23]. The Copeland method is a form of ordinal-ranking algorithm that uses pairwise comparisons to compare a respondent's preference of one element component over another. A regression analysis was also carried out to determine if students' responses varied based on their level of training (pre-clinical versus clinical). Statistical significance analysis was conducted using a 2-tailed *t* test, with statistical significance at $P < .05$.

Results

Respondent Demographics

A total of 163 medical students responded to the survey, yielding a response rate of 25.6% (163/635). Approximately half of respondents (50.3%) were female and half (49.7%) were between the ages of 18–24 years old. A total of 50.9% of respondents were pre-clinical students (Year 2) and 49.1% were in their clinical years (Years 3 and 4). When asked how much radiology exposure they had prior to medical school, 89.6% (146/163) respondents indicated none, followed by 8.6% (14/163) of respondents who indicated 1–2 lectures, followed by 1.8% (3/163) who indicated they had completed a course. Given that only 17 students had any exposure to radiology, we did not test statistical significance between these groups due to limited power and generalizability). A total of 5.5% (9/163) of students indicated that they currently used a radiology mobile app and the apps listed were “Figure 1,” “Night in the ED,” and “Radiopaedia” [24–26]. A few medical students (19.2%) indicated that they would be willing to pay for a radiology app. (Note that the Radiopaedia mobile app was discontinued in March 2018.)

Students' Preferred Organizational Strategies

Most respondents felt that the “very important” organization strategies (5 on the 5-point Likert scale) were approaches to image interpretation (66.9%), imaging anatomy (61.3%), common pathological conditions (50.3%), and radiology-pathology correlation (50.3%) (Figure 1). The strategies which were deemed “not important” (1 on the

5-point Likert scale), included imaging algorithms (13.5%) and radiation dose information (12.9%). Students with clinical experience (Years 3 and 4) rated algorithms as more important than those without clinical experience (Year 2) on a 5-point scale, which was statistically significant ($P < .01$). When the organizational strategies were ranked in priority order from most important to least important, respondents selected: approaches to image interpretation, normal imaging anatomy, common pathological conditions, radiology-pathology correlation, imaging appropriateness, glossary of terms, imaging algorithms, and radiation dose information (Table 1).

Students' Preferred Delivery Strategies

Most respondents felt that the “very useful” delivery strategies (5 on the 5-point Likert scale) included quizzes (49.1%), case presentations (46.0%), and multi-media (42.3%) (Figure 2). Examples of multi-media listed in the survey included illustrations and videos. The strategies that were deemed “not useful” (1 on the 5-point Likert scale) included the ability to link to social media (44.8%), message board functionality (37.4%), ability for gaming/score keeping (20.9%), and audience participation functionality (20.9%). Students with clinical experience (Years 3 and 4) felt that a quiz format was less useful than those without clinical experience (Year 2), and this was statistically significant ($P = .03$). When the delivery strategies were ranked in priority order from most useful to least useful, respondents selected: case presentations, quiz format, multi-media, modules, note-taking functionality, ability for gaming/score keeping, audience participation functionality, message board functionality, and the ability to link to social media (Table 1).

Students' Preferred Management Strategies

The management strategies that respondents felt would be “applicable” to m-learning were ease of use (92.6%), navigation (90.8%), and gestural design (74.8%) (Figure 3). The

strategies deemed “not applicable” were customization (25.2%) and interactivity (16%) (Figure 3). There was no statistical difference between respondents with clinical experience and those without clinical experience. When the management strategies were ranked in priority order from “applicable” to “not applicable,” respondents selected: navigation, ease of use, performance, layout, graphics, gestural design, visual appeal, interactivity, and customization (Table 1).

Discussion

Our study identifies medical student preferences for m-learning in radiology. The role of learner preferences in medical education is controversial as there can be a disconnect between what learners “want” and what they “need” [15]. However, given that there is a lack of data on mobile apps in radiology undergraduate education, soliciting student preferences is an important first step to developing an evidence-based approach to app development. Despite the controversy, learner preferences have been shown to maximize student engagement and motivation, factors which are linked to improved learning outcomes [14]. Awareness of learner preferences may also highlight how undergraduate students' learning needs differ from post-graduate learners, which has been recognized as an important consideration in radiology education [9]. It is important for educators to be aware of when there is a perceived discrepancy between what they feel is important to teach and what learners prefer so that they can consider ways to bridge these gaps while maintaining student engagement [27].

Students identified approaches to image interpretation, normal imaging anatomy, and common pathological conditions as the most important organizational strategies to include in m-learning resources. Although our results are specific to mobile apps, many medical schools do emphasize these strategies in their current teaching, with radiology concepts often being introduced during anatomy teaching [17,19]. The organizational strategies ranked as “not

Table 1
Ranked list of medical students' preferences for m-learning

Prioritized list of student preferences for M-learning		
Organizational strategies	Delivery strategies	Management strategies
1. Approaches to image interpretation	1. Case presentations	1. Navigation
2. Normal imaging anatomy	2. Quiz format	2. Ease of use
3. Common pathological conditions	3. Multi-media	3. Performance
4. Radiology-pathology correlation	4. Modules	4. Layout
5. Imaging appropriateness	5. Note-taking functionality	5. Graphics
6. Glossary of terms	6. Ability for gaming/score keeping	6. Gestural design
7. Imaging algorithms	7. Audience participation functionality	7. Visual appeal
8. Radiation dose information	8. Message board functionality	8. Interactivity
	9. Ability to link to social media	9. Customization

Survey items were based on the theoretical framework and included the way in which the content is organized (ie, organizational strategies), how material is presented (ie, delivery strategies), and the way in which learners interact with the content (ie, management strategies) [16].

Figure 2. Usefulness of various delivery strategies for m-learning. Respondents ranked the importance of these features on a 5-point Likert scale where 1 = not useful; 2 = somewhat useful; 3 = neutral; 4 = useful; 5 = very useful. This figure is available in colour online at <http://carjonline.org/>.

Figure 3. Applicability of various management strategies for m-learning. Respondents ranked the importance of these features on a 3-point Likert scale where 1 = not applicable; 2 = somewhat applicable; 3 = applicable [21]. This figure is available in colour online at <http://carjonline.org/>.

important” included radiation dose information and imaging algorithms, which was unexpected as these strategies are central to clinical practice and patient safety. Students may have ranked these as lower priorities because they did not feel they were conducive to m-learning. However, it is interesting to note that students with clinical experience (Years 3 and 4) felt that imaging algorithms were more important than those without clinical experience (Year 2). This observation suggests that students’ preferences likely change as they progress through medical school and that these more complex concepts should be introduced later in medical school. In this situation, mobile apps may benefit from using distinct organizational strategies for pre-clinical and clinical students with a spiral curriculum [28]. A spiral curriculum is one in which there is an iterative revisiting of content over time with deepening of the teaching with each successive iteration in order to revisit important themes and build on prior concepts [28].

Even though m-learning represents an opportunity for disruptive and innovative approaches to medical education, students ranked more traditional delivery strategies as “most useful” (eg, case presentations, quizzes, modules) and newer teaching formats as lower priority (eg, gaming/score keeping, audience participation functionality, social media linkage). This result was unexpected, as there is preliminary evidence for the use of gamification for teaching in educational technology within medicine [29]. Gamification, which involves the inclusion of “game design elements” to teaching, has been used as a strategy to engage millennial learners and enhance adult learning [29]. Our findings may be due to students’ perception of the complexity of radiology, which has a strong foundation in basic science, and thus, that it may not be compatible with this format or their belief that gamification may not be suited to a mobile app format. Alternatively, results may be due to students’ unfamiliarity with gamification as a pedagogical approach. Interestingly, much of the evidence for gamification comes from the post-graduate literature, with few studies documenting the use of this strategy among medical students [30].

Well-designed technology-enabled resources, such as mobile apps, place the student at the centre of their learning and facilitate their autonomy as learners [2]. Mobile apps contributing to medical education should create a “learner-centered activity system” in which the learner (subject) interacts with the content (object) to become a more competent physician (outcome) [2]. This learner-centered system is enabled through learners’ interactions with the content (ie, management strategies). Almost all respondents felt that ease of use (92.6%), navigation (90.8%), and gestural design (74.8%) were essential to facilitating learning. However, students responded that all of the management strategies listed would be applicable to a radiology app, which is not surprising as these items were adapted from a previously validated scale [22]. Additionally, paying for a mobile app was identified as a barrier to use, with only a few students (19.2%) reporting that they would be willing to pay for an app.

The main limitation of this study is that it was conducted at a single institution and students completing the survey all had similar standardized experiences in radiology. Although standardization has been identified as important in undergraduate radiology education, students’ experiences continue to vary widely throughout North America and Europe [3,18,31,32]. Additionally, there may be an implicit bias in participants, as students with a strong viewpoint on radiology and m-learning may be more likely to take the time to reply. Our study also exclusively focused on students’ preferences for software features (eg, curriculum and technical design) and not on hardware features (ie, type of device). Further studies should consider students’ preferred hardware features (eg, screen size). Lastly, this is a study regarding learner preferences which represents only a part of the evidence-base required to develop mobile apps for medical students [3]. Studies that solicit learner preferences (ie, part of a needs assessment) are key first steps to education innovation, implementation, and evaluation [33]. Additional research is required to determine if these preferences are consistent with educator preferences and if the incorporation of these preferences into resources results in improved learning outcomes and ultimately patient management.

Conclusion

Based on an established theoretical framework, this study identifies the organizational strategies (image interpretation, normal imaging anatomy, common pathological conditions), delivery strategies (case presentations, multimedia, quiz format) and management strategies (ease of use, navigation, gestural design), which medical students feel would be the most valuable to m-learning in radiology. Although students’ preferences are not the only factor to consider in curriculum development, selective inclusion of learners’ preferences into radiology undergraduate mobile app development may increase student motivation, engagement, and ultimately learning in this specialty.

Supplementary Data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.carj.2019.03.007>.

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