Original Research

A student survey exploring app-based radiologic anatomy flashcards for medical education

Kieran Lacey, MD,[1] Angus Hartery, MD FRCPC[1]

1. Faculty of Medicine, Department of Radiology, Memorial University, St. John's, NL, Canada

ABSTRACT

Background: Online learning tools are common in medical education, including digital flashcard sets on web-based apps viewed using a computer or mobile device. However, existing research on apps for learning radiologic anatomy is limited, and further examination of the educational outcomes of using smartphones versus other electronic devices is needed.
Methods: Digital flashcards of radiologic anatomy were created by editing images in PowerPoint and uploading them to an online app (Quizlet). Participants reviewed the flashcard sets on a device of their choosing, either a smartphone or a computer. An online survey was distributed. Anonymous recruitment of medical students and residents at a single university occurred between 2022 and 2024.
Results: Of the 32 respondents, 21 (65.6%) viewed the flashcard sets using a computer, and 11 (34.4%) used a smartphone. Common themes were identified regarding the preference for viewing flashcards on either a computer or smartphone. Regardless of the device, most participants (93.3%, n = 30) agree that digital flashcards are beneficial for learning radiologic anatomy.
Conclusions: Findings suggest that app-based flashcards are a beneficial learning tool for radiologic anatomy. While smartphone accessibility is convenient, our respondents preferentially chose a computer for flashcard review due to its larger images, easier platform to navigate, and fewer distractions (e.g., phone notifications). Future work could evaluate the efficacy of each device for learning radiologic anatomy.

Keywords: Radiology, Anatomy, Application, Flashcards, Medical Education

INTRODUCTION

Medical trainees are required to learn a growing volume of information, albeit while their time in a traditional classroom setting is limited.[1] Due to advances in software and connectivity, online learning tools are playing a more significant role in medical education.[2,3] Of these tools, the most commonly used are web-based applications viewed on the internet or a smartphone application.[2] Such tools provide unlimited access to educational resources in a way that is convenient, efficient, portable, and flexible.[1,2,4,5]

Web-based applications enact the principle of "microlearning," whereby students engage in short teaching sessions throughout the day.[2] Healthcare is a fast-paced environment with frequent updates in clinical practice. Thus, smartphones are increasingly used to access medical information and guidelines anytime and anywhere.[1,3,5-9] In 2017, a survey of medical students at a university in India found that over 90% (n = 446) felt smartphones were helpful in medical education.[10]

Flashcards are an established study tool in medical education.[4,11,12] They utilize the principle of spaced repetition, which is a more effective study technique than short-term mass revision.[11] This is useful for studying anatomy, which has been described as repetitive and time-consuming.[2,5,6] Digital flashcards have several advantages, including being accessible anywhere, enabling detailed analysis of self-testing, and allowing for relatively quick review as needed.[5,12] Anatomy apps have become a valuable resource for medical students, particularly those in programs that do not include cadaver labs.[7]

Students commonly use web-based applications such as Quizlet to create and review digital flashcard sets.[7] It has been reported that students who used Quizlet preferred reviewing text and anatomical images using their smartphone rather than a computer.[7,12] This was due to smartphone portability and processing speed. On the contrary, the main limitations of studying flashcards on a smartphone are the small screen size and the resulting eyestrain.[12] Importantly, according to the American College of Radiology (ACR), smartphone image quality is not yet sufficient for diagnostic purposes, though it can be suitable for teaching.[13-15]

Smartphones and computers were chosen for comparison as they are both commonly owned and used for studying by the modern student. Limited research exists on student preference for using smartphones versus other electronic devices for medical education.[1,12] More specifically, there is a lack of research on these preferences regarding web-based applications for learning radiologic anatomy. The intended purpose of these digital device aids is to optimize information processing and increase content accessibility, albeit while balancing their risk of cognitive overload by distractors and unintentional multitasking [16]. Regarding this balance, one device does not fit every individual's needs, and it may vary depending on the learning environment or study content. Thus, this study aims to explore learners' satisfaction and perceptions towards using radiologic anatomy digital flashcard sets on their smartphones or computers. If this is

better understood, efforts towards learning resource creation could be appropriately targeted towards a modality that is more likely to engage the students and increase their overall usage.

METHODS

Study Design

The flashcard sets were created using original material sourced from the Memorial University of Newfoundland (MUN) diagnostic radiology residency program director (Figure 1). Images were edited in PowerPoint and then uploaded to the app Quizlet. There is an option for medical student or resident-level content. A detailed list of the content covered by each flashcard deck can be found in Figure 2.

This is a one-group post-survey study with a pre-experimental study design. Participants reviewed the flashcard sets on a device of their choosing, either a smartphone or a computer. Survey creation, distribution, and data storage were performed using Qualtrics software, an online survey tool institutionally approved by MUN. The survey consists of three short answer questions and eight five-point Likert-scale assessments (available upon request).

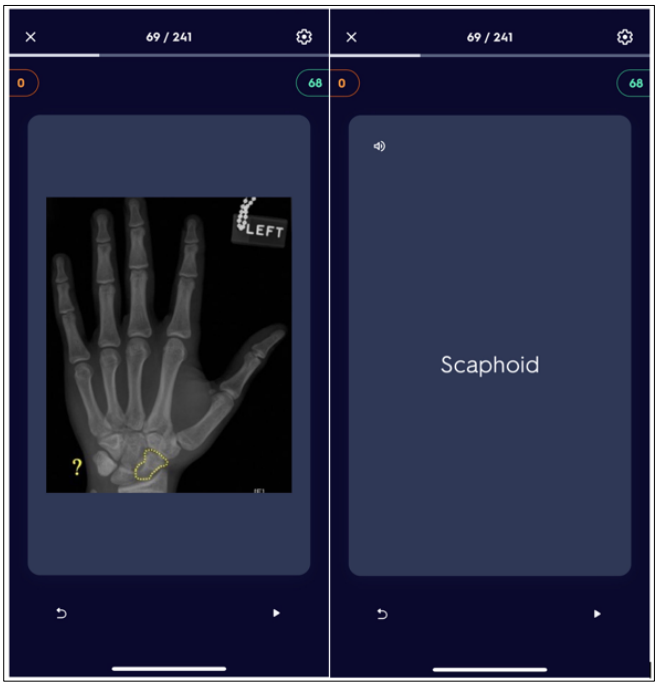

Figure 1. *Smartphone screenshots of a "Quizlet" flashcard from the "MSK" set in the "MUN Medical Student Radiological Anatomy" class.*

Medical Student Level	Radiology Resident Level
Abdominal Viscera	Abdominal Angiogram Anatomy
Abdominal Wall and Inguinal Region	Abdominal Ultrasound Anatomy
Abdominal X-Ray Anatomy	Chest Vascular and Bronchus Anatomy
CT Vascular Anatomy	Chest Vascular and Coronary Anatomy
MSK	Chest X-ray and CT Anatomy
Pelvic Anatomy and Bones	Coronary CT Vascular Anatomy
Pelvic Musculature	Head and Neck Vascular Anatomy
Radiographic Vascular Anatomy	Head MRI Anatomy
Skull, Spine & Vessels	IR Carotid Vascular Anatomy
Urogenital Systems	IR Celiac and SMA Vascular Anatomy
	IR Pancreatobiliary Anatomy
	IR Vascular Anatomy
	Liver Segment and Abdominal Compartment Anatomy
	Lung Segment Anatomy
	MSK Lower Limb
	MSK Pelvic MRI Anatomy
	MSK Upper Limb
	MSK X-Ray Anatomy
	Sagittal MRI of the Knee
	Skull X-Ray Anatomy
	Suprahyoid Neck CT Anatomy

Figure 2. *List of entitled flashcard decks.*

Setting and Recruitment

Participants were eligible to participate if they were current medical students or radiology residents at MUN. This target audience was selected as the digital flashcard sets had been made available to MUN students since their creation in 2019, therefore they would be the most familiar with their content and utility. Anonymous recruitment occurred over two years (October 2022 to March 2024) via institutional email dissemination, in-class promotion, and sharing on the local Radiology Interest Group's private social media page. Given these parameters, we reached 5 medical school classes (approximately 80 students per year) and 6 resident cohorts (approximately 3 students per year), totalling a target audience of 418 students. With an expected survey response rate of 5-10%, the number of potential respondents ranged between 21 to 42 people.

Participants who completed the survey were entered into a random draw to win a gift card valued at CAD 20.00. Survey instructions include a link to a guide on accessing and navigating the Quizlet flashcard sets (available upon request). Informed consent was obtained, and the study was approved by the Newfoundland and Labrador Health Research Ethics Board (Reference # 2022.118).

Data Analysis

Descriptive statistics in the form of proportions/percentages were implemented to compare the participants who preferred using their smartphone or computer, as well as to analyze the responses in each arm of the Likert scale. Using a thematic analysis framework, common themes were identified from open-ended feedback.

RESULTS

The survey received 32 responses (7.7% of the target audience). Of these participants, 25 (78.1%) were medical students, six (18.8%) were radiology residents, and one (3.1%) responded "other" but did not specify their position. The largest cohort of responses came from first-year medical students (n = 9, 28.13%). These demographics are detailed in Table 1.

Table 1. *Training level of the survey participants. MS = medical student. R = radiology resident. Number (i.e. 1) = year of program.*

Training Level	Count (%)
MS1	9 (28.1%)
MS2	5 (15.6%)
MS3	6 (18.8%)
MS4	5 (15.6%)
R1	1 (3.1%)
R2	2 (6.3%)
R3	1 (3.1%)
R4	2 (6.3%)
R5	0 (0.0%)
Other	1 (3.1%)

Of the 32 respondents, 21 (65.6%) viewed the flashcard sets using their computer, and 11 (34.4%) used their smartphone. Of the 25 medical students, 17 (68.0% of medical students, 53.1% of total respondents) used their computers, while eight (32.0% of medical students, 25.0% of total respondents) used their smartphones. As for the 6 residents, four (66.7% of residents, 12.5% of total respondents) used a computer, and two (33.3% of residents, 6.3% of total respondents) used their smartphone. The single respondent with the training level "other" used their smartphone (3.1% of total respondents). A detailed breakdown is depicted in Figure 3.

Two of the 32 respondents did not complete the Likert-scale assessment or open-ended questions, and their responses were not included in the analysis. Therefore, the analysis of the survey questions included 30 respondents. Regardless of the chosen device, the majority (93.3%) agreed that digital flashcards are beneficial for learning radiologic anatomy. They indicated a slight preference for viewing these on their computer (20.0%) over their smartphone (13.4%), while others had a neutral opinion (23.3%) or responded "not applicable" (43.3%). A detailed presentation of the Likert-scale assessment can be seen in Table 2.

The common themes identified regarding the respondent's preference for using a computer include larger images, an easier platform to navigate, and fewer distractions (i.e. phone notifications). The main reason participants preferred the smartphone was its availability and portability. Regarding general comments on the flashcard sets, respondents stated the guide on navigating Quizlet is beneficial, and repetition of flashcards in different sets helped reinforce their learning.

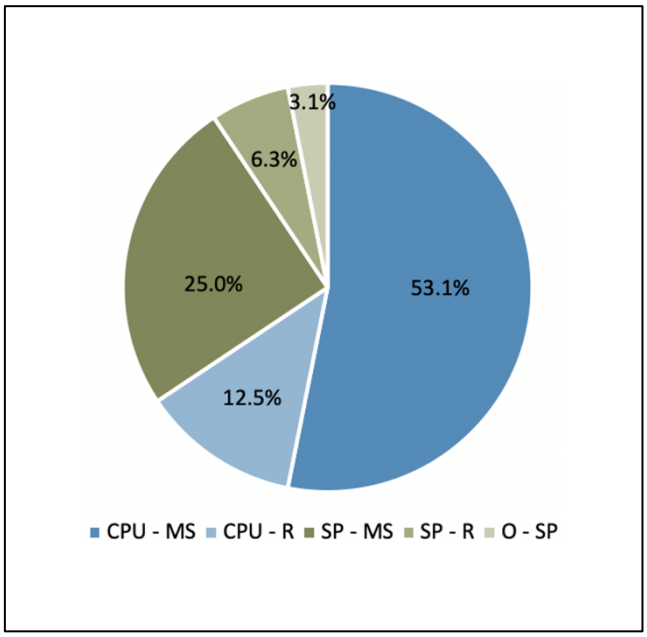

Figure 3. *Breakdown of respondent device usage (n = 32; MS = medical student, R = resident, O = other, CPU = computer, SP = smartphone).*

DISCUSSION

Nearly twice as many participants chose to review the flashcard sets using their computers, which was similar between medical students and residents. Moreover, they indicated a slight preference for using their computer over their smartphone as the images could be larger, there were fewer distractions from smartphone notifications, and the online platform on the computer was easier to navigate. These results are in contrast to prior research, which shows that students who used Quizlet preferred using their smartphones.[7,12] A possible reason for this contradictory finding could be that the prior studies did not discuss the review of detailed radiographic grey-scale images that require larger and better-quality pictures, which are generally more feasible on computers instead of smartphones [12-15]. A second potential influence is that one of the two previous studies was published in 2014 (the other being more recent in 2020), and since this time, smartphones have become increasingly more advanced with a greater potential to cause distraction through ample pop-up notifications. For example, a 2014 article quoted that people received an average of 63.5 smartphone notifications per day, while another published in 2024 found an increase of up to 146 per day, which was even greater for young adults [17,18]. It is well documented that smartphone notifications are distracting, and this increase over time could have possibly led to our participants preferring to study using their computers [19,20]. Direct quotes from participants that

Table 2. *Participant's level of agreement with various statements.*

Statement	Not Applicable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I found this flashcard set helpful for radiologic anatomy comprehension.	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (6.7%)	15 (50.0%)	13 (43.3%)
I found this flashcard set more effective than reading textbook/lecture material alone.	0 (0.0%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	20 (66.7%)	8 (26.7%)
I would recommend this flashcard set to colleagues.	0 (0.0%)	0 (0.0%)	1 (3.3%)	3 (10.0%)	19 (63.3%)	7 (23.3%)
I will use this flashcard set again.	0 (0.0%)	1 (3.3%)	0 (0.0%)	9 (30.0%)	13 (43.3%)	7 (23.3%)
The learning content was appropriate for my stage of learning.	0 (0.0%)	0 (0.0%)	1 (3.3%)	3 (10.0%)	17 (56.7%)	9 (30.0%)
The smartphone image quality was appropriate.	17 (56.7%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	9 (30.0%)	3 (10.0%)
The computer image quality was appropriate.	3 (10.0%)	1 (3.3%)	0 (0.0%)	4 (13.3%)	15 (50.0%)	7 (23.3%)
I prefer this flashcard set on my mobile device (not my computer).	13 (43.3%)	1 (3.3%)	5 (16.7%)	7 (23.3%)	2 (6.7%)	2 (6.7%)

reflected these findings were "I prefer to study and view medical images on a larger screen (i.e. my laptop/computer), and try to have less apps on my phone" and "The computer is less distracting and does not receive as many notifications as a smartphone."

Participants stated that smartphones are more readily available and portable, which is consistent with previous literature.[1,2,4,5] One participant answered, "I always have my phone on me and it is easy to open up - I don't always have my computer and it takes longer to open and start things on." We expected this to significantly influence device choice, given the typically busy and fast-paced healthcare environment whereby medical students/residents attempted to complete the flashcards. However, for the reasons discussed above, participants cited more positive aspects of reviewing the flashcards using a computer.

Regardless of the device used, the majority of participants had a positive opinion of the flashcard sets. Most participants found them to be a beneficial learning tool for radiologic anatomy, an adjunct to reading text, and that the image quality is appropriate.

When designing digital flashcard sets for students, providing the learner with a guide on how to use the app is beneficial. Repeating similar flashcards in different sets also helps to reinforce essential details. A participant stated "The repetition of flashcards helps to reinforce learning. I particularly liked the fact that there were several repeated cards in various sets." Regarding designing flashcards for smartphones, the ability to provide focused and zoomed-in images of specific anatomy may allow for easier viewing. These are key concepts for educators to consider in the future.

Limitations

As this is exploratory research using a one-group post-survey study, with a pre-experimental study design, there are inherent limitations. Without control groups or random assignment,

this study cannot establish causality as to how or why participants chose to use a computer or smartphone. Additionally, the study's generalizability is limited by its one-group analysis with a small sample size, particularly for the resident cohort.

As per the devices used in this study, smartphones and computers are common learning tools among today's students, therefore we assumed all participants had access to these devices. Additionally, image quality and device picture settings were not standardized as participants had the freedom to choose which personal device they used to view the flashcard sets. This could also implement a self-selection bias. Lastly, participants were not made to use both a smartphone and a computer. Therefore, their opinions in this study were formed without comparison to the alternative device.

Future Considerations

This study explored device preference for reviewing radiologic anatomy flashcards by allowing participants to choose which of their own personal devices they used. In order to standardize device image quality and settings, as well as to remove selection bias, a future study could have participants use specific models of both a computer and a smartphone and subsequently make a preference judgement.

This study does not directly evaluate the impact of each device on learning outcomes such as comprehension, recall, or retention. Further research into which device optimizes these learning outcomes would be helpful in guiding students so that they can obtain the greatest value from their study time. The efficacy of these devices could be assessed by implementing pre- and post-testing of radiologic anatomy after reviewing digital flashcard sets and then subsequently conducting long-term follow-up to evaluate for content retention.

Furthermore, in an effort to improve the sample size, generalizability, and infer causality, the target audience could be expanded to involve additional medical schools, groups could be designated to review the digital flashcard sets with only a computer or a smartphone, and there could be a control group that studies the material by reading the content without the aid of flashcards.

Finally, resident training level and learning experiences differ from those of medical students. If more residents were recruited from other institutions, the data analysis could explore differences between the preferences and learning outcomes of these two groups.

CONCLUSION

App-based flashcards are a beneficial learning tool for radiologic anatomy. While smartphone accessibility is convenient, the participants in our study preferentially chose a computer for flashcard review. Future research could address the efficacy of these devices for learning radiologic anatomy.

CONFLICT OF INTEREST

The authors report no conflicts of interest.

FUNDING

The study did not receive any specific grant or external funding.

REFERENCES

1. Short SS, Lin AC, Merianos DJ, et al. Smartphones, trainees, and mobile education: implications for graduate medical education. *J Grad Med Educ*. 2014;6(2):199-202. https://doi.org/10.4300/JGME-D-13-00238.1
2. Schneider M, Binder T. E-Learning in medicine: Current status and future developments. *Hamdan Med J*. 2019;12(4):147-51. https://doi.org/10.4103/HMJ.HMJ_74_19
3. Golshah A, Dehdar F, Imani MM, et al. Efficacy of smartphone-based mobile learning versus lecture-based learning for instruction of cephalometric landmark identification. *BMC Med Educ*. 2020;20(287):1-8. https://doi.org/10.1186/s12909-020-02201-6
4. Eads AW, Hamson-Utley JJ. A study of knowledge and practical skill performance in university students: A comparison of technology enriched versus traditional classroom instruction. *Internet J Allied Health Sci Pract*. 2014;12(2):1-5. https://doi.org/10.46743/1540-580X/2014.1484
5. Golenhofen N, Heindl F, Grab-Kroll C, et al. The use of a mobile learning tool by medical students in undergraduate anatomy and its effects on assessment outcomes. *Anat Sci Educ*. 2020;13(1):8-18. https://doi.org/10.1002/ase.1878
6. Mosa ASM, Yoo I, Sheets L. A systematic review of healthcare applications for smartphones. *BMC Med Inform Decis Mak*. 2012;12(67):1-31. https://doi.org/10.1186/1472-6947-12-67
7. Foti MK, Mendez J. Mobile learning: How students use mobile devices to support learning. *J Literacy Technol.* 2014;15(3):58-78. Available from: https://tinyurl.com/54cdywsx. [Accessed May 18, 2024]
8. Yadalla HKK, Shankar MV. Professional usage of smart phone applications in medical practice. *Int J Health Allied Sci*. 2012;1(2):44-6. https://doi.org/10.4103/2278-344X.101656
9. Trelease RB. From chalkboard, slides, and paper to e-learning: How computing technologies have transformed anatomical sciences education. *Anat Sci Educ*. 2016;9(6):583-602. https://doi.org/10.1002/ase.1620
10. Gavali MY, Khismatrao DS, Gavali YV, et al. Smartphone, the new learning aid amongst medical students. *J Clin Diagnostic Res*. 2017;11(5):5-8. https://doi.org/10.7860/JCDR/2017/20948.9826
11. Murray SL, Phelps J, Altabbakh H. Enhancing exam prep with customized digital flashcards. *J STEM Educ*. 2018;19(4):42-5. Available from:

https://www.jstem.org/jstem/index.php/JSTEM/article/view/1983/2088. [Accessed May 18, 2024]
12. Sage K, Piazzini M, Downey IV JC, et al. Flip it or click it: Equivalent learning of vocabulary from paper, laptop, and smartphone flashcards. *J Educ Technol Syst*. 2020;49(2):145-69. https://doi.org/10.1177/0047239520943647
13. Rodrigues MA, Visvanathan A, Murchison JT, et al. Radiology smartphone applications; current provision and cautions. *Insights Imaging*. 2013;4(5):555-62. https://doi.org/10.1007/s13244-013-0274-4
14. Al-Hasani H, Abboudi H, Ninan T, et al. Smartphone applications for the radiologist. *Open J Radiol*. 2013;3:231-7. http://dx.doi.org/10.4236/ojrad.2013.34037
15. Silosky M, Milman R, Bevins NB. Features to consider when selecting displays for remote reading. *J Am Coll Radiol*. 2022;19(1):73-5. https://doi.org/10.1016/j.jacr.2021.09.038
16. Limniou M. The Effect of Digital Device Usage on Student Academic Performance: A Case Study. *Educ. Sci.* 2021; 11(3):121. https://doi.org/10.3390/educsci11030121
17. Pielot M, Church K, de Oliveira R, et al. An in-situ study of mobile phone notifications. *Proc Hum-Comput Interact*. 2014;16(1):233-242. https://doi.org/10.1145/2628363.262836
18. Franklin, Neil. *People receive a phone notification every ten minutes on average.* Workplace Insight. (2024, May 29). https://workplaceinsight.net/people-receive-a-phone-notification-every-ten-minutes-on-average/
19. David P, Kim J-H, Brickman JS, et al. Mobile phone distraction while studying. *New Media & Soc*. 2014;17(10):1661-1679. https://doi.org/10.1177/1461444814531692
20. Kaminske A, Brown A, Aylward A, et al. Cell phone notifications harm attention: An exploration of the factors that contribute to distraction. *Eur J Educ Res*. 2022;11(3):1487-1494. https://doi.org/10.12973/eu-jer.11.3.1487