# Can alerts from smartphone application improve how family medicine residents prepare for certification examination? A Mixed Methods Study.

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# PREFACE AND CONTRIBUTION OF AUTHORS

I performed this thesis under the supervision and guidance of my thesis committee members: supervisor Dr. Roland Grad, co-supervisor Dr. Pierre Pluye, and committee member Dr. Aliki Thomas. Dr. Roland Grad conceived the original idea of the IAM app project as a multi-phase program of research. He designed the IAM app pilot study and received the approval for the pilot study, instruments and consent form from the Institutional Review Board of the McGill Faculty of Medicine and the Hamilton Integrated Research Ethics Board (see Appendix 2). As a M.Sc. student, I performed the literature review, counted page visits recorded at the central server in log files, performed descriptive analysis using R statistical software, qualitative data collection (semi-structured interviews), transcription, thematic analysis, interpreted both quantitative and qualitative results, and wrote this thesis with input from my thesis committee members.

My supervisors discussed the results of each phase, commented on the draft version of my thesis, and approved the final version of the thesis.

# ABSTRACT

## Background

In 2014, to help family medicine residents prepare for their certification examination, the ITPCRG team (McGill University-Department of Family Medicine) created an IAM smartphone application. This mobile app was inspired by the concept of spaced education (SE). We operationalized SE as follows: access to clinical information on the 99 Priority Topics in Family Medicine and their Key Features, a weekly alert to read one new topic, open ended test questions, and answer feedback. SE has positive effects on long-term knowledge retention in highly focused specialties. However, SE has not yet been studied in the context of the family medicine residency. This study aimed to describe residents' participation in SE, explore the factors that influenced sustainable participation in SE mediated by weekly alerts on the IAM app, and describe strategies for IAM app improvement from residents' perspectives.

## Objectives

Quantitative: (1) To estimate the extent to which an intervention (weekly alerts on the mobile app as a mediator of SE) stimulates residents to visit the IAM app during their first year of training, (2) To identify participants for the second qualitative phase (residents following alerts most closely and least closely). Qualitative: (1) To describe factors, from the perspectives of residents, which facilitate or hinder sustainable participation in SE mediated by weekly alerts, (2) To describe strategies recommended by residents for improvement of the IAM app as an information system for SE.

**Methodology and methods:** Using a sequential explanatory mixed methods research design, two sequential studies were performed. Phase 1: Pre-experimental study was conducted to describe app use among incoming first year family medicine residents at McMaster (2015) and to identify participants for the second qualitative phase (residents following alerts most closely and least closely). Phase 2: In qualitative descriptive study, 13 residents were interviewed. Semi-structured interviews were analyzed using thematic analysis (deductive-inductive approach) to describe residents' perspectives.

## Results

In phase 1, 81 of 96 (84%) first year residents consented to participate in the study. Typical participants were between 25 and 31 years old, predominantly female (71%) and predominantly using iOS devices (76%). Of 81 residents who consented to participate in the study, 65 residents (80%) installed and used the app. A count of page visits per month revealed that the effect of alerts from the IAM app was not sustained. The stimulating effect of alerts was observed only during the first two months of the study. For these who used the IAM app, the number of topics of the week each resident visited within 1-week of the alert (or alert visits) varied from 0 to 34 (mean=1.7, SD=4.5), and the total number of pages each participant visited (total page visits) varied from 1 to 442 (mean=28.3, SD=61.4). In phase 2, both barriers and facilitators to resident's sustainable participation in SE mediated by weekly alerts appeared to fall into five dimensions: user-related factors, information content factors, mobile app design factors, alert system factors, and service factors. Strategies for improvement of the IAM app appeared to fall into four dimensions: information content factors, mobile app design factors, alert system factors, and service factors.

## Discussion and conclusion

These study findings were consistent with the literature on SE. Inspired by the DeLone and McLean Information Systems (IS) Success Model, five dimensions (user-related factors, information content factors, mobile app design factors, alert system factors, and service factors) appear to be potential predictors of users' sustainable participation in SE. Results of this study were used to modify the IAM app according to residents' needs. The next phase of the IAM app project will test a new version of the IAM app and measure the effectiveness of SE.

# RÉSUMÉ


**Introduction**

En 2014, le *Groupe de recherche sur les technologies de l'information en soins primaires* (ITPCRG) a créé une application mobile IAM. Inspirée du concept de l'éducation espacée (EE), l'application IAM a été développée pour aider les résidents en médecine de famille à se préparer à l'examen de certification. L'EE a été mise en œuvre en utilisant 99 sujets d'étude prioritaires (éléments clés), des alertes hebdomadaires incitant à lire un nouveau sujet, et une question ouverte avec une réponse correcte pour chaque sujet. L'EE a des effets positifs sur la mémoire à long terme dans des domaines très spécialisés. Toutefois, l'EE n'a pas encore été étudiée dans le contexte de la formation postdoctorale en médecine de famille. Cette étude visait à décrire la participation des résidents à l'EE, à explorer les facteurs qui ont influencé la participation durable à l'EE médiée par les alertes hebdomadaires de l'application IAM.

**Objectifs**

Quantitatifs: 1) Estimer dans quelle mesure une intervention (alertes hebdomadaires sur l'application mobile en tant que médiateur de l'EE) stimule les résidents à utiliser l'application IAM au cours de leur première année de formation; 2) Identifier des participants pour la deuxième phase qualitative (résidents suivant les alertes de la manière la plus assidue et la moins assidue).

Qualitatifs: 1) Décrire les facteurs, du point de vue des résidents, qui facilitent ou entravent la participation durable à l'EE médiée par une alerte hebdomadaire; 2) Décrire les stratégies recommandées par les résidents pour l'amélioration de l'application IAM en tant que système d'information pour faciliter l'EE.

**Méthodologie et méthodes**

Dans un devis mixte séquentiel explicatif, deux phases de recherche ont été réalisées. Phase 1: Une étude pré-expérimentale a été menée pour décrire l'utilisation de l'application chez les résidents de première année en médecine de famille à McMaster (2015) et pour identifier les participants pour la deuxième phase qualitative. Phase 2: Dans une étude descriptive qualitative,

13 résidents ont été interviewés. J’ai utilisé une approche déductive et inductive pour analyser des entrevues semi-structurées (analyse thématique) afin de décrire les points de vue des résidents.

**Résultats**

Phase 1: 81 des 96 résidents ont consenti à participer. Les résidents typiques avaient entre 25 et 31ans, principalement des femmes (71%), et utilisaient des appareils mobiles iOS (76%). Sur les 81 résidents qui ont consenti à participer, 65 résidents (80%) ont installé l'application IAM. Le nombre de pages visitées par mois a révélé que l'effet des alertes n'était pas maintenu. L'impact stimulant des alertes a été observé uniquement durant les deux premiers mois de l'étude. Pour les résidents qui ont utilisé l'application IAM, le nombre de sujets de la semaine visités dans la semaine d'alerte (visites d'alerte) variait de 0 à 34 (moyenne 1,7 et écart-type 4,5) et le nombre total de pages visitées par chaque participant a varié de 1 à 442 (moyenne 28,3 et écart-type 61,4). Phase 2 : Les obstacles et les facilitateurs de la participation durable à l'EE ont été classés selon cinq dimensions: facteurs liés à l'utilisateur, au contenu de l’information, à la conception de l’application, au système d'alerte et aux services. Les stratégies d'amélioration de l'application IAM proposées par les résidents ont été classées selon quatre dimensions: le contenu de l'information, la conception de l'application mobile, le système d'alerte, et les services.

**Discussion et conclusion**

Les résultats de l’étude sont conformes à la littérature sur l'EE. Inspirée par le modèle de succès des systèmes d'information proposé par DeLone et McLean, je suggère que les cinq dimensions mentionnées ci-dessus sont des prédicteurs potentiels de la participation durable des résidents en EE. Ces résultats ont été utilisés pour renforcer une intervention éducative espacée pour les résidents en médecine de famille.

# ABBREVIATIONS

College of Family Physicians of Canada (CFPC)

Continuing Medical Education (CME)

Basic Science in Oncology Course (BSOC)

Information Systems (IS)

Information Technology Primary Care Research Group (ITPCRG)

Information Assessment Method (IAM)

Multiple choice questions (MCQ)

Professional medical education (PME)

Short Answer Management Problems (SAMPs)

Spaced Education (SE)

# TABLES AND FIGURES

# 1. INTRODUCTION

The decisions of family physicians regarding for example which drug to prescribe or diagnostic test to order, affect not only health outcomes and cost-effective care, but how the health system as a whole is used (Health Council of Canada, 2010; Starfield, Shi, & Macinko, 2005). Family physicians are often referred as gatekeepers to Canada's health care system because they are the first point of contact with the health care system.

To obtain a license for independent practice as a family physician, residents must pass the board certification examination of the College of Family Physicians of Canada (CFPC). According to previous studies, the test scores of family physicians on this certification examination show a sustained relationship with indices of preventive care, as well as acute and chronic disease management over 4 to 7 years of follow up in primary care practice (Tamblyn et al., 1998; Tamblyn et al., 2002). Potentially, an innovative educational strategy may help our future family physicians to better prepare for their licensure examination could improve their clinical performance and the quality of primary health care.

## 1.1 Problem Statement

It is difficult for medical students and residents to retain knowledge and achieve long term knowledge retention in the context of medical education (Augustin, 2014; Custers, 2010; Greb, Brennan, McParlane, Page, & Bridge, 2009). All future doctors are faced with a potentially large and ever growing knowledge base which they are expected to acquire during their formal training. Indeed, medical students often feel stressed and overwhelmed by the excessive amount of factual knowledge that they are obliged to retain in order to prepare for examinations and acquire professional knowledge and skills (Radcliffe & Lester, 2003).

Some have suggested that continuous review of the learned material has a role to play in retention of knowledge (Berden, Willems, Hendrick, Pijls, & Knape, 1993; Custers, 2010; Ebbinghaus, 1964; Yeh & Park, 2015). Bell conducted an educational trial that explored this problem of medical knowledge retention (Bell et al., 2008). Internal and family medicine residents completed an online diabetes tutorial. Subsequently, these residents were randomized to complete a post-test with a delay (1-day, 3-days, 8-days, 21 and 55-days). Medical knowledge was mostly lost to recall at 55 days. From their findings, it was recommended that physicians reinforce new learning after as little as 1 week.

Given the rapidly changing body of medical knowledge, clinician-educators are seeking innovative ways to improve learning and knowledge retention.

To address the issue of long-term knowledge retention for family medicine residents, the Information Technology Primary Care Research Group (ITPCRG) at McGill University created the Information Assessment Method (IAM) smartphone application (hereafter referred to as the IAM app). The IAM app contains clinical information on the key features of the '99 Priority Topics in Family Medicine' as a general guide to prepare for the examination of the CFPC (Allen et al., 2011). The IAM app uses the concept of spaced education (SE), as a strategy to reinforce long-term knowledge retention (Carpenter, Cepeda, Rohrer, Kang, & Pashler, 2012). SE or spaced practice is a concept of studying information across two or more sessions that are separated (i.e., spaced apart or distributed). The successful development and implementation of the IAM app, as any new instructional technology for medical learning, is a very challenging process that requires an early evaluation of users' educational needs (Pereira, Peden, & Campbell, 2000).

### 1.2 Thesis Purpose

This study aimed to explore factors that can influence sustainable use of the IAM app as an information system created to help residents prepare for the examination in the context of the family medicine residency. Specifically, the study sought to:

1) identify family medicine residents' perceived facilitators and barriers to sustainable participation in SE mediated by weekly alerts on the IAM app,
2) identify organizational strategies that could potentially overcome the barriers.

The findings could be used to help mobile application creators working in the field of medical education to design applications that are more sustainable.

# 2. BACKGROUND

I will summarize the literature on SE and mobile learning as background information and explain how the concept of spaced education was implemented in the IAM app.

## 2.1 Smartphones, Mobile Apps and Medical Education

Smartphones are a medium through which medical students and residents may engage in many educational opportunities. In 2012, an electronic survey distributed by medical librarians at four Canadian universities to medical students, residents, and faculty members revealed that mobile device ownership was at 92.6% (Boruff & Storie, 2014). Residents and medical students in their clinical clerkships were the most frequent users of mobile devices: 77% of residents reported greater than daily use; 93.6% used them at least several times a week or more. They used their devices for a broader range of activities than other groups namely to find drug information 92.3%, find clinical practice guidelines 73.8 %, read point-of-care information 73.2%, do clinical calculations 85.6%, perform differential diagnoses 55.3%, take notes 62%, read journal articles 62.6%, or search for journal articles 52.7%. Third- and fourth-year undergraduate medical students and medical residents reported purchasing more resources than did other groups. 73.1% of residents had purchased one or more resources and 29.9%, respectively, had purchased more than five.

There are numerous reported benefits provided by mobile devices and apps for health care professionals: convenience, better clinical decision-making, improved accuracy, increased efficiency, enhanced productivity (Ventola, 2014). Given the benefits of mobile devices, there is an increasing willingness to use smartphones and mobile apps in the context of undergraduate and postgraduate medical education. Very few educational mobile applications (e.g., Anki, Osmosis, Firecracker), employ SE for factual medical knowledge acquisition and long-term medical knowledge retention (Yeh & Park, 2015). I found no studies on mobile applications using SE in preparing for family medicine license examinations

### 2.1.1 The IAM app: what is it?

In 2014, to help family medicine residents prepare for their certification examination, the ITPCRG team (McGill University-Department of Family Medicine) created an IAM smartphone application inspired by the concept of spaced education. This promising concept was

operationalized as: 99 Priority Topics, a weekly alert to read one new topic, test questions to promote understanding of that topic and answer feedback. Particularly, SE was encouraged by an alert system, whereby every Wednesday, the app sent an alert to introduce a topic of the week. Upon accepting this push notification and visiting the topic of the week twice, and when the second visit to that topic occurred at least five days after the first, the learner could receive two open-ended test questions. Test questions were available for ten of the 99 Priority Topics.
In 2015, using semi-structured interviews and log files providing visit dates, a usability study explored family medicine residents' experiences with the app (Ramos, 2015). Residents considered the IAM app as a valuable tool for spacing out their learning. The majority described the IAM app as "intuitive" and "easily accessible". Factors that influenced the use of the IAM app were as follows: individual needs, learning strategies and push notifications, time remaining until certification examination. Barriers to use of the IAM app included technical issues and lack of technical support. Overall, this usability study showed good acceptance (such as ease of use, effectiveness, aesthetics, portability and satisfaction) of the IAM app among volunteer residents.
A subsequent quasi-experimental pilot study started in August, 2015 (Grad et al., 2017) to identify issues around the feasibility of deploying a mobile app for certification exam preparation and to quantitatively determine whether alerts played a mediating role in SE. Furthermore, the study determined the factors that facilitate and hinder sustainable application usage after a weekly alert. In the control group 79 of 85 family medicine residents at McGill University consented to use the app without weekly alert. In the intervention group, 81of 96 first-year family medicine residents (McMaster University, Hamilton, Ontario, Canada) consented to participate in SE. Sixty-five first-year family medicine residents installed the IAM app and started their participation in a 2-year SE mediated by weekly alerts. Through the IAM app, a weekly alert was delivered to residents to encourage reading of one new topic each week (spaced component of the application that stimulates reading in intervals). The app then allows users to complete questions related to the topic of the week and receive answer feedback (this is the testing component of the application that stimulates rereading of the same information to answer the question). Reading compliance after each alert could provide SE and improve long-term knowledge retention for acquiring competence in family medicine.

## 2.2 Theoretical and Conceptual Framework

This study was part of a multi-phase program of research. It was inspired by the theory of spaced education and guided by the framework for adopting instructional technologies.

### 2.2.1 Spaced education (SE): what is it?

SE improves performance on final memory tests of learning in comparison to non-spaced education (Carpenter et al., 2012). SE or spaced practice is a concept of studying information across two or more presentations that are separated. When the spacing gap between two or more presentations of the same information is zero, the presentations are said to be massed. When the gap between presentations is greater than zero, the presentations are said to be spaced or distributed because they are separated by a nonzero time interval. Figure 1 visually displays how SE works. This is typically referred to as the *spacing effect***.** Also, spacing can improve learning of information that is conceptually more difficult. Moreover, learning is enhanced when the learner is required to recall information rather than simply restudying it (Roediger & Karpicke, 2006). This is the *testing effect* or retrieval practice effect. There are two types of the test format: retrieval (i.e., short answer or open-ended questions) and recognition (i.e., multiple choice questions [MCQ]). Research has demonstrated that open-ended questions produce superior long-term retention in comparison with MCQ (Yeh & Park, 2015)**.** Although the testing effect occurs even in the absence of feedback, it is generally accepted that feedback enhances and optimizes the gains achieved from testing through reinforcement of correct responses and correction of incorrect guesses (Butler, Karpicke, & Roediger III, 2007). Also, analyses suggest that a spacing gap and test delay operate jointly to affect performance on a final memory test. In other words, the spacing gap increases as the test delay increases to produce maximal knowledge retention on the final memory test (Carpenter et al., 2012).

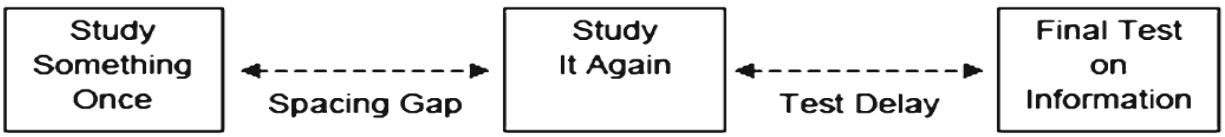



*Figure 1. Design of a typical study on the spacing effect (Carpenter et al., 2012)*

SE can take place in many ways:

- Incorporate into each lesson a brief review of concepts that were learned several weeks earlier,
- Homework assignments,
- Cumulative exams and quizzes,
- Exam feedback,
- 5-Supplement the information from any given lesson with examples from previous lessons.

The optimal spacing gap depends on when the information will be tested in the future. For participants who completed the final test 7 days after their final study session, the optimal spacing gap was 1 day. However, for participants who waited 35 days before taking the final test, the optimal spacing gap was 11 days. For those who completed the final test after 70 days, the best spacing gap was 21 days. In general, the optimal spacing gap equaled 10–20 % of the test delay. In other words, the longer the test delays, the longer the optimal spacing gap. If the goal is to retain information for just a short time, shorter spacing gaps may be ideal. However, if the goal is to achieve retention for much longer periods, spacing gaps of several weeks or months may be best. Indeed, for lifelong preservation of knowledge, spacing gaps of years may well be optimal (Carpenter et al., 2012).

Kerfoot has conducted numerous randomized trials on SE with content delivered via email, largely in the context of medical education in Urology (Kerfoot et al., 2007; Kerfoot & Brotschi, 2009; Kerfoot, Fu, et al., 2010; Kerfoot, Kearney, Connelly, & Ritchey, 2009; Kerfoot, Lawler, Sokolovskaya, Gagnon, & Conlin, 2010). Some of his work has confirmed that spacing and testing effects on knowledge retention can persist for 2 years (Kerfoot, 2009). A recent literature review on SE showed its effectiveness for long-term knowledge retention in numerous educational studies ranging from learning a new language, to mathematical concepts, to surgical skills training, in a wide range of subjects: young children, cognitively impaired adults, and physicians (Yeh & Park, 2015). Also, this literature review suggested that the use of testing, especially retrieval format with feedback, combined with optimally distributed spacing, can greatly enhance learning and retention of factual knowledge in medical education.

The development and implementation of the online technology into the medical education curriculum led to transformation of SE to online education that delivers SE via emails or mobile applications. Presently, there are three mobile app offering SE for professional medical education

(PME): Anki, Osmosis and Firecracker (Yeh & Park, 2015). Traditionally, mobile applications use alert or push-notification as a medium to promote SE. If one considers online SE to be 'self-learning', there are factors that facilitate and hinder the users' sustainable participation in SE after mobile alerts. These factors should be evaluated to facilitate adoption of online SE in medical education.

### 2.2.2 A framework for adopting instructional technologies.

A framework emerged from the lessons learned from developing Web-based courses on palliative care (Pereira et al., 2000). New instructional technologies, especially internet-based learning or web-based applications, play an increasing role in medical education, particularly for distance learning. The successful development and implementation of instructional technologies in medical education require partnerships with various experts. Furthermore, evaluation of the implementation is adopted early in the process. The framework for adopting instructional technologies relies on key objectives in development, implementation and evaluation, as illustrated in Figure 2.

| Objective | Details/examples |
|---|---|
| Form partnerships and collaborations with: | Content experts<br>Instructional designers<br>Programmers<br>Administrative staff<br>Evaluation experts<br>Potential learners<br>Information experts |
| Establish and clarify the goals of the project/course | What is the rationale for incorporating new instructional technologies?<br>What do these technologies have to offer that traditional methods do not? |
| Conduct a needs assessment | Surveys<br>Focus groups<br>Literature reviews |
| Select appropriate technology | |
| Identify resources early in the process | |
| Include all stakeholders early in the process | |
| Adopt evaluation methods early in the process | Needs assessment<br>Formative evaluation<br>Summative evaluation |
| Differentiate between the delivery medium and the instruction | |
| Use sound instruction methods | |
| Train and support faculty members and instructors | |
| Train and support learners and users | |

*Figure 2. A framework for adopting instructional technologies(Pereira et al., 2000)*

According to this framework, the goals of the course are crucial since they will affect evaluation. There are two key questions: (a) what is the specific need for implementing instructional technology? (b) does its use add something that would be impossible without it? On the one hand, in the context of the current project, the specific needs were easier access to the key features of all 99 Priority Topics as a general guide to family medicine residents preparing for the board examination. In addition, there was a need to build SE for improving factual knowledge acquisition and long-term retention. On the other hand, mobile applications are widely used by medical students and residents for study purposes. Thus, SE delivered via mobile applications should be acceptable by these end-users who are residents working at widely dispersed clinical sites. Nonetheless, there was a challenge observed during a previous usability study of the IAM application. Family medicine residents did not use the IAM app in a sustained manner and only proximity to exam dates changed this pattern of usage, as illustrated in Figure 3.

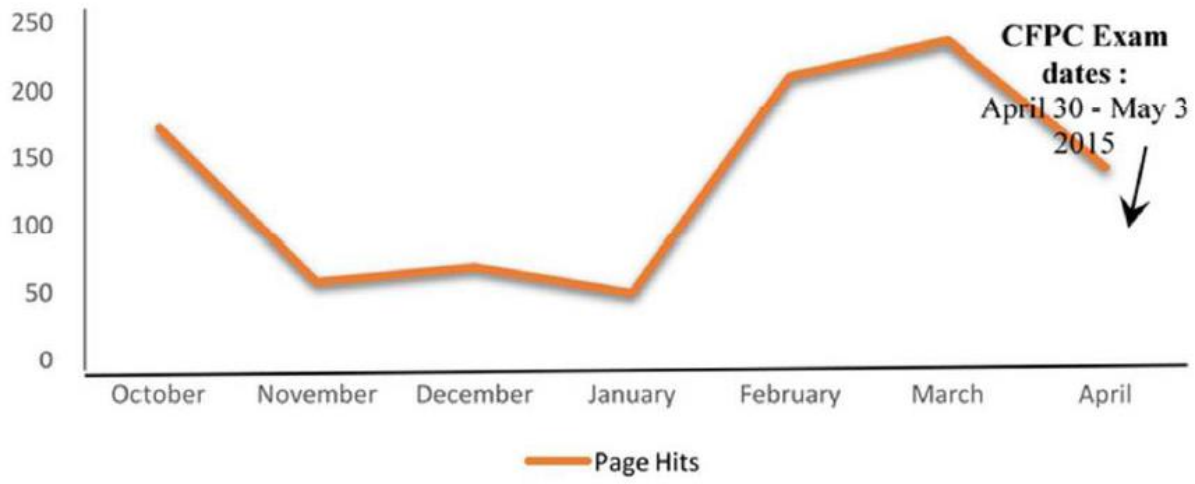



*Figure 3. Page hits per month (Ramos, 2015)*

In summary, evidence suggests that we can expect improvements in long-term knowledge retention if participants read about priority topics after weekly alerts and sustainably used the IAM app. As such, it becomes important to identify residents' concerns regarding a weekly alert in order to ensure better participation in an educational program involving SE. Given the intention to study the IAM application in a multi-phase program of research, this study seeks to

improve understanding of family medicine residents' concerns regarding weekly alerts, particularly which factors positively or negatively influence sustainable participation in a SE intervention mediated by a weekly alert.

# 3. LITERATURE REVIEW

While there are numerous studies of the effectiveness of SE, few studies have explored the needs and concerns of end-users of the SE in the context of their professional medical education (PME). In medical education, there is no systematic review on this topic. Therefore, I performed a dissertation literature review (Randolph, 2009) with qualitative thematic synthesis using an inductive approach (Thomas & Harden, 2008). This synthesis would be further described below.

## 3.1 Review Question

What are the barriers and facilitators reported by learners about SE mediated via email or via alerts from a mobile application in the context of Professional Medical Education (PME)?

A summary of the literature review is presented below and details are presented in Appendix 1.

## 3.2 Methods

### 3.2.1 Eligibility criteria.

***Inclusion criteria.***

- Empirical studies
- Focus on online SE or spaced online course mediated via email or alerts from a mobile application etc.
- Focus on specific aspects of SE, including barriers, facilitators, needs, concerns, and ideas for effective interventions and implementation reported by learners in the context of PME.
- Type of participants: Any users of online SE in the context of Professional Medical Education (PME). Using Medical Subject Headings of the National Library of Medicine, I defined Professional Medical Education, as "Education, Professional".[1] It includes all formal education and training in preparation for the practice of a profession (ex: clinical clerkship, education medical graduate, education undergraduate medical, Internship and residency, education medical continuing, education dental, education pharmacy, education nursing etc.) . Also,

[1] Education, Professional: Formal education and training in preparation for the practice of a profession. Year introduced: 1998. Unique ID: D004517, National Library of Medicine https://meshb.nlm.nih.gov/record/ui?ui=D004517

for the purpose of this study, I identified any learner in the context of PME as health professionals.

- World-wide
- Study design: qualitative study, qualitative part of a mixed-methods study

***Exclusion criteria.***

- Online SE not related to the clinical practice
- Not empirical research (e.g., editorials, description of an intervention, without empirical data, no data collection).
- Methodological papers/ Protocols
- No intervention: standard curriculum.

***Limits.***

Studies conducted after 1990 (after the deployment of Internet), primary empirical studies.

### 3.2.2 Main sources of information.

I searched MEDLINE, a previous literature review on the same subject (Yeh & Park, 2015), textbooks, as well as my supervisor's reference database. I also performed citation tracking up to saturation in the Scopus citation database. That is, I searched for references at the end of a relevant article (backward tracking) as well as who cited the article (forward tracking). I used reference management software (EndNote) to maintain search records and full bibliographic information of the relevant studies.

### 3.2.3 Search strategy.

A strategy was developed and adopted in collaboration with a specialized librarian. When we searched the literature about SE, it was difficult to find any study that explored barriers and facilitators of online SE; thus, I started with broader key concepts that were not specifically focused on barriers or facilitators. The main key concepts used to identify relevant studies were as follows:

Spaced education **AND**

Healthcare professionals **AND**

Online technology

Concepts were combined with **AND**. Subject heading and keywords were identified for each concept and combine with **OR**. My full 'Search strategy' is presented in Appendix 1.

### 3.2.4 Selection of relevant studies.

Given that the dissertation literature review does not require two independent reviewers or interrater agreement, I performed all steps of study selection. All studies were extracted to reference manager software (EndNote). A separate group was created for MEDLINE and for my supervisor's database. All studies were imported to each database group and then combined. Duplicates were eliminated according to Wichor Bramer –Erasmus MC (Bramer, Giustini, de Jonge, Holland, & Bekhuis, 2016) and using preferences/ compare order (Author; Year; Secondary title etc.). All records identified in databases after deduplication procedure screened by reading the titles and abstracts. This step was based on the eligibility criteria. The full-text of all relevant records was retrieved using reference manager software (EndNote) and screened in order to identify relevant studies and data for thematic synthesis. Also, I performed citation tracking for the relevant studies via Scopus database. The flow diagram of study selection process is presented in Appendix I.

### 3.2.5 Data extraction.

I identified the 'key concepts' from all selected qualitative studies and from the qualitative part of the mixed-methods studies (Campbell et al., 2003). I took study findings to be all of the text labelled as 'results' or 'findings' in study reports –though I also found 'findings' in the abstracts which were not always reported in the same way in the text (Thomas & Harden, 2008). I documented all the results of the qualitative and qualitative part of the mixed-methods studies verbatim manually into a Word document (see results of the individual studies in Appendix 1.

Other information, which could be relevant for the analysis, about selected studies was extracted and presented in a table of study characteristics (see Appendix 1). Columns, recommended by my supervisor, were as follows:

- First author, year of publication, country;
- Title;
- Study design;

- Participants;
- Intervention;
- Comparison intervention (if applicable);
- Study results;
- Details on spaced online education intervention.

### 3.2.6 Synthesis.

I gave a priority to qualitative analysis. In order to create analytical themes, I synthesized all text findings of the included studies according to my review question. I employed a thematic synthesis (Thomas & Harden, 2008). The synthesis took the form of three stages which overlapped to some degree: the free line-by-line coding of the text findings of primary studies; the organization of these 'free codes' into related areas to construct 'descriptive' themes; and the development of 'analytical' themes by using the descriptive themes to answer the literature review question.

## 3.3 Results

Eighty-two references were identified from Medline and 10 from my supervisor's database. After a deduplication procedure and review of titles and abstracts, 5 studies were chosen on the basis of eligibility criteria. Additional search for the backward and forward citations tracking up to saturation in the Scopus citation database yielded 35 studies. After another deduplication procedure, they were searched on the basis of title and abstract using the inclusion and exclusion criteria. Finally, the same five publications (two qualitative and three qualitative part of mixed-methods studies) met the eligibility criteria after search on full text and were included for the review. The flow diagram is presented in Appendix I.

### 3.3.1 Description of included studies.

In summary, participants of the five included studies were third-year medical students on general medical clerkships, oncology trainees, or family medicine residents or senior clinicians working in the field of oncology. SE was tested in the context of medical student clerkship, residency training and in continuing medical education. Case-based scenarios or clinical topics with multiple choice questions and feedback were the most frequent format of the SE

intervention. Also, clinical topics with notification to read were another type of the SE intervention. Two studies used individual competition that was appreciated by learners (Janssen et al., 2016; Shaw et al., 2012). Also, SE was often combined with an adaptive algorithm that tailors the length of the spacing intervals and number of repetitions of the content for each learner based on his or her performance (Janssen et al., 2016; Robinson et al., 2017; Shaw et al., 2012)

Study one was a mixed methods study (cross sectional study/ descriptive qualitative study) conducted in Australia, Denmark, and the USA (Janssen et al., 2016). Thirty-five junior oncology doctors received game-based SE about the Basic Science in Oncology Course (BSOC). The intervention targeted key safety and quality issues encountered by physicians training in medical oncology. SE was delivered via email every 2 days containing at least 2 cases. There were 8 short case-based scenarios with expert feedback and with an adaptive algorithm that tailored the length of the spacing intervals and number of repetitions of the content for each learner based on his or her performance. If they answered a case incorrectly, it was re-sent 5 days later. There was no control group. Participants were given the opportunity to leave free-text comments regarding strengths and weakness of the program. Fourteen participants consented to participate in semi-structured interviews about the program.

SE in the context of the BSOC was reported to be generally positive. Respondents enjoyed the course because of the expert feedback on cases, the competitive aspect of the course, and the flexibility and manageability of the course format. One respondent appreciated that the cases covered scenarios that were less commonly considered in education and training. Of the participants who did not find the course beneficial, the most commonly cited reason was that the cases were too easy. This was closely followed by respondents stating they would prefer receiving more cases. Semi-structured interviews with participants revealed five broad themes: Impact of course on knowledge and confidence, enjoyment and engagement, motivation for course completion, online learning / Qstream format, and course content in general.

Study two was also a mixed methods study including a cluster-randomized trial and a descriptive qualitative component (Blazek, Dantz, Wright, & Fiedorowicz, 2016) conducted over one academic year in the USA. 71 third-year medical students received an intervention targeting management of psychiatric patients in multidisciplinary settings. There were a series of 10 emails about key psychiatric concepts targeted to students in their core clerkships. Emails

contained clinically relevant case scenarios and multiple-choice questions repeated over time intervals according to the clerkship schedule. Control group (n=61) did not receive emails. Students, who actively responded to questions, demonstrated significantly higher scores on a knowledge test. Email users valued succinct, "high yield" format, the timing and format of delivery and application of psychiatric principles outside the psychiatric setting where it can be applied. Participants recommended simplifying the format and previewing the benefits of spaced learning in advance, to optimize use of this educational method and impact.

Study three was a pilot qualitative descriptive study conducted in Australia (Robinson et al., 2017). In the context of continuing medical education, a SE program consisted of 3 case examples with multiple choices and feedback was created in order to deliver the latest guidelines about types of ovarian, fallopian tube and primary peritoneal cancer. Program used an adaptive algorithm that tailors the length of the spacing intervals and number of repetitions. If participants answered a question incorrectly, the same question was resent 5 days later. If the question answered correctly it was resent 8 days later. Participants were required to answer each question correctly on two occasions before it was retired. Eleven participants evaluated this program via an interview. Participants included five registrars, two nurses, four medical oncologists, four gynecologic oncology staff specialists, two gynecologic oncology fellows and one unstated. The final thematic analysis yielded several themes, such as knowledge change, content and format, and perceived changes in referral patterns. The majority of participants agreed that the program had helped them update their knowledge about referring women for assessment and consideration of genetic testing. Ten participants agreed that the program increased their knowledge. Even when the program was not seen as changing participant knowledge, its importance for disseminating new knowledge to colleagues was acknowledged.

Study four was a mixed methods study (randomized controlled trial/qualitative descriptive study) in the USA (Shaw et al., 2012). In the context of an internship in surgical and medical specialties, 16 clinically-relevant case-based MCQs with immediate feedback were delivered to the intervention group (n=53). The SE program was about joint commission national patient safety goals. The SE item was repeated over 1-12 weeks based on user performance. Questions were retired when answered correctly twice. Control group (n=48) received traditional slides-based online training. Participants were interns in surgical specialties (Surgery and OB-GYN) and medical specialties (Medicine, Anesthesiology, Emergency Medicine and Psychiatry

Programs). Qualitative data indicated that SE was more contextually relevant than traditional slides-based online training, and significantly more engaging. Participants valued the content of the SE program and the repeating nature of SE.

Study five was a usability qualitative case study conducted in Canada (Ramos, 2015). This study sought to evaluate the usability of the IAM mobile application. In the context of family medicine residency training, content on 99 priority topics was presented in a mobile application. Family medicine residents received a weekly alert to read one new topic each week. Residents participated in this program during 6 months. They used the app more frequently as the exam date approached. Cross-case analysis identified five themes: factors that impacted the use of the app, role of the app, motivation to use the app, use preference, and acceptability of the app. Barriers to use of the IAM app included technical issues and lack of technical support.

### 3.3.2 Thematic synthesis.

In order to identify the 'key concepts' in my primary studies, I took study findings to be all of the text labelled as 'results' or 'findings' in study reports and in abstracts. Then, I entered manually all the results of the studies verbatim into my database. I performed a free line-by-line inductive coding of the findings of the primary studies (Britten et al., 2002). Twenty codes were identified by translating concepts between studies: (a) Clinical knowledge acquisition/confidence; (b) Dissemination of updated clinical guidelines/ leaders' opinion; (c) Change referral patterns; (d) Interdisciplinary clinical information; (e) Low time consuming/ succinct, easy to read message; (f) Flexibility and manageability of the course format via personal phone; (g) Quizzes with case scenarios/MCQ/feedback format; (h) Advance notice about the educational message/alert; (i) Competition/ gamified aspect of the SE course; (j) Structure for learning; (k) Clerkship-specific message delivery; (l) Lack of external stimulation; (m) Lack of knowledge about the effectiveness of SE; (n) Individual preference for other learning tools; (o) Technophobia; (p) Too easy information content; (q) Complex design; (r) Technical issues; (s) Pitfalls in the platform design; (t) Lack of technical support.

I then began the process of synthesis. Through the recurrent process, I checked the consistency of my interpretation. I searched for similarities and differences between the codes and grouped them into descriptive themes. Finally, I synthesized the data into four analytical sub-themes that emerged from descriptive themes of the inductive analysis of empirical study

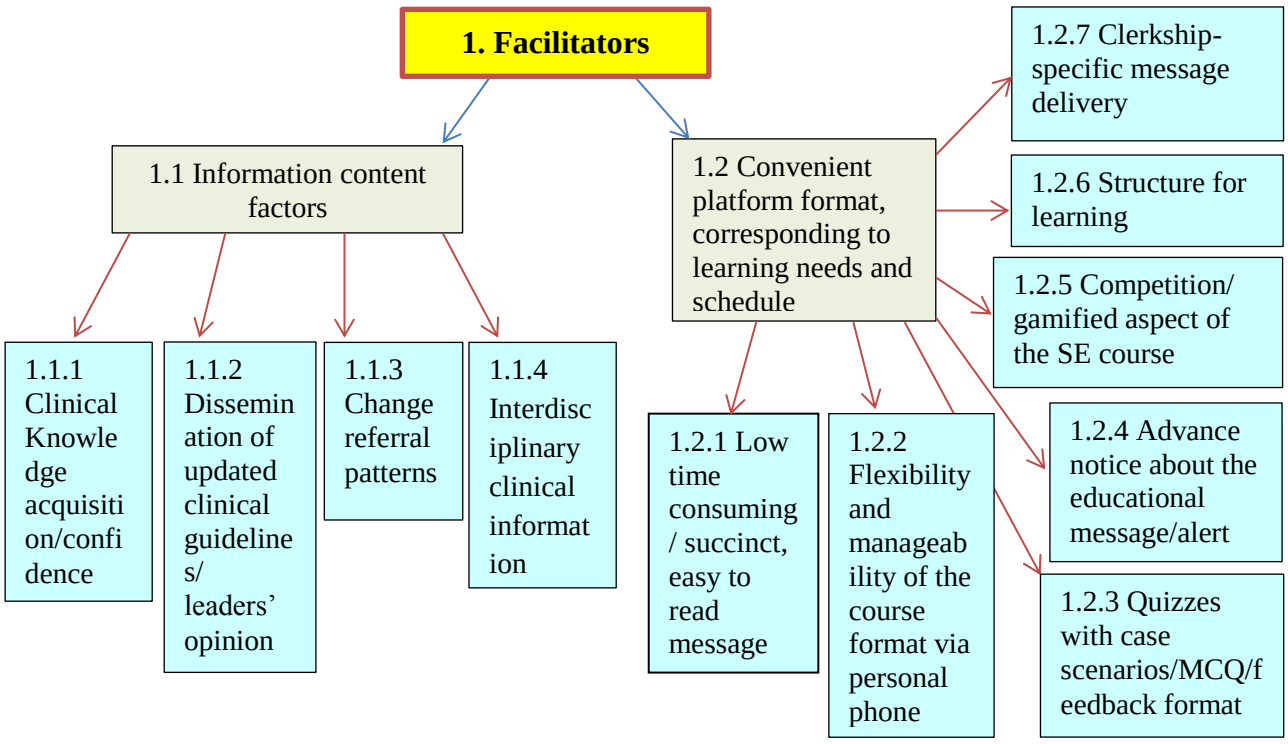
findings: (a) Information content factors; (b) Convenient platform format, corresponding to learning needs and schedule; (c) User-related barriers; (d) Barriers at the level of SE platform as an information system.

Numbers mentioned hereafter are referring to thematic synthesis results.

Analytical themes

1. Facilitators of SE in the context of PME emerged from health professionals' points of view. It was presented by two analytical sub-themes: (1.1) Information content factors; (1.2) Convenient platform format, corresponding to learning needs and schedule.
2. Barriers of SE in the context of PME emerged from health professionals' points of view. It was presented by two analytical sub-themes: (2.1) User-related barriers; (2.2) Barriers at the level of SE platform as an information system.

Tree structure of the analytical themes is presented in Figure 4



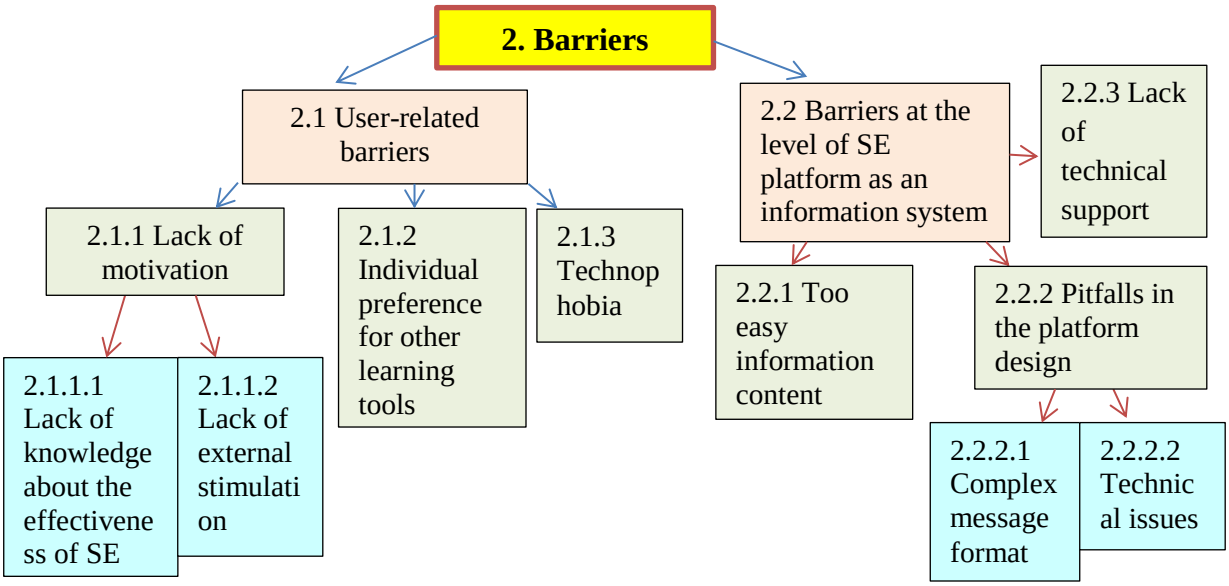



*Figure 4. Tree structure of the analytical themes*

### 3.3.3 Theme 1. Facilitators of SE in the context of PME.

***Sub-theme 1.1 Information content factors.***

The majority of comments reflected how information content was valuable from the users' viewpoint. These comments related to the relevance of the information content of the SE course in clinical participants. In all studies, clinical relevance of the information content was expressed as clinical knowledge acquisition or confidence (1.1.1). Particularly, health professionals valued information content that led to clinical knowledge acquisition or gave users confidence in their clinical knowledge. For example, family medicine residents using the IAM app to prepare for their certification examination mentioned that easier access to clinical information on the app was one of the factors positively influencing the use of the app. In another study evaluating SE, interns reported that the content could impact the outcomes of the patients (Shaw et al., 2012). Also, junior oncology trainees from Australia, Denmark, and the USA stated that their primary driver to complete the SE course was knowledge acquisition, or interest in the topics covered in the course (Janssen et al., 2016). At the same study, information retrieved from SE was highly appreciated because of its impact on users' knowledge and confidence, as well as because of its applicability to users' clinical practice. Moreover, participants appreciated cases that were less commonly considered to be issues in education and

training. Also, participants from the same study valued that SE disseminated the latest clinical information as updated clinical guidelines and leaders' opinion (1.1.2). The information content of SE illustrated similarities and differences in cancer care globally. Another study in the context of continuing medical education (CME) also indicated that SE was very appropriate for dissemination of the updates to clinical guidelines and protocols (Robinson et al., 2017) . The majority of participants of the same study (n=10) agreed that the information content of the SE program helped update their knowledge of how to refer women, and eight agreed that they would now change their referral patterns (1.1.3). The next element of relevant information content was interdisciplinary clinical information (1.1.4). For example, one study evaluated SE using emails to integrate psychiatry into general medical curriculum and found that practitioners appreciated interdisciplinary clinical information (Blazek et al., 2016). The clerkship-specific delivery of psychiatry issues was valued by medical students because they could learn ‘‘how to address psychiatry issues in every rotation".

***Sub-theme 1.2. Convenient platform format, corresponding to learning needs and schedule.***

The second facilitator of SE was not only platform related, but also reflects how SE platform format was compatible with learning needs and clinical work load. In other words, convenient platform format and its' flexibility according to the users' needs facilitated participation in SE or motivated users to complete the course.

One of the elements of the convenient user-friendly platform format was a low time consuming/succinct, easy to read message (1.2.1). In one study examining SE in the context of multidisciplinary clerkships for third-year medical students, users valued succinct "high yield" formats and timing (Blazek et al., 2016). Also, participants from the same study recommended simplifying the format. Some oncology trainees from another study enjoyed and engaged in SE due to format itself because "it didn't take very long to do" (Janssen et al., 2016). In a pilot study evaluating SE in the context of CME, participants also enjoyed the fact that it took little time to complete the reading and testing and thus fitted very well with doctors' schedule (Robinson et al., 2017).

Another reported facilitator of SE was flexibility and manageability of the course format via personal phone (1.2.2). For example, in the usability study of the IAM app, many family

medicine residents appreciated the flexibility of the SE because it was accessible via personal mobile phone and learners could use it even if they had just a few minutes (Ramos, 2015). Participants from another study also liked to access their CME via cell phone (Robinson et al., 2017).

Quizzes with case scenarios, MCQs and feedback (1.2.3) were perceived by learners as a facilitator of SE. For example, the study evaluating the effect of SE using email to integrate psychiatry into the general medical curriculum showed that users valued the cases and questions for application and reinforcement (Blazek et al., 2016). In another study, participants valued case study with quizzes as a good learning tool because they were remembering information more than if they were just reading (Robinson et al., 2017).

Another element of the convenient platform format was an advance notice about the educational message or alerts (1.2.4). In a study exploring the experiences of 71 third-year medical students with SE, email recipient non-users reported that they either had no memory of receiving the emails or no context if they did read them. Users and non-users both suggested that they would be more likely to utilize the emails for learning if they were given advance notice (Blazek et al., 2016). Several junior oncology doctors from another study liked the way the system prompted participants to complete cases they may have forgotten about (Janssen et al., 2016). The prompt came through and it would come through again if the participant didn't answer the question. One learner mentioned that the prompt reminded him that the course was there because he can forget about it. The usability study of the IAM application suggested that users' intent to use the IAM app also might be related to the push notifications.

Competition or gamified aspect of the SE course (1.2.5) was interpreted as a facilitator. Junior oncology doctors received game-based SE about the Basic Science in Oncology Course. Interviews revealed that participants enjoyed the SE course due to its competitive aspect (Janssen et al., 2016). Individual and team based competition was found to predict participants' persistence in SE mediated by emails.

The next element of the convenient format was the availability of a structure for learning (1.2.6). Particularly, family medicine residents form McGill University suggested that the IAM mobile application inspired by the concept of spaced education might serve as an advance organizer for planning learning around the 99 Priority Topics.

Clerkship-specific delivery of the learning message (1.2.7) was also important for the users of the SE. For example, in the study of SE to integrate psychiatry into the general medical curriculum, medical students valued clerkship-specific delivery of psychiatry issues because they could learn ‘‘how to address psychiatry in every rotation” (Blazek et al., 2016).

### 3.3.4 Theme 2. Barriers of SE in the context of PME.

***Sub-theme 2.1. User-related barriers.***

Barriers at the level of the user were as follows: 2.1.1 lack of motivation, 2.1.2 individual preference for other learning tools, and 2.1.3 technophobia. In the study using SE to integrate psychiatry into the general medical curriculum, lack of motivation (2.1.1) seemed to have a significant effect on students’ participation in SE (Blazek et al., 2016). It was related to the lack of knowledge about the effectiveness of SE (2.1.1.1). Participants from this study recommended explaining the positive effects of spaced education in advance. Lack of external stimulation (2.1.1.2) such as incentives or obligations, could lead to the lack of motivation to continue SE. In the same study users mentioned that they would be more likely to do reading for an incentive or if participation were required.

Individual preference for other learning tools (2.1.2) was another barrier of SE. For example, in the study evaluating SE in the context of CME, two participants disliked the question/answer format as a tool for disseminating new or updated guidelines. Moreover, they preferred to get any relevant information from genetic counsellors (Robinson et al., 2017).

Also, technophobia (2.1.3) was reported as user-related barriers to participation in SE via mobile application (Ramos, 2015). One resident mentioned that technophobia prevented him from installing the app.

***Sub-theme 2.2. Barriers at the level of SE platform as an information system.***

A second group presented barriers at the level of the platform as an information system for SE: 2.2.1 too easy information content, 2.2.2 pitfalls in the platform design (complicated design and technical issues), and 2.2.3 lack of technical support.

Information content that was perceived as too easy (2.2.1) was reported as one of the barriers to participation in SE about key safety and quality issues in medical oncology (Janssen et al., 2016). It was related to perceived lack of knowledge acquisition. For example, of the

participants who did not find the course beneficial, the most commonly cited reason was that the cases were too easy. Commonly, participants in SE reported pitfalls in the platform design (2.2.2) (Blazek et al., 2016; Ramos, 2015). Particularly, they complained about complex design (2.2 2.1). For example, in the context of SE mediated by emails, medical students received 10 emails about key psychiatric concepts targeted to the other core clerkships (Blazek et al., 2016). Subsequently, participants reported that the title, ‘‘Keep Psychiatry in Mind’’ implied an attempt to recruit students into the field of psychiatry, making the emails less appealing. They suggested simplifying the format and eliminating the visual image which dominated screen-space on a cell phone. Also, users disliked having to switch screens to view the answer explanations. In addition, two studies reported technical issues (2.2.2.2). Technical problems of receiving notification were identified as a barrier in a study exploring SE mediated by emails. Email recipient non-users reported that they either had no memory of receiving the emails or no context if they did read them (Blazek et al., 2016). In usability study of the IAM app, family medicine residents also complained about technical problems, such as failure of push notifications, fail to download the IAM app form unknown source (jailbreak issues), instability of the mobile application (crashing), and some external links failing to work (Ramos, 2015). The most relevant technical failure was related to the lack of receiving the push notifications because it led to discontinuation of participation in SE. Also, residents provided several suggestions that mostly identified pitfalls in the platform design, such as lack of activity tracking. Some of these suggestions were implemented to improve the current version of the IAM app. Another factor that prevented participants of the same project from continuing to use the IAM app was a perceived lack of technical support (2.2.3) related to system failure.

### 3.4 Knowledge Gaps

Spaced education can have a positive effect on medical knowledge acquisition and retention, but this intervention has not been explored in the context of family medicine residency training programs.

I found five studies exploring health professionals’ points of view about their participation in SE in the context of PME. Four studies evaluated health professionals’ experience of SE in the context of very short and focused intervention: eight short case-based scenarios in oncology, ten emails about psychiatric concepts targeted to the other core clerkships, three case-based

scenarios about ovarian cancer management and 16 clinical cases about patient safety. Thus, these results are not necessarily transferable to SE for 99 topics as a guide for the assessment of competence in family medicine, at the start of independent practice.

One of these studies was a usability study of the IAM mobile application. The primary goal of this study was to evaluate the usability of the IAM mobile application and it was not focused on the barriers or facilitators of SE mediated by weekly alerts. Also, IAM app was early in the process of development; thus results from this usability study are not easily transferable to future studies evaluating other versions of the IAM app, or other apps designed for exam preparation.

Three studies mentioned potential benefits from the advance notice about the educational message or alerts (Blazek et al., 2016; Janssen et al., 2016; Ramos, 2015). Participants from two of these studies complained about the failure of push notifications (Blazek et al., 2016; Ramos, 2015). Also, gamified aspect of SE, such as individual competition and MCQ, motivated participants to continue SE mediated by emails (Janssen et al., 2016; Shaw et al., 2012). Nonetheless, there are no studies exploring barriers or facilitators of reading, testing and learning associated with mobile app alerts in a SE system.

Beyond the usability study of the IAM mobile application, there is little information about the extent to which the weekly alert, as an intervention, on the mobile application stimulates family medicine residents to read more clinical information.

One study evaluating SE mediated by emails briefly mentioned some strategies to increase users' participation (incentives/obligations, previewing the benefits of SE) (Blazek et al., 2016). The usability study of the IAM app described residents' suggestions related to the app features (Ramos, 2015). Nonetheless, I found no studies of strategies, from the perspectives of users of SE, to overcome barriers to their participation in SE mediated by mobile alerts and reading compliance after mobile alerts.

In summary, there is little information available about an alert on a mobile application as a mediator of SE. We need to explore family medicine residents' perspectives about facilitators and barriers to sustainable participation in SE. This gap in the literature has led to the formulation of the following research questions and objectives.

# 4. RESEARCH QUESTIONS AND OBJECTIVES

## 4.1 General Objectives

The overall purpose of this two-phase explanatory mixed methods study was to collect and analyze quantitative data first. This data were then used to evaluate the effect of the weekly alert on the users' sustainable participation in SE, identify and purposefully selecting key informants following alerts most closely and least closely, and then follow up with qualitative data collection and thematic analysis to explain quantitative results obtained in the first phase. This design allowed me to identify and describe facilitators and barriers to residents' sustainable participation in SE in more depth.

### 4.1.1 Quantitative objectives.

1. To estimate the extent to which an intervention (weekly alerts on the mobile application as a mediator of SE) stimulates family medicine residents to visit the IAM app during their first year of training.
2. To identify participants for the second qualitative phase (residents following alerts most closely and least closely).

### 4.1.2 Qualitative objectives.

1. To describe factors, from the perspectives of family medicine residents, which facilitate or hinder sustainable participation in SE mediated by weekly alert on a mobile application.
2. To elicit and describe the strategies that family medicine residents recommend for improvement of the IAM app as an information system for SE.

## 4.2 Research Questions

### 4.2.1 Quantitative question.

To what extent do weekly alerts on a mobile application stimulate family medicine residents to read clinical information during their first year of training?

### 4.2.2 Qualitative questions.

1. What factors, from the perspectives of family medicine residents, facilitate or hinder sustainable participation in SE mediated by a weekly alert on a mobile application during their first year of training?
2. What strategies do family medicine residents suggest for improvement of the IAM app as an information system for SE?

# 5. METHODOLOGY AND METHODS

## 5.1 Sequential Explanatory Mixed Methods Research Design

My research question requires both quantitative and qualitative methodologies and methods, and their integration using mixed methods. Using available quantitative data from my supervisor, I conducted a two-phase sequential explanatory mixed methods study (J. Creswell, Plano Clark, Gutmann, & E Hanson, 2003). I chose this design in order to provide more evidence than either qualitative or quantitative research alone, explain initial quantitative results, and identify and purposefully select the best participants for the second qualitative phase (J. Creswell et al., 2003; Morgan, 1998; Tashakkori & Teddlie, 1998). The quantitative data were collected and analyzed in Phase I. Subsequently, Phase-1 results informed how the qualitative data were collected and analyzed in Phase II, while Phase-2 findings helped to explain Phase I results (J. W. Creswell & Plano Clark, 2011; N. Ivankova, Creswell, & Stick, 2006; N. V. Ivankova & Stick, 2007). The quantitative and qualitative phases were connected when I purposefully selected participants who followed alerts most closely and least closely, and when I developed the individual interview guide based on the quantitative data and study results from the first phase (Hanson, Creswell, Clark, Petska, & Creswell, 2005) . Finally, integration of the quantitative and qualitative results was also performed through the comparison and discussion of the results of both phases (J. Creswell et al., 2003). The sequential explanatory mixed methods design procedures in the current study are presented in Figure 5.

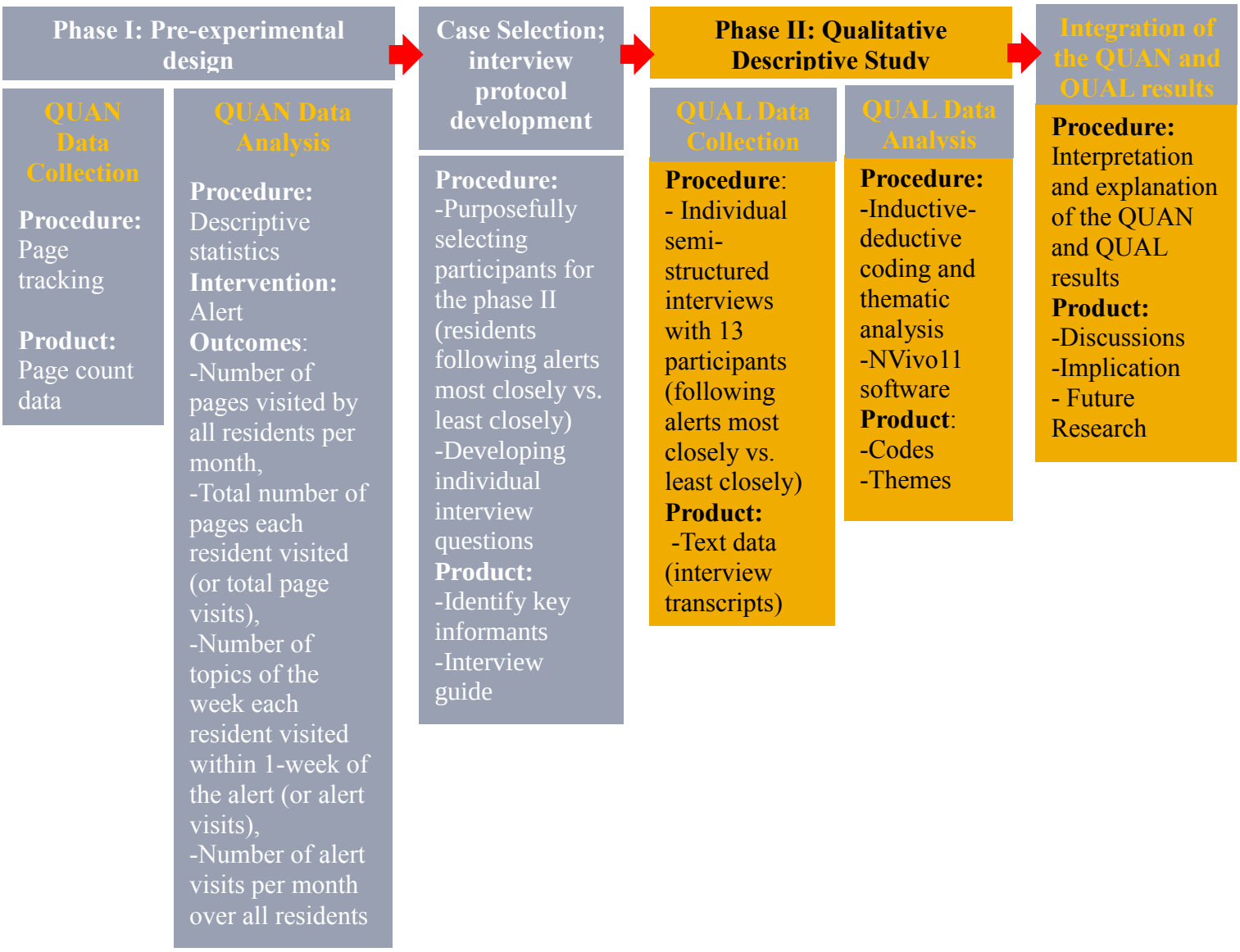



*Figure 5. Visual model for mixed methods sequential explanatory design procedures*

## 5.2 Quantitative Phase 1

I used a pre-experimental design without control group (Sackett & Mullen, 1993; Salkind, 2010).

### 5.2.1 Data collection.

Numerical data were recorded by the central server in log files, providing detailed information on usage patterns (date and time when topics were opened by each resident). At

McMaster University, 81 first year residents consented to receive the IAM mobile application and receive one alert per week to read new priority topic as an intervention.

### 5.2.2 Participant description.

Participants were recruited in July 2015 from all incoming first year family medicine residents at McMaster University. Approval for the IAM app pilot study, instruments and consent form was received from the Institutional Review Board of the McGill Faculty of Medicine and the Hamilton Integrated Research Ethics Board. This pilot study included participants from the intervention group (McMaster University) who received weekly alerts as an intervention and participants from the control group (McGill University) who did not receive weekly alerts. For the purpose of my thesis, the control group was not included in the analysis as I focused on the intervention group and on testing the weekly alert as mediator of SE. 81 (48%) residents at McMaster consented to participate in a 2-year pilot study. They agreed to be contacted for an interview and signed a consent form (see Appendix 2). Consenting residents received a user name and password via email to download the app from a web page created for this study. Following installation of the IAM app, residents started to receive one alert to the priority topic of the week, every Wednesday at 1:00 P.M.

Data collection started from the first day of consent when participants were asked to complete a brief demographic questionnaire. Then, phase one study participants downloaded the IAM mobile application and started to receive the weekly alert beginning August 19, 2015. Numerical data on page visits were recorded at the central server in log files. This data provided information on the date and time when each resident visited priority topics. The following data were collected: user ID, last name, user name, topic name, date and time that topic was visited. I finished quantitative data collection on August 24, 2016.

### 5.2.3 Quantitative analysis.

After 1 year, I calculated the number of pages visited by all residents per month, total number of pages each resident visited (or total page visits), number of topics of the week each resident visited within 1-week of the alert (or alert visits), and number of alert visits per month over all residents. An alert visit was defined as one or more page visits to the topic of the week, within a 7-day time window following an alert to that topic. After one year, 52 weekly alerts

were sent to 57 topics, as five alerts announced two topics. Thus, alert visits per user could vary from 0 to 57.

## 5.3 Qualitative Phase 2

I conducted a qualitative descriptive study (Sandelowski, 2000). The selection of participants for this phase was informed by phase 1 findings. The goal of this phase was to explain why the method of spaced online education mediated by weekly alerts worked well for some residents, while it did not work well for others. Research team and reflexivity, study design, analysis and findings of this study are reported using the consolidated criteria for reporting qualitative studies (COREQ) (Tong, Sainsbury, & Craig, 2007).

### 5.3.1 Conceptual models.

To explain the results of the current study, to guide a semi-structured interview and to do a thematic synthesis of the qualitative data, I used the Information Systems Success Model and A Model of Compelled Nonuse of Information. The former describes the relationships between main critical dimensions of a successful information system (Delone & McLean, 2003). Nevertheless, this model does not encompass all potential barriers and facilitators because it reflects only information system dimensions and not user-related factors. Consideration of the user-related factors is important because my literature review about barriers and facilitators of the SE revealed that barriers can occur at the user level in addition to the system level. To address this missing dimension, I used the Model of Compelled Nonuse of Information that reflects somatic barriers and cognitive barriers to use of information (Houston, 2009).

#### *DeLone and McLean Information Systems (IS) Success Model.*

The IAM application is not a simple mobile application that provides examination specific information. This application is an IS that integrates the SE concept mediated by weekly alerts for the purpose of factual medical knowledge acquisition and retention. The DeLone and McLean Information Systems (IS) Success Model is an information system framework based on theoretical and empirical IS research (Delone & McLean, 2003). The model is useful for measuring IS success. It reflects a comprehensive understanding of IS success by explaining the relationships between main dimensions of IS success. These dimensions are described as:

information quality, system quality, service quality, usage intentions/system use, user satisfaction, net system benefits.

There are quality dimensions: information, system and service. Subsequently, these quality dimensions affect usage intention/system use and user satisfaction. Finally, there is a mutual relationship between usage intention/system use, user satisfaction and net benefits as illustrated in Figure 6.

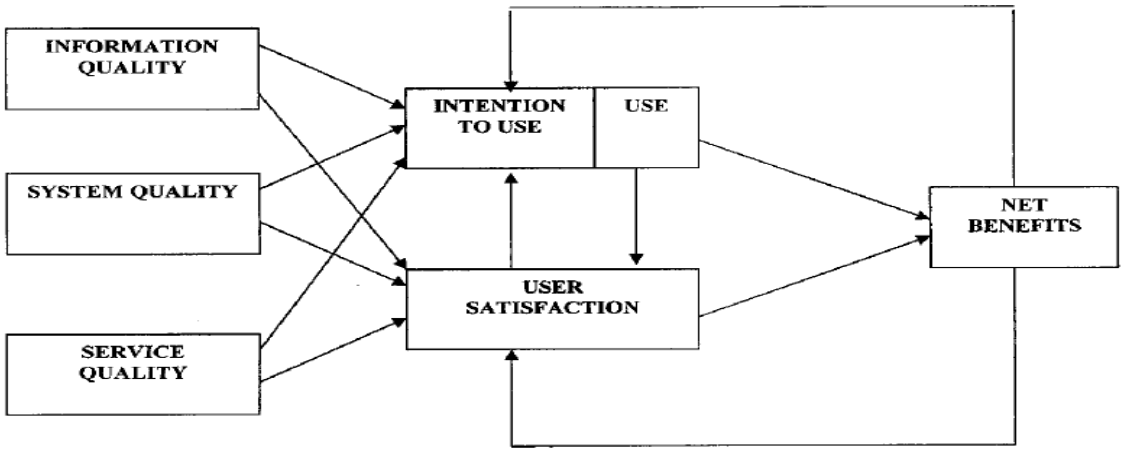



*Figure 6. DeLone and McLean Information Systems (IS) Success Model (Delone & McLean, 2003)*

- Information quality captures the e-content issue. Content should be personalized, complete, relevant, easy to understand, and secure. Information quality impacts user satisfaction with the IS and user intentions to use the IS. Subsequently, it impacts the extent to which the system can produce net benefits for the users and organization.
- System quality, in the internet environment, measures the desired characteristics of an e-system. Usability, availability, reliability, adaptability, and response time (e.g., download time) are examples of qualities that are valued by users of an e-system.
- Service quality, the overall support delivered by the service provider, applies regardless of whether this support is delivered by the IS department, a new organizational unit, or outsourced to an internet service provider (ISP). Assurance, empathy, up-to-date hardware and software, dependability and responsiveness are examples of aspects of service quality.
- Usage measures everything from a visit to a Web site or Mobile application, to navigation within them, to information retrieval.

- User satisfaction remains an important means of measuring users' opinions of the e-system and should cover the entire customer experience cycle from information retrieval through purchase, payment, receipt, and service.
- Net benefits evolve beyond the immediate user and suggest additional IS impact, such as work group impacts, inter-organizational and industry impacts, consumer impacts, and societal impacts. Net benefits are the most important success measures as they capture the balance of positive and negative impacts of the e-system users, suppliers, employees, organizations, markets, industries, economies, and even our societies. Net benefits measures must be determined by context and objectives for each e-system. For example, for the IAM app, net benefits would be: improvement of license examination results, improvement of the learning curriculum, improvement of the individual's clinical practice, and improvement of patient service quality.

Figure 6 shows that the quality dimensions are the basic dimensions because they consequently influence other dimensions of IS. Thus, after identification of the facilitators and barriers at all levels of the quality dimensions and using this information accordingly, we could generate the cascade mechanism for increase of IS use, user satisfaction and net benefits.

***Model of Compelled Nonuse of Information.***

A model of compelled nonuse of information comes from information science (Houston, 2009). This model reduces hundreds of theories of information behavior to a conceptually manageable taxonomy of six conditions that lead to nonuse of information. The six conditions include:

- Intrinsic somatic conditions

  These conditions include: physical impairments, psychological predispositions and intrinsic somatic conditions of uncertain origin

- Socio-environmental barriers

  Examples of socio-environmental barriers include geographical or temporal isolation, inadequate or malfunctioning information systems, and lack of applicable economic, cultural, or social capital.

- Authoritarian controls

These conditions include: censorship (including restrictive information systems), disinformation, reward and punishment, explicit approval or disapproval, tacit approval or disapproval, misinformation, bureaucracy and mistakes

- Threshold knowledge shortfall

This condition reflects an idea of the prior information as a threshold that must exist in a person as knowledge before new information can make a difference in that person's behavior. Examples of lack of threshold knowledge include illiteracy, unfamiliar handwriting and electronic information systems, lack of skills and experience, and lack of awareness of the availability of information.

- Attention shortfall

In other word, it is a lack or loss of focus. These conditions include: engrossment/flow/involvement/presence/rumination, distraction, affect (emotion or mood) and priming.

- Information filtering

These conditions include: least effort (ex: avoidance of cognitive overload) and least conflict (ex: nonuse of information from a schema of the world that might conflict with the person's own schema). These two categories frequently overlap, because conflict requires effort and reduced conflict requires reduced effort.

The Compelled Nonuse of Information frequently resulted from two or more elements or one element leading to another. Also, intrinsic somatic conditions, socio-environmental barriers, authoritarian controls were grouped as somatic barriers. They involve a person's body, as with externally induced trauma or as the result of intrinsic somatic barriers such as psychological predispositions. Threshold knowledge shortfall, attention shortfall and information filtering are grouped as cognitive barriers to use of information. Cognitive barriers control a person's cognition and represent a cognitive "lack of pull" from a person.

In summary, given the results of my literature review, I used the “DeLone and McLean Information Systems Success Model” and the Model of Compelled Nonuse of Information to develop an interview guide, and then to prepare my deductive codes for thematic analysis of the interviews.

### 5.3.2 Participants or case selection; interview protocol development.

I utilized a purposeful sampling technique to select the key informants for the qualitative phase 2 (J. Creswell et al., 2003; Morgan, 1998; Tashakkori & Teddlie, 1998). Particularly, I used a maximal phenomenal variation of purposeful sampling strategy to reach qualitative data saturation (Sandelowski, 1995). Potential interviewees as key informants were purposefully selected according to their persistence in SE mediated by weekly alerts. The quantitative and qualitative phases were connected when I selected residents who followed alerts most closely and least closely for qualitative interviews and developed an individual interview protocol based on the individual usage pattern that was identified from the quantitative phase 1. Usage pattern was based on analysis of the total number of pages each participant visited, number of topics of the week each resident visited (alert visit), log data on resident's usage of the IAM app with time and date. I sent interview invitation for residents following alerts most closely and least closely and simultaneously performed qualitative date collection and analysis until qualitative data saturation was reached (no new ideas emerged in the final few interviews). In sum, three rounds of interview invitations were sent to 30 residents following alerts most closely vs. least closely. I performed six interviews after the first round, four interviews after the second round, and three interviews after the third round, respectively. Thirteen participants were interviewed to reach data saturation with maximum phenomenal variation of purposeful sampling according to residents' sustainable participation in the SE mediated by weekly alerts (Sandelowski, 1995).

### 5.2.3 Qualitative data collection.

Qualitative data were collected through individual semi-structured phone interviews with R-1 family medicine residents who installed the IAM mobile application in August, 2015 (McMaster University, Hamilton, Ontario, Canada). I decided to perform phone interviews because of geographic distance, time constraints and budget constraints. Previously, researchers have argued in favor of phone interviews as they allow interpersonal communication without a face-to-face meeting and provide high quality data that is cost effective (Cachia & Millward, 2011; Sturges & Hanrahan, 2004). The interviews were guided by an interview guide with a set of predetermined questions (Whiting, 2008) and log data on resident's usage of the App. Other questions emerged from our dialogue. The interview guide for semi-structured interviews was

discussed with colleagues at meetings of the ITPCRG and tested on two family medicine residents at McGill. The interview guide is presented in Appendix 3.

Interviews lasted from 30 to 60 minutes. After introducing the purpose of my study, I guarantied confidentiality for each interviewee. I received verbal informed consent, from all interviewees, for conducting and recording the interview. Interviewees' confidentiality was assured by use of pseudonyms and no personal information (Kaiser, 2009). Further, participants were interviewed about their experience with the IAM app. We discussed positive and negative features of the app that facilitated and hinder sustainable participation in the SE and reading after weekly alerts. For example, participants were asked about IAM app design, installation, routine use, information content and their experience with a weekly alert and the alert system. Also, interviewees were asked what they would recommend as possible strategies for improving the IAM app. Finally, participants were asked about six somatic and cognitive conditions that led to nonuse of information on the IAM app after weekly alert, for example: physical health or psychological conditions, geographic isolation and workload.

The interviews were registered on two different audio recorders for data preservation in case of technical problems. Audio files were then securely downloaded and stored on a personal computer. Using the "Sound Organizer" program, I transcribed interviews verbatim. I anonymized personal information, and imported interview transcripts into a new NVivo project for thematic analysis. Interview data collection and analysis were carried out simultaneously in order to reach qualitative data saturation with maximum phenomenal variation of purposeful sampling (Sandelowski, 1995). I sent interview invitations for potential participants until qualitative data saturation was reached (no new ideas emerged during analysis of the last few interviews). Data collection took place from January to April 2017.

### 5.2.4 Qualitative data analysis.

I used NVivo 11 qualitative data analysis software for organizing, managing, and coding data in a more efficient manner. I anonymized personal information, imported interview transcripts into a new NVivo project and performed thematic analysis. I carried out qualitative thematic analysis with a hybrid approach of inductive and deductive coding and theme development (Fereday & Muir-Cochrane, 2006). I used an approach recommended by Fereday

and Muir-Cochrane and undertook six stages of data coding and theme identification: (a) developing the coding manual; (b) testing the reliability of codes; (c) summarizing data and identifying initial themes; (d) applying templates of codes and additional coding; (e) connecting the codes and identifying themes; and (f) corroborating and legitimizing coded themes.

A theme was defined as "a pattern in the information that at minimum describes and organizes the possible observations and at maximum interprets aspects of the phenomenon" (Boyatzis, 1998). A hybrid approach included both a deductive approach with a priori template of codes (codebook) and a data-driven inductive approach (Boyatzis, 1998; Crabtree & Miller, 1999) . I started with hypothesis coding that was an application of a predetermined list of codes to assess a researcher-generated hypothesis (Miles, Huberman, & Saldaña, 2014). In other words, I started with a deductive coding. The codes came from the combination of the "DeLone and McLean Information Systems (IS) Success Model" (Delone & McLean, 2003) with the Model of Compelled Nonuse of Information (Houston, 2009), my literature review about barriers and facilitators of SE, and list of research questions. Specifically, I used results of my literature review with two previously mentioned models in order to create a coding manual. I conceptualized that facilitators, barriers and strategies for improvement of the SE can be distributed in four dimensions: user, service quality, system quality, and information quality. A provisional "start list" of codes (coding manual) was applied to the first sets of field note and then examined closely for fit and for conceptual and structural utility (Miles et al., 2014). In addition, I used an inductive coding method; thus, other codes emerged progressively during data collection and analysis. For example, system quality code was revised and divided into platform quality and alert system quality, other descriptive sub-codes for each dimension and research objectives emerge progressively. Coding manual and coding results were discussed with my supervisor, co-supervisors and graduate students at McGill until a consensus was reached. The final codebook is in Appendix 4.

# 6. RESULTS

## 6.1 Quantitative Results

At McMaster, 81 of 96 (84%) first year family medicine residents consented to participate in the study and completed a demographic questionnaire. The median age of residents was 27 years. Typical participants were between 25 and 31 years old, predominantly female (71%) and predominantly using iOS mobile devices (76%). Demographic characteristics of consenting participants are displayed in Table 1.

*Table 1. Participant demographics*

| | **McMaster (n=81, 84%)** |
|---|---|
| **Age (median, 25%-75)** | 27 (25-31) |
| **Sex (% female)** | 71 |
| **Sex (% male)** | 29 |
| **Smartphone (% Android)** | 24 |
| **Smartphone (% iOS)** | 76 |

Of 81 family medicine residents who consented to participate in the study, 65 residents (80%) installed and used the app; 16 residents (20%) never used it. Given objectives of this study, these 65 participants who installed the IAM app and had a chance of receiving weekly alerts were included in the analysis.

From August 2015 to August 2016, 52 weekly alerts were sent to 57 topics. These alerts concerned 57 of the 99 Priority Topics, as five of 52 weekly alerts announced two topics in that week. For each user, I calculated the number of topics of the week visited within 1-week of the alert (or alert visits) and the total number of pages visited in the app over all 99 Priority Topics (or total page visits).

In year one, the total number of pages visited by all residents was 1,840. For residents who ever used the IAM app, the total number of pages visited varied from 1 to 442, as presented in Table 2. For total number of pages each participant visited, the central tendency was as follows: mode (2) < median (13) < mean (28.3).

*Table 2. Summary of the individual usage pattern during 1 year*

| | Number of topics of the week visited within 1-week of the alert (or alert visits) | Total number of pages visited (or total page visits) |
|---|---|---|
| Number of participants | 65 | 65 |
| Mean | 1.7 | 28.3 |
| Median | 1 | 13 |
| Mode | 0 | 2 |
| SD | 4.4 | 61.4 |
| Min | 0 | 1 |
| Max | 34 | 442 |
| 1st Qu. | 0 | 5 |
| 3rd Qu. | 2 | 27 |

Examination of figure 7 revealed the longer tail from the right of the box plot, median shifted toward the 1st quartile and presence of few outliers. These outliers had 64, 65, 68, 70, 105, 225, and 442 total page visits in the app over all 99 Priority Topics. Histogram analysis confirmed the right skewed distribution with the mode around 2 pages, high frequency of low total number of pages each participant visited and outliers with high total number of pages visited as shown in Figure 8. In addition, there was a smaller peak around 17 pages. Total number of pages each participant visited was clustered between 1-43 pages.

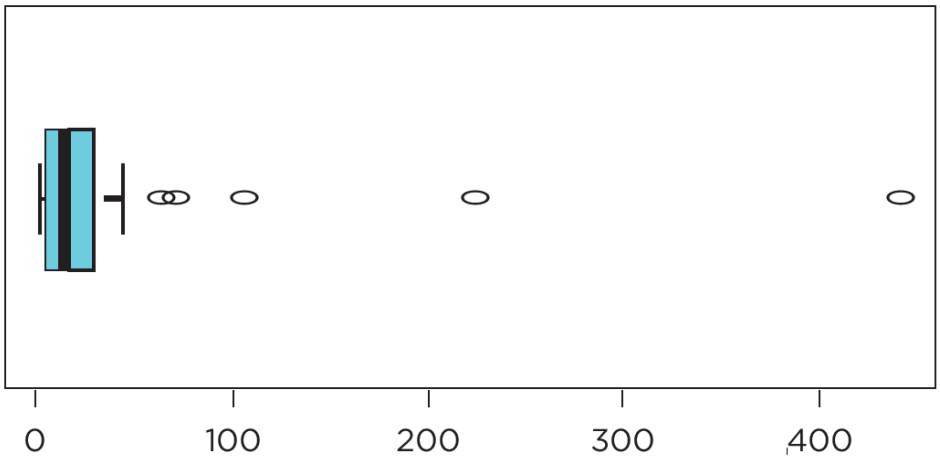



*Figure 7. Boxplot of the total number of pages each participant visited*

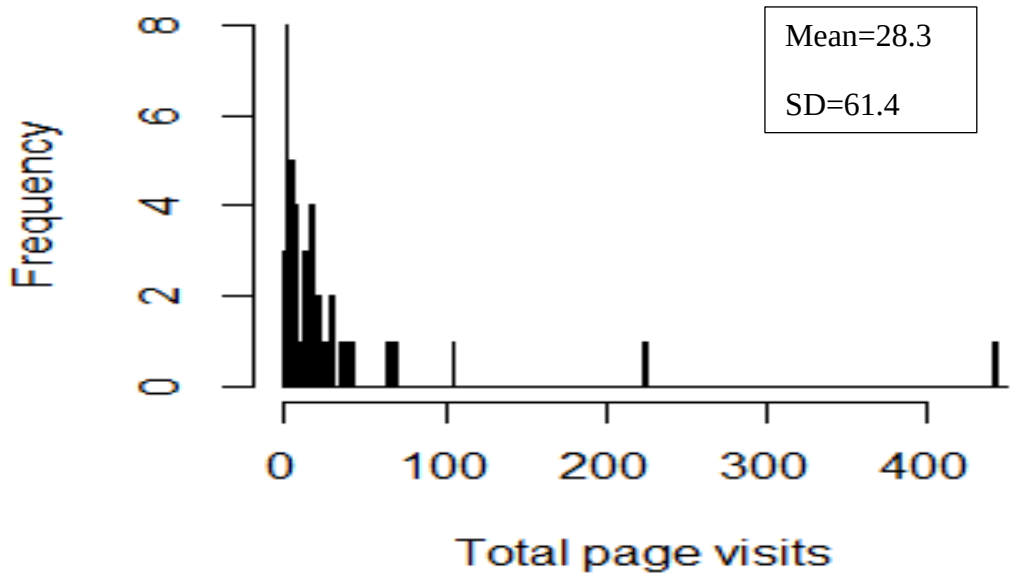



*Figure 8. Histogram of the total number of pages each participant visited*

The number of pages visited by all residents per month is presented in Figure 9. Participants used the IAM app most frequently during the first two months of the study. The number of pages visits was 421 in August, 2015 and 538 in September, 2015. In the next two months of the study, the number of page visits gradually declined and then dropped to 63 in November, 2015. During next nine months, from November 2015 to August 2016, the number of monthly page visits was in the range of 25 to 91. The lowest activity was in May, 2016.

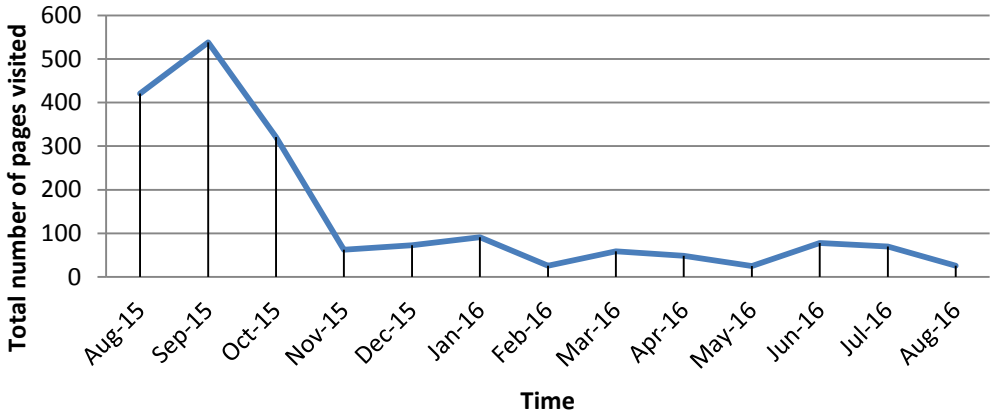



*Figure 9. The number of pages visited by all residents (per month)*

Given 52 alerts to 57 topics of the week, the number of topics of the week each resident visited within 1-week of the alert (or alert visits) varied from zero to 34. For these who used IAM, the mean (SD) was 1.7 (4.5) alert visits, the mode was zero, the median was one, the 1st quartile was zero, the 3rd quartile was two, as presented in Table 2. The central tendency of alert visits was as follows: mode (0) < median (1) < mean (1.7). A box plot of the number of topics of the week each resident visited within 1-week of the alert (or alert visits) revealed the long right tail from the right of the box, no left tail and presence of outliers, as shown in Figure 10. These outliers had greater than 5 alert visits (6, 9 and 34 alert visits, respectively). The histogram of the frequency of the number of topics of the week each resident visited within 1-week of the alert (or alert visits) demonstrated the right skewed distribution with high frequency of low number of alert visits as illustrated in Figure 11. Most alert visits clustered between 0-6 topics. The mode was 0 alert visits.

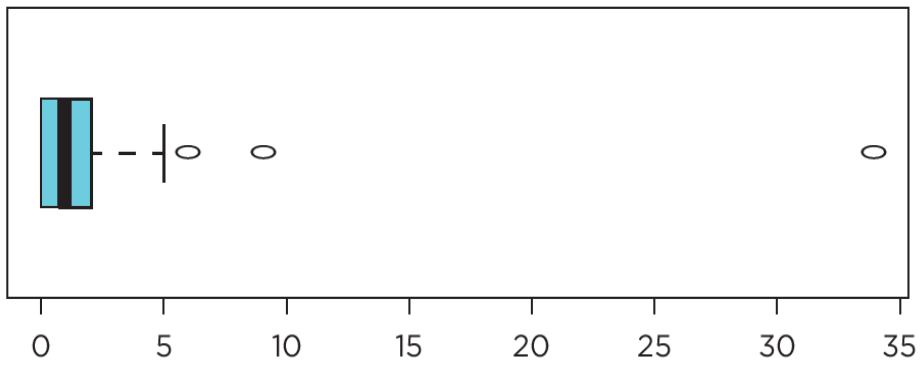



*Figure 10. Box plot of the number of topics of the week each resident visited within 1-week of the alert (or alert visits)*

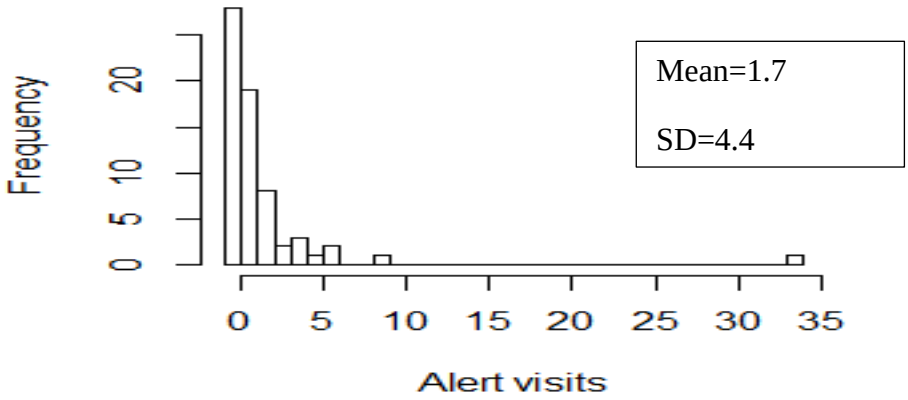



*Figure 11. Histogram the number of topics of the week each resident visited within 1-week of the alert (or alert visits).*

Finally, all participants performed 113 alert visits. During the first month of the study, participants performed 18 alert visits as illustrated in Figure 12. A maximal peak of 34 alert visits was observed in September 2015. During the subsequent month, alert visits dropped to 12 and then continued to decline gradually from November to December, 2015. From December 2015 to the end of the study, the number of topics of the week all participants visited within 1-week of the alert fluctuated in the range of one to eight alert visits. The lowest activity was in April, 2016.

In summary, given that the mean was 1.7, the median was one, and the mode was zero of alert visits for each participant and 57 maximal available alert visits for each participant, the effect of alerts from the IAM app was much smaller than anticipated. A stimulating effect of alerts from the IAM app was observed only at the beginning of the study, as it was not sustained.

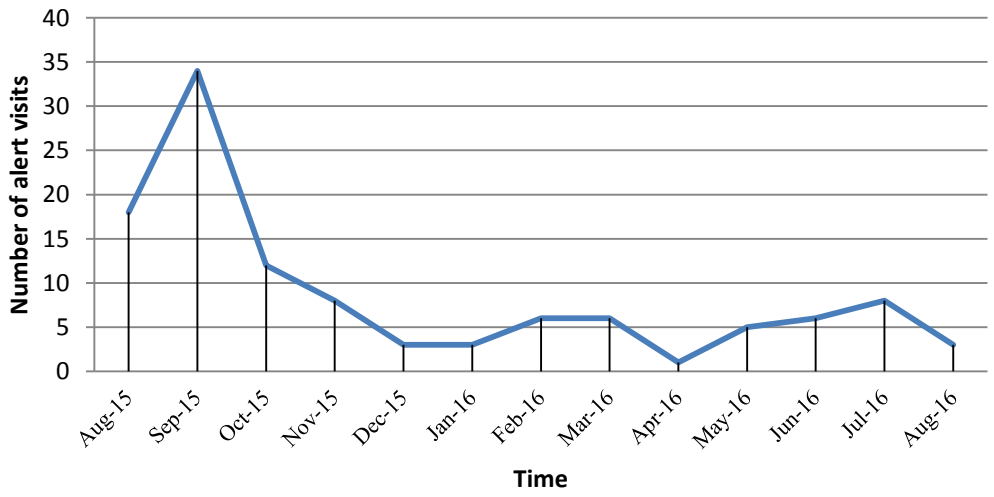



*Figure 12. Number of alert visits per month*

Figure 13 displays a summary of app use for each resident. In this figure, each dot represents an individual usage pattern of one resident in their first year of residency.

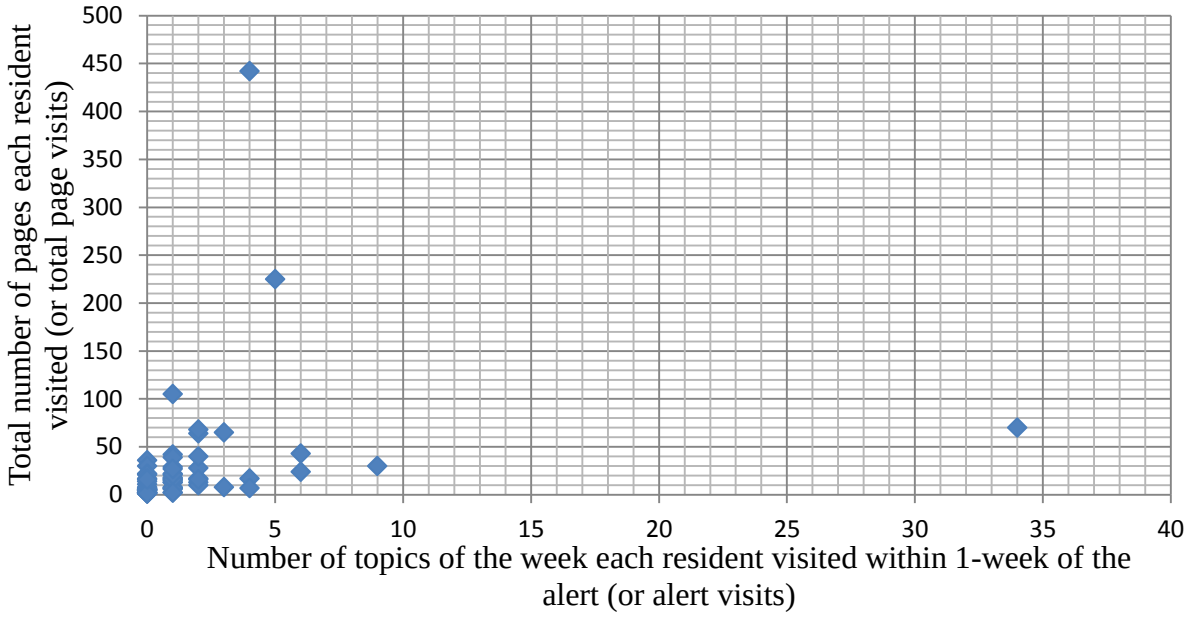



*Figure 13. Individual usage pattern of each resident during 1 year*

## 6.2 Qualitative Results

In the second stage of my project, 13 participants who were identified from the first stage of the study according to their persistence in SE mediated by weekly alerts (following alerts most closely and least closely) participated in a semi structured interviews. Table 3 presents usage patterns of all interviewees. For each participant I hereafter use a pseudonym (alias) in order to protect confidentiality (Kaiser, 2009). Nine participants (69%) were female. Also, nine participants were between 26 to 28 years old (69%). Eight participants had an Android mobile device (61.5%).

Phone interviews lasted from 18 to 45 minutes. The interview results revealed factors contributing to family medicine residents' sustainable participation in SE mediated by weekly alerts. The study findings are summarized below in more detail according to research questions.

My first research question was focused on facilitators and barriers to residents' participation in SE mediated by weekly alerts. Barriers and facilitators of the reading compliance after each weekly alert and user's persistence in the SE appeared to fall into five dimensions: user-related factors, information content factors, mobile app design factors, alert system factors, and service factors. My second question was focused on strategies for IAM app improvement. Residents discussed their ideas and recommendations that would encourage them to persist in SE mediated

by the alert system. Strategies for improvement of the IAM app appeared to fall into four dimensions: information factors, mobile app factors, alert system factors, and service factors. The interviews results were clustered according to previously mentioned dimensions and structured into themes and sub-themes as derived during the thematic analysis.

*Table 3. Stage 2 Participants' extent of IAM app use*

| Interviewee | Alert visits | Total visits |
|---|---|---|
| Sara | 0 | 11 |
| Lara | 0 | 21 |
| David | 0 | 30 |
| Julia | 1 | 22 |
| Eva | 1 | 29 |
| Tommy | 2 | 64 |
| Sandra | 3 | 65 |
| Anna | 4 | 7 |
| Bob | 5 | 442 |
| John | 6 | 24 |
| Lia | 6 | 43 |
| Dalila | 9 | 30 |
| Lisa | 34 | 70 |

### 6.2.1 Facilitators of residents' sustainable participation in SE mediated by weekly alerts on a mobile application.

Facilitators of residents' sustainable participation in SE mediated by weekly alerts were any factors that facilitated reading after weekly alerts and persistence in the SE mediated by weekly alerts. It included description of any positive experience or outcome related to participation in SE. These facilitators appeared to fall into five dimensions: user-related factors, information content factors, mobile app design factors, alert system factors, and service factors. User-related factors were related to family medicine residents themselves. The last three factors encompassed all factors that characterized the information system of the IAM app as a whole. Information content factors reflected the information content of the IAM app. Mobile app design factors reflected the IAM app characteristics: its general appearance, structure, and functionality. Alert system factors were related to the weekly alert system as a mediator of SE. Service factors reflected the support delivered by creators of the IAM app.

In summary, family medicine residents had a common motivation to pass the licensure

examination; this motivation stimulated them to engage with different learning materials. Residents had comfort with information technology. The IAM app was perceived as a good learning tool. Residents felt the information content of the IAM app was useful for exam preparation because it was recommended by an authority (CFPC). Residents indicated that IAM app as a learning platform was easy-to-use. The repeating nature of the alert system with quizzes was also considered positively. Some residents mentioned that alert timing on Wednesday was convenient. Another factor that facilitated participation in SE was prompt service on request. Residents said that technical support staff quickly communicated and resolved their questions. A summary of facilitators is presented in Table 4.

*Table 4. Facilitators of residents' sustainable participation in SE mediated by weekly alerts on a mobile application*

| **1. Facilitators of residents' sustainable participation in SE mediated by weekly alerts on a mobile application.** |
|---|
| **Theme 1.1. User-related factors**<br>***Sub-theme1.1.1. Positive motivation to pass the examination***<br>***Sub-theme1.1.2. Comfort with information technology*** |
| **Theme 1.2 Information content factors**<br>***Sub-theme 1.2.1 Information useful for examination preparation***<br>***Sub-theme 1.2.2. Reliable information from an authority*** |
| **Theme 1.3. Easy-to-use Mobile app**<br>***Sub-theme 1.3.1. Easy initial installation***<br>***Sub-theme 1.3.2. Easy accessible learning tool***<br>***Sub-theme 1.3.3. Concise information structure of the IAM app platform***<br>***Sub-theme 1.3.4. Topic tracking*** |
| **Theme 1.4. Alert system factors**<br>***Sub-theme 1.4.1. Convenient alert timing on weekdays or days of academic teaching***<br>***Sub-theme1.4.2. Availability of quizzes related to topics of the week*** |
| **Theme 1.5. Prompt service on request** |

**Theme 1.1. User-related factors.**

Thematic analysis revealed user-related factors. Family medicine residents mentioned facilitators that were specifically related to their personal wishes, motivations, and skills. Positive motivation to pass the examination successfully encouraged residents to download the IAM app and participate in SE. Further, comfort with information technology facilitated their participation in SE.

### ***Sub-theme 1.1.1. Positive motivation to pass the examination.***

Eight participants mentioned a common positive motivation to study for their examination. It was the main driver that stimulated them to explore information resources. A wish to pass the examination stimulated participants to use the IAM app as a potential learning tool for examination preparation.

*"I think all of us need to study and all of us need to make time to study , so the app is more like helping us prepare and giving us another resource"-Sara*

One of the participants, who followed alerts most closely, said the following:

*"Well, I want to pass my exam, so I will gather any materials to do it well."-Bob*

Another resident said that she experienced a lot of stress because of the exam. Strong motivation to pass the license examination and to overcome this emotional discomfort encouraged her to perform the highest number of alert visits:

*"First year, I had more stress and concerns about the exam, so I tried to keep on top of it. That's why I think I did it a little bit more in first year, trying to keep on top of it."-Lisa*

### ***Sub-theme 1.1.2. Comfort with information technology.***

Residents made an interesting comment regarding information technology. They mentioned that paper-based learning and e-learning complement each other. Thus, residents felt the IAM app would be suitable for delivery of medical education. From residents' perspectives, information technology was a valuable alternative method of learning that might improve their education:

*"I use printed guidelines and sometime I do on my phone. So, if I'm just looking on app or accessing something on the computer or reading an article, it helps because, you know, accessing the same information but using different means to do it."-Dalila*

*"I think it quite useful way to adjunct studying. If we have availability of this issue incorporated as well. I use my phone a lot in any way to be in touch with other residents and preceptors when I am on call or in clinic, to get information. So it just would be another way to do that."-Lia*

All residents stated that they had no fear regarding new information technology. They use mobile phones in their everyday clinical practice, so they felt comfortable to work with the IAM app:

*"I am not one of these technical that could understand everything, but I think I have enough understanding that I was able to download the app without problem. So, I think I have enough understanding on phones and computer to be able to navigate the app."-Anna*

### Theme 1.2. Information content factors.

Residents mentioned positive aspects of the information content of the IAM app. A number of residents indicated that the information content was helpful for exam preparation. Also, residents valued that the IAM app used the information content recommended by the CFPC.

#### *Sub-theme 1.2.1. Information useful for examination preparation.*

Nine residents valued the information content of the IAM app as helpful for examination preparation. Residents expressed satisfaction because content reflected the 99 Priority Topics, key clinical information for exam preparation:

*"I liked the 99 topics that rather will be on the exam. They are well laid out and there was some information for all topics."- Lia*

*"So, the application gave me access to information, for example like study notes that I found were helpful to study for the exam."-Sandra*

*"For the exam, it's more about diagnosis and investigation. So, for the exam, it's appropriately useful."-John*

Another resident who had 0 alert visits and 30 total page visits also mentioned that information was useful for examination preparation mostly as a review tool:

*"I guess that this is more like a review source for exam […] now in my second year as I review topics, I was looking at something several days ago. It probably functions its' main purpose as a review tool. So, as a review tool, it's good."-David*

#### *Sub-theme 1.2.2. Reliable information from an authority.*

Two residents appreciated that information content of the IAM app was based on the key features of the 99 Priority Topics recommended by the CFPC for exam preparation. The CFPC encourages residents to use the key features of all 99 Priority Topics as a general guide to

prepare for the board examination. One resident emphasized that the key features were directly from the CFPC:

*"…I like that they used the key features that were directly from the college, that we will be examined on in a very short time"-Julia*

### Theme 1.3. Easy-to-use mobile app.

One of the most commonly reported facilitators was ease of use. Three residents who followed alerts most closely and two residents who followed alerts least closely provided a direct comment that the IAM app was very easy to use:

*"I thought it was easy to use. It was nice because of all the topics pre listed, and I wasn't restricted to what the topic of the week was."-Sara*

Further thematic analysis revealed a number of sub-themes: easy initial installation, easy access, concise information structure of the IAM app platform, and topic tracking. These sub-themes explained why, from residents' perspective, the IAM app was easy-to -use.

#### *Sub-theme 1.3.1. Easy initial installation.*

A number of residents indicated that the initial installation was pretty easy and straightforward:

*"It was quite easy , we had somebody from the research team come in on Wednesday and he went through with how to download it and it was pretty easy download and he was there if we had any questions. So that was quite straightforward."-Lia*

#### *Sub-theme 1.3.2. Easily accessible learning tool.*

A number of residents reported that the IAM app was an easily accessible learning tool. At any time, it was easily accessible on a personal mobile phone**.** One resident elaborated on how she easily accessed the IAM app during her travels:

*"Quit handy App I find that when I was traveling, I had the phone on me. I can quickly go to the app and quickly go to the topic."-Dalida*

Another resident mentioned that accessibility of the learning tool allowed her to spend free time productively:

*"The mobility of it as an app is very useful as you can access the information anytime. it's also very useful for studying depending on where you are ...I also find myself using the app when I was sitting ever in a waiting room or in the airport. I was doing something more productive than just looking online or messaging people, and I used the app to read topic at that time."-Julia*

One resident appreciated that all topics were easily accessible:

*"I really like that the minute you had to open it, you had all 99 topics with it. So wasn't restricted to have to go through that particular week and that is good because I could use that as a resource as well. If I am with patients and want to use it as a resource, it will be easy to find."-Sara*

***Sub-theme 1.3.3. Concise information structure of the IAM app platform.***

A number of residents said that they enjoyed the structure of the IAM app, how everything was put together. The IAM app presented information at three levels or pages: Topics, Key Features, and Clinical Information. At the first level (Topics), all 99 Priority Topics were listed. The second level (Key Features) presents a list of key features for each topic as established by the CFPC. The third level (Clinical Information) contained additional information about each key feature. From residents' perspectives, information structure was concise. It facilitated reading and assimilation of information:

*"I really like the way you put it together… It's a pretty well made app. It has a pretty front page, concise and then you have a link to specific page. It's not like million different things. You know like the UP TO DATE app you keep scrolling forever. Here it's pretty well made. If you want something specific you click and you get to it. That is good. I like that."-David*

*"They are quite concise. It was pretty easy to read."-Lia*

***Sub-theme 1.3.4. Topic tracking.***

The first page of the IAM app contained titles of all 99 Priority Topics. Residents can determine when they last visited each topic, as a date was provided to the right of the topic title. A number of residents found that this topic tracking feature was very useful. It facilitated tracking of topics that residents read and that they have to read in order to complete all topics:

*"I like that it tracks which topic I sort of looked at. That's quite useful. I know always what I read and what I haven't read."-Tommy*

*"So that is a nice feature that it will keep track what I looked at last week or whatever.'-Bob*

**Theme 1.4. Alert system factors.**

Alert system consisted of weekly alerts introducing a topic of the week and open-ended test questions with feedback. Upon accepting a weekly alert and visiting the topic of the week twice, and when the second visit occurred at least five days after the first, residents could receive two open-ended test questions with feedback. Thematic analysis identified that residents appreciated weekly alerts. Residents mentioned that weekly alerts reminded them about the IAM app and encouraged them to read priority topics. The following comments confirm this idea:

*"I liked the reminders that popped up, with the specific priority topic […] I like the alert because it provides the reminder that you still have the app because without the reminder I probably wouldn't even go into the app."-Anna*

*"We get weekly reminder on topic to study. This is a great idea."-John*

*"I like the reminders […] It wasn't too hard to get the information and the reminder made it easier […] the reminders were helpful when I first started."-Lia*

***Sub-theme 1.4.1 Convenient alert timing on a weekday or academic teaching day.***

Some residents said that alert timing was convenient. They received alerts on Wednesday. It was a weekday, and it was matched with the time of academic teaching:

*"Pop up on the Wednesday that was good because that's an academic day"-Anna*

Another user never received a weekly alert because of technical problems. Nevertheless, she said that she would prefer to get alerts on weekdays:

*"I think on the weekends if I got notifications I won't look at it, like on the weekdays like Monday. We usually choose days, like Wednesday. Those are the best days to give notifications."-Sara*

***Sub-theme 1.4.2. Availability of quizzes related to topics of the week.***

Only one resident who performed the highest number of alert visits mentioned that quizzes on the topic of the week were helpful because she was able to test her understanding of the topic:

*"I like that it had automatic prompt that came up. It's kind of alert to read topic every week. And I did like that it has questions, so you could test your knowledge after reading the topic […] I actually liked questions. The fact that we got the feedback on it, it was great."-Lisa*

**Theme 1.5. Prompt service on request.**

Several residents were satisfied with technical support. They emphasized that technical staff provided sufficient support on request. One resident described a problem with reinstallation where she sent an email and received a prompt feedback from a member of the technical team:

*"The installation itself wasn't difficult. I just didn't remember how to do it after almost a year. I needed a password and such. Bethany was very helpful. She guided me on how to re-install it. Whenever I had a problem with the password, I was able to email and frequently got a response back right away from one of your study support staff."-Julia*

Another resident described how she received an email from technical staff that resolved malfunctioning of the IAM app:

*"There was, I guess like an app wide issue. We received an email saying that there was malfunctioning. That was quickly communicated with us and resolved. So, I don't have any complaints or concern to the staff."-Lisa*

### 6.2.2 Barriers of residents' sustainable participation in SE mediated by a weekly alert on a mobile application.

In the first phase of the study, we saw that the effect of the weekly alerts was not sustainable and observed only at the beginning of the study. Thus, barriers to residents' sustainable participation in SE mediated by weekly alerts became a key objective of analysis in the second phase of the study. Barriers should explain why residents did not persist in SE mediated by weekly alerts. Family medicine residents indicated a number of themes: user-related barriers, insufficient information content, pitfalls in mobile app design, pitfalls in the alert system and insufficient support from the service provider. A summary of barriers is presented in Table 5.

*Table 5. Barriers of residents' sustainable participation in SE mediated by weekly alerts on a mobile application*

| **2. Barriers of residents' sustainable participation in SE mediated by weekly alerts on a mobile application** |
|---|
| **Theme 2.1. User-related barriers**<br>***Sub-theme 2.1.1. Lack of time from workload***<br>***Sub-theme 2.1.2. Information filtering***<br>***Sub-theme 2.1.3. Alert fatigue***<br>***Sub-theme 2.1.4. Individual preference for other learning tools***<br>***Sub-theme 2.1.5. Personal mobile device issues***<br>*Sub-theme 2.1.5.1. New phone as a reason for forgetting about the app*<br>*Sub-theme 2.1.5.2. Insufficient memory space on personal mobile device* |
| **Theme 2.2. Insufficient information content**<br>***Sub-theme 2.2.1. Lack of structured clinical information for every day practice.***<br>***Sub-theme 2.2.2. Clinical information was incomplete regarding specialized clinical rotations.***<br>***Sub-theme 2.2.3. Lack of updated clinical guidelines.***<br>***Sub-theme 2.2.4. Lack of information about CFPC exam objectives*** |
| **Theme 2.3. Pitfalls in the mobile app design**<br>***Sub-theme 2.3.1. Pitfall in mobile app structure***<br>***Sub-theme 2.3.2. Technical/programming issues***<br>***Sub-theme 2.3.3. Installation was more difficult than an average app*** |
| **Theme 2.4. Pitfalls in alert system**<br>***Sub-theme 2.4.1. Unobvious functioning of the alert system***<br>***Sub-theme 2.4.2. Inconvenient alert timing***<br>***Sub-theme 2.4.3. Topic of the week was irrelevant in the context of resident's learning schedule***<br>***Sub-theme 2.4.4. Technical problems of receiving weekly alerts*** |
| **Theme 2.5. Insufficient support from the service provider** |

**Theme 2.1. User-related barriers.**

Residents reported individual factors that hindered their participation in SE mediated by weekly alerts from the IAM app. Residents complained about the lack of time from workload. It led to an adaptive mechanism of information filtering. Residents were focused on current clinical rotations. Other user-related factors were apparently related to alert fatigue, individual preference for other learning tools and trouble with their personal mobile device.

***Sub-theme 2.1.1. Lack of time from workload.***

Commonly, residents reported they were very busy with their everyday duties. One resident who performed 1 alert visit said that she tried to keep up with weekly alerts, but she was too busy:

*"I was trying to keep up with the weekly topic and then after a while I was getting behind. I was kind of too busy[…]so initially, I thought that it was a good app to use, like for example, when I'm sitting on the bus or waiting for something, but then I didn't always have time like that[…] I think residents in general are pretty busy people. It is not just at work. If we are not at work we are doing something else too."-Eva*

A number of residents indicated that they were busy with clinic and rotations:

*"I was busy with work and it kept giving me the alert. I was doing a hard rotation, internal medicine, and I was feeling guilty because I am not studying."-David*

*"Probably, it was difficult to stay on top of it every week. Just a new prompt coming in, there is often a clinic that's going on. I didn't always have a chance to look at the topic"-Lisa*

Some residents mentioned that usually they were busy specifically at the moment of the weekly alerts:

*"On Wednesdays when I received the notifications, I was very busy and was doing a lot of stuff. It's not really the time when I sit down and study."-Tommy*

***Sub-theme 2.1.2. Information filtering.***

Residents were busy with specialized clinical rotations and everyday clinical duties. They suffered from information overload. Residents tried to filter information in order to reduce cognitive overload. They were focused on current clinical rotations and rotation-related information. As a result, residents had their own learning pattern that didn't always fit with the schedule of weekly alerts:

*"I found it was easier in the beginning of the residency because in the beginning of residency you are like fresh y trying to learn everything. Then you have so much information coming from all directions. You're doing different rotations. When I'm on obstetrics, I'm learning purely obstetrics; when I'm on "P", I'm learning only pediatrics, when I'm in emergency I'm thinking about that. On top of that, I was doing tutorials on Wednesdays and we have a family medicine half day. I found that there was too much information and I needed to start targeting my studying. I needed to succeed in each rotation and just focus on my rotations… I realized that I will need this information eventually, but I will have time to prepare for this individually. In residency, it's just so much information. You have to target your study"-Lia*

### ***Sub-theme 2.1.3. Alert fatique.***

Several residents mentioned that the alert system was not a useful tool in their case because they received numerous alerts from other mobile applications. Residents were annoyed by different alerts and removed all alerts without reading them:

*"…If there are too many notifications on the phone that pop up, I just cleared it, just like clear up the space and then I just forgot it."-Anna*

*"I start getting messages from friends and all these notification appear first, right? And then often the next one is emails, right? So by the time I get down because I have other apps right now too and they give me notifications, and I find that by the afternoon I'm just deleting the notifications all together and I don't even bother, even looking at them."-Sara*

### ***Sub-theme 2.1.4. Individual preference for other learning tools.***

In three interviews, residents mentioned that for studying, they prefer to use text books or a personal computer. One resident, who performed three alert visits and 65 total page visits, said the following:

*"I find that I do not like that it's always on my phone, I would prefer to use my laptop […] for studying and for doing more reading."-Sandra*

Another resident who had one alert visit explained why she preferred to use e-text books:

*"Usually, if I have time to study I'm not going to use the app I'm going to work on the text book. When I go to the gym I do open the textbook on my phone and I read it like the electronic version. I think the main thing is that the e-text book, there are different headers and colors and visualizations and graphics. It's easy to look at."-Eva*

One resident said that she had a personal preference for paper materials, but she would use a mobile application if it was very good:

*"I think I have a preference for paper. I use quite a lot of apps because when you are running around in the hospital you can't carry all the paper. So if you have a really good app that sometimes all you need."-Lara*

***Sub-theme 2.1.5. Personal mobile device issues.***

*Sub-theme 2.1.5.1. New phone as a reason for forgetting about the app.*

Some residents switched to a new phone. Subsequently, they experienced difficulties with reinstallation of the IAM app and insufficient technical support:

***"****Personally, I switched to my new phone and I can't download the app on this phone."-Anna*

*"I got a new phone and I emailed to see if I can download the App on my new phone, but then no one replied to me, so then just after that I never got to access the App."-Sara*

*Sub-theme 2.1.5.2. Insufficient memory space on personal mobile device.*

For other residents, insufficient memory space on their personal mobile device was a reason to delete or to not reinstall the IAM app:

***"****Right now there is not much space for me to download apps and the app takes quite space. I had an old version of Samsung. That could be result of that. Now I have my apps for day to day practice, like calculator and drug charts and up-to-date app etc.… I can't delete them to download the IAM app so I sort of compromise in this one."-Lia*

*"I had a problem with my own phone. I did not have enough space on my device and I completely deleted it."-Eva*

**Theme 2.2. Insufficient information content.**

Although many residents evaluated the information content of the IAM app as useful for examination preparation, from residents' perspective, it was not enough to use the IAM app as a complete study tool. They were essentially concerned by how comprehensive the information was. As noted by Lara: *"I was very concerned by how comprehensive the information was for each topic which I think was probably one of the biggest reason why I didn't continue using it […] I used Up to Date, family medicine notebook, and it didn't really compare to the information that I could find there, I think the app is more suitable for a brief and kind of quick overview and it was not enough to use as a complete study guide."*

Another interviewee, John had a similar comment and stated the following:

*"When I first started residency I didn't know what exactly material I would use. By day to day, I realized that the amount of details on the app was far from adequate. I mean, it did vary a little bit from topic to topic, but most just didn't have enough details."*

Information content was one of the main reasons why residents decided to use other information resources and gradually drop-out from SE. Residents also mentioned the following: lack of structured clinical information for everyday practice, lack of updated clinical guidelines, and lack of information about CFPC exam objectives. Also, information content was incomplete regarding specialized clinical rotations.

***Sub-theme 2.2.1. Lack of structured clinical information for everyday practice.***

Residents would like to have a mobile application for everyday practice. After a period of using the IAM app, they realized the information content of the IAM app was designed for review of priority topics. Thus, to treat patients in clinic, residents used other clinical resources:

*"I was using it in my first year through my family medicine rotation to look up information, re-treat patients […]. This is not what you guys are trying to do here. I understand why there is not more information. It is more comprehensive […]. It is more for review, for the exam, but I want to read up information for a patient that I see in my clinic. I probably should be doing something else like go on Up to Date or other clinical resources."-David*

*"It didn't answer all my questions. Sometime if I have questions, I couldn't find the information there… I think the app cannot be a guide for practice."-Dalida*

***Sub-theme 2.2.2. Clinical information was incomplete regarding specialized clinical rotations.***

Specialized clinical rotations require specialized learning materials. Thus, residents perceived the information content of the IAM app as general and targeted to family medicine:

*"I would be more likely to use it when I'm on family medicine only because the other rotations they have their specific resources that they give to the resident. For example for pediatrics we have a little manual. We use that and then in terms of internal medicine they give us a little red book that all residents, most residents use for that rotation."-Lara*

*"The information we need in the rotation is a lot more specific and targeted and in more detail. So, I would probably, if I'm going to use the app for rotations, I'm going to read them at the beginning of the rotation to get a good background and supplement."-Lia*

### ***Sub-theme 2.2.3. Lack of updated clinical guidelines.***

Updated clinical guidelines are key elements for residents' clinical practice. For one resident who performed the highest number of alert visits, a lack of updated guidelines was a reason for switching to other information resources. She noticed that some topics of the IAM app were up to date and helpful only in the first year:

*"The information was helpful in first year, but in second year, I noticed that there were new guidelines and more depth that I had to know. That was not offered by the app."-Lisa*

### ***Sub-theme 2.2.4. Lack of information about CFPC exam objectives.***

One resident mentioned that key features of the 99 Priority Topics were not clearly introduced as key objectives of the certification examination. She reflected on this point and stated the following:

*"I think the other barrier is that I didn't know what I should expect from the CPFC exam when I was introduced to the app in my first year of residency and I didn't understand the role of key features and how I would need to approach them and how I would need to study them. But now I understand the key features and the content of the exam better so I think I would at this stage make better use of the app than I did in my first year."-Julia*

## **Theme 2.3. Pitfalls in the mobile app design.**

A number of residents mentioned pitfalls in the IAM app structure and technical/programming issues. Also, residents complained that the installation of the IAM app was more difficult than an average app.

### ***Sub-theme 2.3.1. Pitfall in mobile app structure.***

Two residents stated that the structure of the IAM app was inconvenient to find some specific information for everyday clinical practice. The IAM app presented information at three levels in the following order: "Topics", "Key Features", "Clinical Information" and hyperlinks to access

information from external websites. This information structure of the IAM app was adapted specifically for topic reading and not useful to find patient-specific information. One resident elaborated on this point:

*"It just looks like basically the 99 topics with a bunch of links that you can click at. Is it a good idea? For patient management, no. It's a little bit hard because you need to click through different things and you are not absolutely sure where you can actually find the information that you are looking for. For day to day practice it's not something that I would use. I don't know how useful this is for me to read through the 99 topics themselves right? For example, in old patients with some specific disease, it is really obvious that it will not help me for the exam."-Tommy*

The same resident also mentioned that lack of a comprehensive search function was another pitfall of the structure:

*"The only thing is that there is no search option… because I wouldn't search for abdominal pain [priority topic title] for example, but I would search for example for blood pressure targets."-Tommy*

***Sub-theme 2.3.2. Technical/programming issues.***

Residents who used the IAM app more frequently complained about technical/programming issues. One of these bugs was related to a programmed algorithm that forwarded readers to the main menu after a period of inactivity. Residents said that it was inconvenient and distracted them from reading:

*"I dislike the fact that when I am looking in a subject and when I minimize the app, it won't stay in the subject. It will kick me out and then make me go back to the main menu, and then I have to go scrolling back through and find the topic and the point I was on etc. That's like annoying."-Bob*

The same resident indicated other technical/programming issues as non-functioning external links and chart visualization:

*"There was a technical support issue with programming senses[…]You couldn't move across and see the entire chart , but then when I contacted they apparently changed and fixed it…*

*otherwise no other complaint. Oh yeah, actually sometimes when they put some links, these links didn't work."-Bob*

***Sub-theme 2.3.3. Installation was more difficult than an average app.***

Initial installation was successfully supported by one of the members of our research team. However, residents indicated that installation was more difficult than an average app, and re-installation of the IAM app was not always successful:

*"It's more difficult than the average app. Like, I can generally install any app on App store. Then this one, you have to go to the website to install it."-Bob*

*"It was kind of a hard process to re-install it because it's not in the App store. You have to go to the web page, and I forgot my username and my password… it was little bit confusing. You have to go to your setting and authorize because it's unknown or untrusted program. I think if it stopped working, I wouldn't have been able to reinstall it if I didn't have to go through all these things that I forgot, and I lost the instruction manual. The instruction manual was buried in my email."-David*

**Theme 2.4. Pitfalls in the alert system.**

Analysis of interviews identified a number of pitfalls in the alert system that hindered residents' participation in SE that was mediated by weekly alerts. For example, residents indicated that functioning of the alert system was not obvious and was not clearly explained. Also, alert timing was inconvenient, and topics of the week were irrelevant in the context of their learning schedule. Also, two residents faced technical problems. They complained that they never received weekly alerts.

***Sub-theme 2.4.1. Unobvious functioning of the alert system.***

The alert system of the IAM app consisted of weekly alerts to one new topic and quizzes with feedback. The alert system encouraged SE; therefore, residents received weekly alert first and then quizzes with feedback after visiting the topic of the week twice, and when the second visit occurred at least five days after the first. This algorithm of the alert system was not explained to residents; thus, the majority did not benefit from test questions. Moreover, they did not realize that the IAM app provided quizzes:

*"So I don't think I've used it enough and I wasn't aware of the question feature in the app... I never got that first I need to read through the topic and then I'll get a question and then a feedback... I thought it was just an app with a bunch of information and that's it. So, my assumption was wrong. It sounds pretty cool actually."-Tommy*

Interviews revealed that residents had a strong interest in receiving quizzes. Nonetheless, for the few residents who received quizzes, weekly alerts did not stimulate reading because algorithm for receiving quizzes was unclear:

*"I did it from time to time [question], but actually it popped up randomly. I wasn't sure why I've gotten these questions sometimes, not others. So, I wasn't really sure why that was happening. I mean it was nice to have that option, but I'm not really sure why I'm not getting more questions. It seems, like, it's very sporadic."-Bob*

*I guess, I didn't' realize that actually I have to visit the topic twice to get questions."-Lisa*

***Sub-theme 2.4.2. Inconvenient alert timing.***

A number of residents indicated that alert timing was inconvenient. Alert timing didn't fit with individual preferences and with their learning schedule. Thus, residents simply ignored weekly alerts or forgot to read the topic later during the week:

*"It was mainly schedule related. I was in class and I needed to pay attention to what's going on in the class on Wednesday. It generally popped up during a round presentation. If I was in clinic, it discouraged certainly, I can't get to my phone for extended period of time."-Julia*

*"It [alert] came on Wednesday, and we have a class on Wednesday […]. Sometime we have lunch time round, and it usually came during that time, and we were in the middle of something […]. I just looked at the alert and didn't click on it. I think that was one of the biggest factors,"-Dalida*

Another resident explained that he dismissed alerts because Wednesday was not his typical study day:

*"I guess like Wednesday, it's not my typical study day. I typically study on weekend. Like, I got a notification and I kind of feel guilty that I should read that, but it's not my typical study*

*day. So, maybe I'll say ok, let's study on weekend. But like it's Wednesday and then 2-3 days pass and then you already forget about it."-David*

***Sub-theme 2.4.3. Topic of the week was irrelevant in the context of resident's learning schedule.***

Commonly, residents reported that IAM app would be more useful during family medicine rotation. Or at least, residents would like to read topics that were relevant regarding their current clinical rotation:

*"I think in second year, the app would be more useful because in first year I am not on family medicine the full time. I am doing other rotations. May be if I have the app only during family medicine, I would pay attention to it little bit more, but if I'm on internal medicine or obstetrics or something else like pediatrics it's not always relevant for me to read about schizophrenia. It was not as relevant as if I was on full time family medicine."-Lara*

One interviewee said that he turned off the alert system after a while because topics of the week were random:

*"When I was on family medicine rotation, it was easier to study this kind of stuff because it's applicable to my work. But if I was on pediatrics or internal medicine then I would rather use my time to learn about internal medicine or pediatrics… After a while, I turned off the notifications because it wasn't useful […] It was sending notifications about things that I didn't want to study anymore. It was giving me random notifications about certain topics that I already knew. So, I didn't want to study it anymore."-David*

***Sub-theme 2.4.4. Technical problems of receiving weekly alerts.***

Two residents who had no alert visits said that they never received or noticed weekly alerts:

*"I actually don't remember getting the weekly alert."-Lara*

Another resident tried without success to fix this problem of receiving weekly alerts. She said that she never received weekly alerts, and it was the main reason why she forgot about the IAM app. She reflected on this point and stated the following:

*"I was looking at the different topics myself, and then I remember, I wasn't getting the notifications. I had email to figure it out, and I think they were working on it, and then still*

*didn't get any notifications […] I think it was a barrier for me because I didn't have the weekly reminders. I forgot that the app was there, and I wasn't using it as regularly."-Sara*

**Theme 2.5. Insufficient support from the service provider.**

Several residents reported that the support from the service provider, the creators of the IAM app, was insufficient to facilitate their participation in SE. There was an error that led to a delay in renewal of an iTunes certificate. As a result, the IAM app was not functional for about one week, and residents had to reinstall it. A number of residents said that they dropped-out from SE after this situation related to insufficient support:

*"I had to re-install the app numerous times. So, we received emails that said we had to go through the process to re-install it. I think that explain some of my large gap for using it because I just left the email in my inbox and I just didn't get around re-installing it… So, we got an email from Bethany who was one of the research support group member, and she just said that there was an update with the iTunes system or something like that with Apple. I think it wasn't the app itself I think it was a larger problem that required the whole app to be re-installed , so that was a barrier to use the app"-Julia*

Another resident, who was not able to receive weekly alerts and reinstall the IAM app on her new phone, did not receive technical support:

*'I wasn't getting the notifications and I think I had email to figure it out, and I think they were working on it, and then still I didn't get any notifications […] I think it was a barrier for me, because I didn't have the weekly reminders."-Sara*

*"I had emailed someone because I had a new phone then I didn't get any reply so I kind forgot about it completely."-Sara*

### 6.2.3 Strategies for IAM app improvement.

Finally, residents were asked to describe how the IAM app as a platform for SE should be improved. Particularly, I asked about strategies to overcome barriers to their sustainable participation in SE and reading compliance after alerts. These recommendations potentially could increase residents' participation in SE mediated by mobile app alerts and overcome user-related barriers of SE in the context of residency training. In summary, thematic analysis

revealed four themes reflecting strategies for IAM app improvement: (3.1) provide relevant, comprehensive concise structured information, (3.2) to improve app design, (3.3) improve the alert system, and (3.4) provide proactive technical support with outreach. For mobile app design, residents recommended an intuitive mobile app structure. Also, residents suggested implementing comprehensive search function, installation via App or Play Store, automatic update of the mobile app, attractive appearance of the mobile app structures, and podcasts. For alert system improvement, residents recommended: to use quizzes as primary driver of the alert system, to personalize the alert system according to users' needs, to include gaming format in the alert system, to send additional alerts for unread topics, and to send alerts about updated clinical guidelines. Also, from the resident's perspective, creators of the IAM app should provide proactive support with outreach in order to attract more users. A summary of strategies for IAM app improvement is presented in Table 6.

*Table 6. Strategies for IAM app improvement*

| ***3.*Strategies for IAM app improvement** |
|---|
| **Theme 3.1. Provide relevant, comprehensive concise structured information.**<br>***Sub-theme 3.1.1. Comprehensive information content linked with every day clinical practice***<br>***Sub-theme 3.1.2. Balance between concise and complete***<br>***Sub-theme 3.1.3. Introduce CFPC exam objectives*** |
| **Theme 3.2. Improve mobile app design**<br>***Sub-theme 3.2.1. Use intuitive mobile app structure***<br>*Sub-theme 3.2.1.1. Mobile app structure reflecting app functions*<br>*Sub-theme 3.2.1.2. Information content structure useful for every day clinical practice*<br>***Sub-theme 3.2.2. Implement comprehensive search function***<br>***Sub-theme 3.2.3. Do installation via App or Play Store***<br>***Sub-theme 3.2.4. Implement automatic update of the App***<br>***Sub-theme 3.2.5. Implement podcast***<br>***Sub-theme 3.2.6. Improve visual appearance***<br>*Sub-theme 3.2.6.1. One-page-topic*<br>*Sub-theme 3.2.6.2. Tracking usage activity*<br>*Sub-theme 3.2.6.3. Attractive visual objects* |
| **Theme 3.3 Improve the alert system according to users' learning needs, with the interactive gaming format**<br>***Sub-theme 3.3.1. Possibility to adjust alerts according to users' needs***<br>*Sub-theme 3.3.1.1. Individualized alert timing and frequency*<br>*Sub-theme 3.3.1.2. Matching topics of alerts with the teaching curriculum or clinical rotations*<br>*Sub-theme 3.3.1.3. Setting alternative alerts via email or google agenda*<br>***Sub-theme 3.3.2. Send an additional alert for incomplete topics of the week***<br>***Sub-theme 3.3.3. Use quizzes as primary driver of the alert system*** |

| |
|---|
| ***Sub-theme 3.3.4. Include an interactive gaming format into the alert system***<br>*Sub-theme 3.3.4.1. Quizzes*<br>*Sub-theme 3.3.4.2. Competition with other users*<br>*Sub-theme 3.3.4.3 Communication/interaction with other residents*<br>*Sub-theme 3.3.4.4. Performance tracking*<br>*Sub-theme 3.3.4.5. Incentives*<br>***Sub-theme3.3.5. Send alerts about updated clinical guidelines*** |
| **Theme 3.4. Provide proactive support with outreach** |

**Theme 3.1. Provide relevant, comprehensive concise structured information content.**

Information content of the IAM app was a key driver of participation in SE mediated by weekly alert. Residents wanted access to relevant, comprehensive yet concise and structured information. Residents recommended the following elements of comprehensive information content: 99 priority topics with key features, red flags, risk factors, differential diagnosis, management, workup, diagnostic criteria, exclusion criteria, treatment, updated guidelines and CFPC exam objectives.

***Sub-theme 3.1.1. Comprehensive information content linked with every day clinical practice.***

One resident recommended comprehensive information content that addresses all specific questions outlined by CFPC (for example: red flags, differential diagnosis, management, and priority topics with key features). She emphasized the following:

> *"I think my barriers to re-install it [the IAM app] were that I just didn't find the content as useful, but I think if the information was comprehensive then I have no issues downloading it again… I think, just follow the outline of what the CFPC has. So for example headache, they have specific questions that they want you to know like the red flags, different types of headache or the management for each kind. I think, just follow the key priority topics and key features that they want. It would be valuable to me."-Lara*

Also the same resident recommended including information useful in everyday clinical practice:

> *"…if you have additional resources. For example for back pain, there is core back tool that Dr. O'Toole had developed and it's very useful tool. So, that would be useful, so linking to resources that perhaps you would use in clinic. Or even just like different scoring systems for*

*specific diseases, like COPD [Chronic Obstructive Pulmonary Disease]. These scoring systems may be useful."-Lara*

In other words, for increasing app use, the IAM app has to be useful not only for exam purposes but also in everyday clinical practice:

*"I would like to use the app that not only helps with exam purposes, but also with clinical use as well too."-Sara*

Other residents elaborated on this point and added other important elements of information content: risk factors, workup, diagnostic criteria, exclusion criteria and treatment.

*"It should go through a differential diagnosis, the risk factors for serious diseases and what workup is and what the management is. That's how it should be… That's how doctors think. So, having that information is extremely important. Also, what is going to come up on our exam will be more relevant to us… I mean the thing that I just run over, it's the things that we need to have: the risk factors, you know we don't really need to know things like epidemiology but it's sometimes useful. So, yeah risk factors, differential diagnosis, investigations including labs and imaging, diagnostic criteria for different diseases and then treatment."-John*

*"I guess if I was using it as a clinical tool, maybe add treatment for different things. I'm looking at the app right now. I don't think I see treatment. It is all just like diagnosis and history. I am looking now at abdominal pain. There is like investigations, differential diagnosis to chronic pain. It's kind of general approach to the patient. I guess, you can say something like-"Oh this patient has a reflux. Well, what's the treatment? You know PPI, H2-blockers or different type of treatment."-David*

Also residents recommended adding information about updated clinical guidelines as an important element of clinical practice. One resident noticed that clinical guidelines are the most difficult to remember; thus, it would be very useful to have this information at your fingertips in app format:

*"Things that we need to know are new hypertension guidelines, new diabetic guidelines. This stuff is changing every year. That would be really high yield to have that at your fingertips just like on the way to work, or when you have a little break looking at the guidelines and updating yourself because I find the guidelines is the hardest to remember."-Lia*

### ***Sub-theme 3.1.2. Balance between concise and complete.***

From the resident perspective, it is also important to strike a balance between information content that is concise and too detailed:

> *"I think it has to be a balance between being too concise versus too detailed because if I'm studying for the exam and I'm using the app as a primary resource I want to make sure I'm learning everything I need to know, so being too concise it make me worried that it not have all the information."-Eva*

### ***Sub-theme 3.1.3. Introduce CFPC exam objectives.***

Another important element is information about CFPC exam objectives and how the IAM app addressed these objectives:

> *"A lot of people don't know where to start when they are studying or don't know exactly how the exam is structured. So, I think it's just a basic few slides or pages on how the exam is structured and how this app is in accordance with those objectives, would be very helpful. So, I find in the beginning of the residency we were not very concerned about studying for the exam, we were doing well on our clinical rotation. I believe that the app is a good reminder to continuous self-study for exams but also for rotations, but I don't I think I appreciated how it would help me for the CCFP exam. So, if I had known a little bit more about the exam itself and what to expect on the exam then I think I would have utilized the app better."-Julia*

## **Theme 3.2. Improve mobile app design.**

Family medicine residents recommended improving the IAM app design by using intuitive mobile app design structure (3.2.1), implementing comprehensive search function (3.2.2), installation via App Store (3.2.3), automatically updating the App (3.2.4), implementing podcasts (3.2.5), and improving visual appearance (3.2.6).

### ***Sub-theme 3.2.1. Use intuitive mobile app design structure.***

Mobile apps present information at different levels in order to organize information content**.** An intuitive structure of mobile app design should facilitate participation in SE mediated by weekly

alert. Intuitive structure should reflect mobile app function as providing SE and should be useful to find patient-specific information for every day clinical practice.

*Sub-theme 3.2.1.1. Mobile app structure reflecting app functions.*

Residents recommended an intuitive mobile app structure. It should reflect mobile app functions and options. Particularly, the intuitive structure should reflect availability of SE mediated by alert system with topics of the week, quizzes and feedback:

*"In residency, we are overwhelmed with lots of different resources. It needs to be very intuitive. If it isn't very obvious from the onset then nobody will read through the instruction. Like for example, right now, if I open the app I just see 99 topics right? If for example there is a little menu that says 99topics, SAMPs [Short Answer Management Problems], feedback then immediately I'll get the idea of the app and that there are different things that I can do and how I'm doing these things. That's bit more intuitive because then I know "Ooo there is option of feedback. I can get a certain score or I can just do something else than read through 99 topics."-Tommy*

*Sub-theme 3.2.1.2. Information content structure useful for every day clinical practice.*

The same resident suggested using a structure that divides and presents information content in order to be useful in clinical practice. He proposed to use outlines presenting each topic according to clinical tasks, for example: history, physical examination, differential diagnosis, treatment, key features etc.

*"I don't know how useful this is for me to read through the 99 topics themselves right? For example in old patient with some specific disease, it is really obvious that it will not help me for the exam to just read through that. But, if I just see the outline: what am I supposed to ask, what the physical exam is, what the treatment is, what differential is and which key things that the topic looks for. May be that is little bit more useful."-Tommy*

***Sub-theme 3.2.2. Implement comprehensive search function.***

A number of residents indicated that a comprehensive search function would facilitate SE:

*"I want to use the search function it would be easier."-Sara*

Another resident elaborated on this point. He would prefer to have a comprehensive search function rather than to search a topic title:

*"The only thing is that there is no search option… I wouldn't search for abdominal pain for example, but I would search for example for blood pressure targets."-Tommy*

***Sub-theme 3.2.3. Do installation via app or play store.***

To facilitate installation and re-installation of the IAM app, residents suggested the app be available on App or Play Store.

*"It was kind of a hard process to re-install it because it is not in the App store. You have to go to the web page and I forgot my username and forgot my password so I didn't re-install it till recently… It is easier to install when it comes up in App store... So, if you put it on app store it would be much easier to install."-David*

***Sub-theme 3.2.4. Implement automatic update of the app.***

Given the need to update and re-install, one resident recommended to implement automatic update of the IAM app. In this regard, the resident said:

*"We received emails numerous times and we had to go through the process to re-install it. I think that explain some of my large gap for using it… It would be better if the app had an update feature instead of having to re-install the whole app."-Julia*

***Sub-theme 3.2.5. Implement podcasts.***

One resident recommended implementing an audio version of each priority topic. She mentioned that she could listen to audio files while driving:

*"I don't know how you would call it, like when I was driving and I want to read about depression, put in the audio version, and just have someone read what was written there. It would be a nice feature. So, when you are driving you could be learning as well."-Lara*

***Sub-theme 3.2.6. Improve visual appearance.***

It was a common recommendation to improve visual appearance of the IAM app. For example, residents suggested implementing attractive objects (such as: pictures, colorful headers, tables,

pictures etc.). Some residents suggested tracking usage activity. Residents following alerts least closely recommended using a one-page topic with folders that expand and collapse.

*Sub-theme 3.2.6.1 One-page-topic.*

Four residents would prefer to see all information about one topic on one page and to scroll up and down through it. From residents' perspectives, the one-page-topic would facilitate reading and learning:

*"My preference is to see everything on one page and scroll through it. This is because I do not need to click and then sort of lost things… and when you press, for example, peritonitis then all things extend and you can read through"-Tommy*

*"It would have been nice to have something under each key feature to explain each topic without having to click the words. I found it challenging because I'm someone who likes to see everything on one page. So I would have liked to see it like a study note where the key feature was then followed by a paragraph or some bullet points about that key feature."-Julia*

*Sub-theme 3.2.6.2 Tracking usage activity*

Some residents recommended tracking usage activity, such as the IAM app should stay on the same page where user stopped reading.

*"I need to go the topic where I stopped."-Dalida*

*"I just want the screen to stay on the same page. It shouldn't go back to the main menu."-Sandra*

*Sub-theme 3.2.6.3 Sub-theme: Attractive visual objects*

Residents recommended using attractive visual objects. One resident who followed alerts least closely had a personal preference for text book and e-text book. It was related to visual appearance and visual aids; thus, she recommended using more visual objects, as for example: tables, diagrams, graphics, pictures, different headers and colors. She suggested that:

*"If there were more diagrams, clinical pictures, different headers and colors and visualizations and graphics, something like that cause I think in the app a lot of black and white, right? And with a long time after reading you can get tired, and with a text book you*

*have the graphs and the tables and all sources with different colors and stuff. It's easy to look at. "-Eva*

Another resident suggested using closer line spacing and smaller letters:

*"About the app, if you can adjust maybe the spacing and also the letters. Right now, it's very spaced out. It used a lot of space on my screen… Now, there is about 1,5 space between each line."-Tommy*

One resident proposed using an attractive logo of the IAM app icon. The logo that captures attention and reflects 99 topics for exam preparation:

*"Why don't you use some logo like 99 topics? When you're looking through the icons, it doesn't capture your eye that this is something that you can use for study. Maybe just like big 99 and you know there are 99 topics and you could read about that."-David*

**Theme 3.3. Improve the alert system according to users' learning needs, with the interactive gaming format.**

Residents were asked to describe how they believed they could improve the alert system. The recommendations focused on five different sub-themes: possibility to adjust alerts according to users' needs (3.3.1), send additional alert for unread topics of the week (3.3.2), use quizzes as a primary driver of the alert system (3.3.3), include the interactive gaming format into the alert system (3.3.4), and send alerts about updated clinical guidelines (3.3.5).

***Sub-theme 3.3.1. Possibility to adjust alerts according to users' needs.***

Analysis showed that residents had different preferences but a common desire to adjust alerts according to their needs. From residents' perspectives, alerts need be individualized given three sub-themes: individualized alert timing, matching topics of alerts with the teaching curriculum or clinical rotations and setting alternative alerts (email or google agenda).

*Sub-theme 3.3.1.1. Individualized alert timing and frequency.*

Residents had various preferences regarding alert timing and frequency. Some residents would like to receive alerts on weekdays, others on the weekend. Some residents reported that alert timing was convenient, but others recommended sending alerts early in the morning. Thus, an

individualized alert timing would allow residents to set up time and frequency of alerts according to their needs. One resident, who performed one alert visit, elaborated on this point:

*"Some people may want more frequent alerts or someone may want less, like maybe 4 topics in one month or maybe 2 topics in one week. Like if you could change it, I'll feel less pressure to do it... Personally I think that if there are a list at the beginning of the week, like here your three topics for this week or something. And then I choose from them and pick them. So, I could space out myself throughout the week because some weeks are busier than others."-Eva*

The same resident proposed implementing a special button, as for example-*"remind me tomorrow"* or *"another time":*

*"If an alert tells that you should read this topic and I don't feel like that then you don't do it because I'm doing something else, like going to the gym or dinner and then I'll forget about it. That is why I said maybe if there was a little button saying "remind me tomorrow or another time"-Eva*

Another resident who had the highest total number of page visits preferred to read a number of topics in a single day. He said that alerts were not helpful because he was always ahead of the proposed alert schedule:

*"I would look up a number of subjects in a single day. I don't want just one a day I would look at a number of them. So when I saw-"ooo next week we're going to look at this topic." I was like, well, I already looked at that two months ago. I was more like 20 topics ahead."-Bob*

*Sub-theme 3.3.1.2. Matching topics of alerts with the teaching curriculum or clinical rotations.*

Another recommendation was to match alerts on Priority Topics to the teaching curriculum or clinical rotations. One resident described how this would occur:

*"I think may be if you could categorize topics, so for example if I'm going on to my obstetric rotation, I would read more about obstetrical care. I still like a group of topics. So, you'll send me the alert that may help too, so I'm reading not just before my exam. I'm reading during my rotations. So, it's also relevant and interesting to me. For example, I knew my schedule at the beginning of the year. In January I'm going to pediatric, in February palliative care and then if there was a way to enter that in the app so the app knows what I'm doing in what month and*

*what week and then they can send me the relevant topic for those times. I would probably read it because I want to be prepared for my rotations. If I'm on geriatrics and there is a topic about the care of elderly or polypharmacy. If I see it in the alert, I would probably click it because I need to know it this week. But if I'm on geriatrics and it's giving me a newborn care then I may not click it because I'm busy trying to prepare for my own rotation."-Eva*

*Sub-theme 3.3.1.3. Setting alternative alerts via email or google agenda.*

A possibility to set alternative alerts via email or google agenda was recommended by one resident, who performed two alert visits. He said that alerts were not useful in his case because he was annoyed by different alerts on his mobile phone and suffered from alert fatigue. He would not mind to receive emails or alerts via google agenda:

*"I think on my phone I get maybe 7 alerts per day… If there is an alert, I am usually annoyed by it. I don't really like alerts… I don't mind emails because you can't get a buzz or be worried. You don't get distracted by it. So, that is useful. For example, if you bring it in google agenda, there is alert with the job that you need to do. It may be useful."-Tommy*

***Sub-theme 3.3.2. Send an additional alert for incomplete topics of the week.***

Other residents who also showed signs of alert fatigue or lack of time from workload recommended sending an additional alert*:*

*"So, having another reminder sometime midweek or at the time of the weekend, if I hadn't done it that week. So, having another reminder just in case, that could help."-Anna*

Also, additional alerts could encourage residents to read a topic more completely. As noted by Dalila: *"If I get a second reminder I would have completed the topic."*

***Sub-theme 3.3.3. Use quizzes as primary driver of the alert system.***

Residents would like to have to quizzes without any condition on the alert system. Residents liked the idea of receiving quizzes with feedback because they can learn more effectively by answering questions. One of the residents who followed alerts least closely commented on this point:

*"Questions are really great. If I just can learn by answering the questions, that is really great way of learning… Why would you put a condition on when we read something or when we*

*open something? I don't understand why that would be necessary... If there is the SAM [self-assessment module] of the week, that may be nice. I never got that first I need to read through the topic and then I'll get a question and then a feedback."-Tommy*

Another resident, who performed five alert visits and the highest number of total page visits, noticed that all residents should receive quizzes because wrong answers may stimulate residents to read:

*"I think it's a good idea, but I think they need to send the questions to everybody not just the person who read the topic… because when someone feels like they know a lot about that topic they don't want to read it, but it's still good to test them. If they don't do well, then they know they would read it; but if they do well, they know they are ok."-Bob*

For another resident who never performed alert visits, quizzes with particular emphasis on each priority topic were valuable if it was in an examination format. This resident would like to receive questions that residents would be tested on. She recommended going through topic-specific quizzes using the same format as in the licensure examination:

*"I think we have the priority topics on the CFPC exam. It has specific questions that they want you to focus on. So, I think going through these questions would probably be best in terms of what to cover because that's exactly what we would need to study for the exam. I think it will be nice to have the questions and then what the answers are and what the approach is for the specific topic. It is valuable."-Lara*

### ***Sub-theme 3.3.4. Include an interactive gaming format into the alert system.***

A number of residents in the SE program recommended implementing an interactive game in the IAM app. Residents suggested using the following elements in the interactive game: quizzes (3.3.4.1), competition with other users (3.3.4.2), communication/ interaction with other users (3.3.4.3), performance tracking (.3.3.4.4), and incentives (3.3.4.5). So, residents would like to chat with each other and see their progress on learning and testing. Also, incentives, for example banking of CME credits were mentioned as potential facilitators of sustainable participation in SE mediated by alerts. One of the residents mentioned an interactive game and recommended five elements:

*Sub-theme 3.3.4.1. Quizzes.*

As mentioned above, residents recommended using quizzes as primary driver of the alert system. From residents' perspectives, quizzes should be a basic element of the gaming format:

*"Personally, I would like to have a more interactive app. So it's almost like a game with quizzes at the end, and you can compare scores, and get high scores. "-Eva*

*Sub-theme 3.3.4.2.Competition with other users.*

The same resident continued the idea of gaming with quizzes and proposed using completion with other users in order to stimulate participation in SE mediated by weekly alerts:

*"If we're able to connect with other residents or other people and see how other people are doing, like more interactive I think, that would be nice too… and you can compare scores and get high scores. Or may be like, you could see the progress of certain residents. Like I was looking at something and there is like ooo, my friend got 3 lectures… I think it is very competitive and people probably want to see how people are doing and try to catch up."-Eva*

*Sub-theme 3.3.4.3. Communication/interaction with other residents.*

Then Eva added that it would be nice if she can interact with other users and share information:

*"Or may be like chat, like let's say for example, I have a question, like there is one of the guidelines and I can put a pretty little comment, and someone could agree… Maybe if you can ever add, like, people can make comments and suggestions or add articles or something like that. The interaction with your friends and make it more like a game."-Eva*

*Sub-theme 3.3.4.4. Performance tracking.*

Performance tracking was indicated as a facilitator that could stimulate reading and completion of learning tasks:

*"I think maybe if it told me what percentage I finished. Let's say I was looking at the well-baby exam and the app telling me that I read 1% or 20 % of it. It could encourage me to go back and finish it. The alert tells me that I have that percentage and asks me if I want to go finish this topic."-Eva*

*Sub-theme 3.3.4.5. Incentives.*

One resident mentioned incentives related to components of the gaming format (such as competition with other users and quizzes) and to knowing that people who used this app have a better score:

*"For example if you use SAMPs that may be an incentive. Or, if I know that people who used this app have a better score. Or, I know that I am doing better than colleagues. That is an incentive, if I can compare myself."-Tommy*

As an incentive, another resident recommended offering new features on the app or any external incentives after completion of certain amount of learning tasks:

*"If it's like you know you read a certain amount and there are incentives for completing a certain amount of reading every 6 months and you unlock new features. Motivate residents by kind of external incentives."-Lara*

Continuing medical education credit banking also was mentioned as a potential incentive. One resident explained that all family doctors have to obtain a certain number of continuing medical education credits. Thus, getting credits via the IAM app would be a nice feature that could reduce conference expenses:

*"…maybe like medical education credits. I don't know if this would be possible. It may work because we have to file the number of CME credits once we finish residency and we can actually start collecting them while in residency, so you can bank them, and a lot of us are trying to do that now […] I'm sure that would be a nice feature. It's not only studying for the exam, but you also getting credits that you need any way… This is kind of a nice easy way to get credits without having to go to the conferences or pay for conference or travel."-Lara*

***<u>Sub-theme 3.3.5. Send alerts about updated clinical guidelines.</u>***

Residents who followed alerts most closely had a common recommendation to send alerts about updated clinical guidelines:

*"Every year, there are updates on guidelines and new drugs. So in terms of that, in order to keep up to date, you cannot just study textbooks, you have to look at the articles and know what is most up to date. So, if a new guideline came out, we should know it as a part of our practice. If that was included into the app, it would be quite beneficial. Like a separate alert, alerting us to a new guideline like osteoporosis, hypertension, diabetes, things like that."-Lia*

One resident had an individual learning pattern: he was always ahead of the proposed alert schedule. He mentioned that alerts about updated topics or updated clinical guidelines would stimulate him to read this specific information. Thus, it can be an alternative way of spaced re-exposure to information learned previously:

*"Maybe if an alert was about updated information, about new guidelines that came out, I would like to know that. This can make it more valuable. So, if I'm working, and I knew the topic, and then there is a notification saying "hi, topic X was updated with new information", so I would probably review it, most definitely."-Bob*

**Theme 3.4. Provide proactive support with outreach.**

Four residents emphasized that proactive support with outreach would contribute to residents' persistence in SE. From resident perspectives, creators of the IAM app have to be more proactive in order to promote the IAM app: organize encounters with residents, recruit chief residents, send emails etc. The same strategy may be effective for early identification of users' problems:

*"The thing that would be useful in terms of like retention of residents, it's just thinking maybe getting more residents to do this. Maybe after doing the consent form, like 3 months later, just kind of checking in and see how everyone is doing with the app. You know what I mean, like coming in for 5 minutes, asking about issues. Do people still remember this app? It's just kind of nice to have this face to face and just remind them to use the app, or even email, or like telling the chief resident and the chief resident can provide that information. I find that when you don't really hear about it [the app] or talk about it, you will forget about it."-Sara*

*"I think that that was one thing that I was lacking because if they had a real advertisement, a lot more people would have used it. You know if it was mentioned on academic half day that we would check it out."-Dalida*

One resident recommended implementing a technical support line. This support line should identify residents who do not use the app and send them friendly emails offering assistance. She said that it might remind her to reinstall the IAM app on her new phone:

*" I guess for this study maybe like around the holidays, just seen which people haven't been using the app frequently and then send them email saying-"In August, you haven't been using the app" or "is there anything I can help you with?" This is like a technical line, just kind of*

*an e-mail reminder. It would serve as a reminder that this app still exists because when I switched my phone I forgot about it."-Anna*

Another resident recommended doing a little presentation in order to explain how elements of the IAM app are functioning. Particularly, how the alert system is functioning:

*"If you have someone like administrative, just give like a 5 min presentation about the app, going to the app and focusing on the task that there are simple question at the end to test the understanding then there may be better". Anna*

One resident mentioned an incentive that was related to outreach. If users of the IAM app had better exam scores, then they should promote this fact in order to encourage residents to use the app:

*"If I know that people who used this app have a better score... That is an incentive.-Tommy*

# 7. DISCUSSION

## 7.1 General Summary

The overall purpose of this mixed methods study was to estimate the extent to which weekly alerts on a mobile application stimulated family medicine residents to visit the IAM app over a 1-year period. In addition, we sought to identify barriers and facilitators to resident participation in SE mediated by weekly alerts and to describe the strategies recommended by residents for app improvement.

In the quantitative phase-1, a count of page visits per month revealed that the effect of alerts from the IAM app was not sustained. The stimulating effect of alerts was observed only at the beginning of the study during the first two months. For those who used the IAM app, the mean of alert visits (SD) was 1.7 (4.5) alert visits (number of topics of the week each resident visited within 1-week of the alert), and the mean of total page visits (SD) was 28.3(61.4) page visits (total number of pages each participant visited).

Both quantitative and qualitative findings highlighted unforeseen pitfalls in SE mediated by weekly alerts on the IAM app. More specifically, numerous barriers identified in the qualitative phase-2 helped explain why weekly alerts, as the mediator of SE, did not have a sustainable effect on residents. Analysis of interviews with residents revealed factors that hindered sustained participation in SE. These barriers were represented by: user-related barriers, insufficient information content, pitfalls in mobile app design, pitfalls in the alert system, and insufficient support from the service provider. So, residents mentioned user-related barriers and group of barriers reflecting quality dimensions of the IAM app as the information system delivering SE. This corresponds with the findings from my literature review that identified user-related barriers and barriers at the level of the SE platform as an information system. Also, residents revealed factors that facilitated initial participation in SE during the first two months of the study. Among these facilitators were the following: user-related factors, information content factors, easy-to-use mobile app, alert system factors, and prompt service on request. Nevertheless, after a period of using the IAM app, barriers began to have a greater impact on residents' behaviors. Commonly, residents following alerts least closely complained about: insufficient information content, insufficient support from the service provider, information filtering, and lack of time from heavy workload.

Therefore, a major contribution of my thesis is as follows. Both barriers and facilitators to resident participation in SE mediated by weekly alerts appeared to fall into five dimensions: user-related factors, information content factors, mobile app design factors, alert system factors, and service factors. The last four dimensions were related to the information system of the IAM. It was not surprising, therefore, that strategies recommended by residents for app improvement represented the same four dimensions of the IAM app information system: information content factors, mobile app design factors, alert system factors, and service factors. These four dimensions were consistent with basic quality dimensions of the DeLone and McLean Information Systems (IS) Success Model (Delone & McLean, 2003). Information quality was represented by information content factors, system quality was represented by mobile app design factors and alert system factors, and service quality was represented by their experience of service factors.

My quantitative and qualitative results supported the Information Systems (IS) Success Mode, i.e., that quality dimensions consequently influence intention to use/system use, user satisfaction, and net benefits of the information system. The quantitative results showed insufficient participation in SE and very low response to the weekly alert. Qualitatively, residents reported barriers at all four quality dimensions that had a negative effect on participation in SE mediated by weekly alert. At the same time, the DeLone and McLean Information Systems (IS) Success Model does not consider user-related factors. However, this model is a model for measuring Information Systems (IS) success. It was not specifically tailored to assess barriers and facilitators of an information system in the context of SE. Therefore, I propose that user-related factors affect user's intention to everyday use of an information system for SE. A better understanding of user-related factors is one of the key dimensions in the successful development and implementation of instructional technologies in medical education. From a resident's perspective, information content factors, mobile app design factors, alert system factors, and service factors could be modified to address user-related barriers and facilitators. For example, resident's positive motivation may be increased by incentives and proactive support with outreach. Adjusting alerts according to users' needs may overcome inconvenient alert timing, information filtering, and lack of time from workload.

In summary, five dimensions (user-related factors, information content factors, mobile app design factors, alert system factors, and service factors) appeared to form a construct of the

SE Success Model, as presented in Figure 14. I suggest these dimensions are potential predictors of users' sustainable participation in SE.

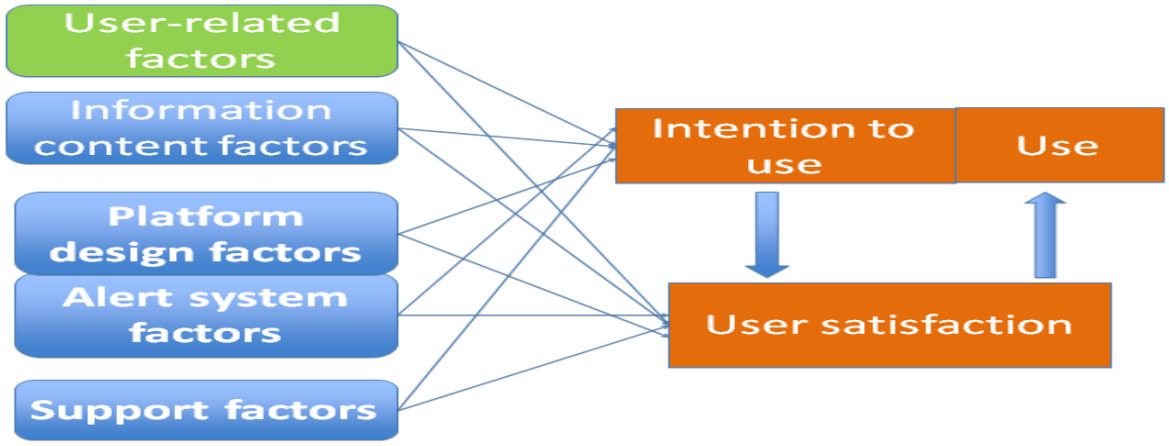



*Figure 14. SE Success Model*

In general, these findings are consistent with the literature on SE (Table 7) and the models I used for interpretation of the qualitative data. Inspired by the DeLone and McLean Information Systems (IS) Success Model, I assumed that five key dimensions comprise the SE Success Model. This assumption may be tested in future research.

*Table 7. The five dimensions of SE Success Model*

| | **Literature review** | | **Study results** | | |
|---|---|---|---|---|---|
| | **Facilitators** | **Barriers** | **Facilitators** | **Barriers** | **Strategies for IAM app improvement** |
| **User-related factors** | | √ | √ | √ | |
| **Information content factors** | √ | √ | √ | √ | √ |
| **System factors** | √ | √ | √ | √ | √ |
| **Alert system factors** | √ | √ | √ | √ | √ |
| **Service factors** | | √ | √ | √ | √ |

In the paragraphs that follow, I will present further discuss these five dimensions in line with residents' recommendations.

### 7.2 User-Related Factors

The qualitative analysis identified that all residents were highly motivated to pass the CFPC examination. Residents tried to explore different leaning resources and tools. Apparently, it could explain why 81 of 96 first year residents (84%) consented to this study of SE. In general, residents who downloaded the IAM app reported positive attitudes toward information technology; learning via the IAM app was convenient for them. Positive motivation and comfort with information technology could explain the relatively high level of initial use of the IAM app during the first two months of the study. Nonetheless, residents emphasized that over time barriers started to hinder their participation in SE. Some of these barriers were user-related factors. Lack of time from workload and information filtering as avoidance of cognitive overload were the most daunting. Residents who were less satisfied with SE also reported alert fatigue, individual preference for other learning tools, and personal mobile device issues. As strategies for IAM improvement, residents recommended to increase motivation through incentives, improving the alert system according to users' learning needs and with interactive gaming, providing relevant/comprehensive yet concise structured information, previewing CFPC exam objectives and how the IAM app addresses them, and providing proactive support with outreach. User-related factors were partially consistent with a thematic synthesis of results reported in other studies. In one study using SE to integrate psychiatry into the general medical curriculum, positive motivation was mentioned by students as one of the facilitators of SE (Blazek et al., 2016). Students who actively participated in SE demonstrated significantly higher scores on the knowledge test. Subsequently, they recommended increasing the motivation of future students in order to increase participation and effect of SE. Particularly, they suggested using incentives, obligations (mandatory course), and previewing and explaining benefits of SE. In another study, participants indicated that a gaming format of SE with team competition was a good motivation to complete the course (Janssen et al., 2016). Individual preference for other learning tools was mentioned as a barrier of SE in the study evaluating SE in the context of continuing medical education (Robinson et al., 2017). Although users never mentioned alert fatigue as a barrier of SE, alert fatigue is a well-known problem with clinical decision support systems (Kane-Gill et al., 2017)

### 7.3 Information Content Factors

As mentioned earlier, residents reported information system-related factors that affected their initial motivation and participation in SE over time. The first dimension of the IAM app information system was information content factors. Residents appreciated that the information content of the IAM app was useful for examination preparation and provided directly by the authority (CFPC). Nonetheless, residents indicated that this information was not enough to use as a complete study guideline. Insufficient information content was a common reason why residents following alerts least closely did not continue participation in SE. Residents following alerts most closely had the same complaint, but it was not a main reason for dropping out from SE. They used information content of the IAM app as a review tool.

The relevance of information content was supported by other studies examining advantages and disadvantages of online SE. In one study evaluating SE among oncology trainees, some participants reported the information content of the course was too easy (Janssen et al., 2016). Other studies emphasized that the information content of SE was an important factor (Blazek et al., 2016; Janssen et al., 2016; Robinson et al., 2017; Shaw et al., 2012). It was linked to the relevance of the information content in clinical practice. Participants valued the information content of SE courses because of its impact on their knowledge and confidence. They learned something new or they gained confidence in their knowledge. Participants valued that SE disseminated updated clinical guidelines or leaders' opinion (Janssen et al., 2016; Robinson et al., 2017). Moreover, senior clinicians agreed that they would now change their referral patterns according to new information presented in SE (Robinson et al., 2017).

### 7.4 Platform Design Factors

Commonly, residents valued the IAM app as an easy-to-use learning platform. It was easily accessible on a personal mobile device. On the one hand, easy initial installation supported by the research team, concise information structure, and topic tracking facilitated residents' participation in SE. On the other hand, installation was more difficult than it is for an average app and hindered reinstallation, the structure of the IAM app was inconvenient to retrieve specific information for everyday clinical practice, and technical/programming issues interfered with topic reading. Residents recommended implementing an intuitive mobile app structure with comprehensive search function, installation via App Store, automatic updating, podcasts, and improving the visual appearance of the IAM app.

These findings mostly confirm prior research. Commonly, participants in SE praised the low time consuming and easy to read message, how it was organized and structured (Blazek et al., 2016; Janssen et al., 2016; Ramos, 2015; Robinson et al., 2017). Similarly, participants appreciated accessibility and flexibility of SE on their personal mobile device (Ramos, 2015; Robinson et al., 2017). Also, some participants reported visual presentation of the message to be of importance when they participated in SE through their smart phone (Blazek et al., 2016; Ramos, 2015). Pitfalls in the platform design were reported in two studies, such as complex design (Blazek et al., 2016), failure of push notifications (Blazek et al., 2016; Ramos, 2015), and fail to download the IAM app form unknown source (Ramos, 2015).Up to now, podcasts have not been implemented in the context of SE. However, they have been described as a promising learning tool for medical education. (Jham, Duraes, Strassler, & Sensi, 2008).

### 7.5 Alert System Factors

The alert system was an element of the design of this mobile app. At the same time, the alert system of the IAM app was a mediator of SE. It represented a key interest and objective of this study. Thus, I considered the alert system as a unique element for analysis. Both residents following alerts most closely and least closely liked the idea of weekly alerts. However, my analysis of interviews revealed pitfalls in the alert system that hindered resident's sustainable participation in SE mediated by weekly alerts or reading behavior after weekly alert. First, there was technical problem of receiving weekly alerts. Two residents following alerts least closely said they did not receive or notice the weekly alert. Residents suggested implementing proactive technical support with a support line to identify and fix any technical problems**.** Second, one aspect of the alert system was unobvious for residents following alerts most closely and least closely. Particularly, they did not realize that the IAM app provided test questions and feedback under the following conditions: 1. they visited the topic of the week within one week of the alert, and 2. they re-visited that topic a second time. As a result, most participants did not benefit from all the available components of SE. As strategies for improvement, residents recommended quizzes as a primary driver of the alert system. Also, the intuitive structure of the IAM app should reflect availability of SE mediated by the alert system with topics, quizzes and feedback. Also, they recommended a face-to-face presentation in order to explain how the algorithm of the alert system is functioning. Third, residents following alerts least closely indicated that alert timing was inconvenient because it didn't fit with their preferences or learning schedule.

Although some residents liked that the alerts were sent on Wednesday as this is their academic teaching day, they disliked receiving alerts at 1p.m. At that moment, residents were busy or distracted by numerous notifications on phone screen (calls, messages, and alerts from other apps). Some of them preferred to study on weekends. Moreover, residents following alerts least closely reported that priority topics to which they were alerted seemed random and irrelevant in the context of their learning schedule.

In summary, as a strategy for improvement, residents recommended to send additional alerts for incomplete topics of the week on weekends. Also, they suggested implementing the individualized alert system. So, they would be able to customize the time of alerts, alternative alerts via email or google agenda, and the topic of the alert according to their learning needs. Regarding topics of alerts, residents suggested using quizzes as initial driver of the alert system, matching topics of alerts with the teaching curriculum or clinical rotations and sending alerts about updated clinical guidelines. Finally, some residents proposed to implement the interactive gaming format into the alert system in order to increase motivation. The interactive gaming format should comprise quizzes, performance tracking to enhance competition and interaction with other users, and incentives such as continuing medical education credits, competition with other users, and quizzes.

I found no studies exploring the barriers or facilitators to encourage learning associated with alerts in a SE system. However, in one study, medical students mentioned that advanced notice may facilitate their participation in SE and email reading (Blazek et al., 2016). Junior oncology doctors from another study liked that the system prompted them to answer questions (Janssen et al., 2016). The prompt came through and it would come through again if participants didn't complete cases. Moreover, the usability study of the IAM app showed that interest in having access to push notifications and technical issues leading to failure of push notifications impacted the use of the application (Ramos, 2015). Also, residents from the same study recommended implementing activity tracking. In general, users of SE in the context of Professional Medical Education valued case scenarios with quizzes and feedback as a good concise learning tool (Blazek et al., 2016; Ramos, 2015; Robinson et al., 2017). Also, gamified aspect of the SE with individual competition motivated participants to continue SE mediated by emails (Janssen et al., 2016; Shaw et al., 2012).

### 7.6 Service Factors

Prompt service on request was identified as one of the facilitators of SE mediated by weekly alerts. In contrast, residents following alerts least closely indicated that the support from the service provider was insufficient. One example was when the app was temporarily unavailable due to a delay in iTunes certificate renewal and lack of feedback from technical staff. From residents' perspectives, creators of the IAM app should provide proactive support with outreach: organize encounters with residents, recruit chief residents, and implement a technical support line. Both residents following alerts most closely and least closely mentioned that better outreach would encourage more people to participate in SE. Also, one of the residents following alerts least closely mentioned that if users of the IAM app were to have better exam scores, the founders of the IAM app should promote this fact. It would encourage residents to use the app and participate in SE.

The importance of support from the service provider was consistent with results of the usability study (Ramos, 2015). A lack of support hindered use of the app. Regarding outreach, senior clinicians from another study recommended communicating the benefits of SE in advance to enhance student persistence in SE mediated by emails (Blazek et al., 2016).

### 7.7 Recommendation as Practice Points

The results of the current study are aimed at numerous stakeholders: curriculum developers, mobile app designers and innovators in medical education. In summary, practice points that should be taken into consideration by stakeholders working in the field of medical education are as follows:

- Consider user-related factors;
- Provide relevant, comprehensive concise structured information;
- Balance between concise and complete information content;
- Implement easy-to-use mobile app with an intuitive structure, comprehensive search function, installation via App or Play Store, automatic updates, podcasts, and attractive visual appearance;
- Implement the alert system according to users' learning needs, consider individualized alert timing and frequency, additional alerts for incomplete tasks, interactive gaming format, and quizzes as primary driver of the alert system;
- Provide prompt proactive support with outreach.

### 7.8 Strengths and Future Research Directions

The current study is the second step in a multi-phase program of research. This study enriches our knowledge about facilitators and barriers to sustainable participation in SE mediated by weekly alerts on a mobile application.

The first strength of this study was related to its innovative nature; the IAM app is the first mobile application implementing SE in the context of family medicine residency training. Both barriers and facilitators to increase reading after each weekly alert appeared to fall into five dimensions: user-related factors, information content factors, mobile app design factors, alert system factors, and service factors. Inspired by the DeLone and McLean Information Systems (IS) Success Model (Delone & McLean, 2003), I assume that the SE Success Model is comprised of these dimensions. This model can serve as a basis for future studies. Also, it can contribute to the successful development and implementation of the new instructional technology for medical learning. Creators of new instructional technologies with SE may take under consideration each dimension as a predictor of success. In addition, these dimensions can guide development of a questionnaire as an instrument for SE platform assessment.

The second strength of the study was the research design. The explanatory mixed methods design conducted in two separate phases allowed me to collect only one type of data at a time. Moreover, the second qualitative phase explained results obtained from the initial quantitative phase, in which the effect of alerts from the IAM app was not as big as it could be.

The third strength of this study lies in its practical implications. The study focused on early assessment of a weekly alert on a mobile application as a mediator of SE. Residents recommended strategies for IAM app improvement. As more information on residents' perspectives emerges, it will become easier to implement an effective intervention that optimizes SE in residency training. Results of this study will be used to modify the IAM app according to residents' needs. The next phase of the IAM app project will test a new version of the IAM app and measure the effectiveness of SE using board examinations scores as the study outcome. Potentially, the IAM app project could improve residents' scores on this test of medical knowledge. As better certification exam scores correlate with better clinical performance in actual practice, primary health care patients could benefit indirectly from the results of this multi-phase program of research.

### 7.9 Limitations

As with all research, this study has limitations.

First, the IAM app was disabled for about one week in this 1-year study. This technical problem was related to a delay in iTunes certificate renewal. Subsequently, residents had to reinstall the app to continue SE. The qualitative phase of the study helped to describe this technical failure from the resident's viewpoint and identify pitfalls in IAM app design. Commonly, residents indicated that it was a reason for drop-out from SE. Further, they proposed how to resolve similar problems in the future: installation via App or Play Store, automatic update of the App, and proactive support with outreach.

Second, I used a pre-experimental design for quantitative phase I. This design has numerous threats to internal and external validity because of the absence of a control group and no randomization (Sackett & Mullen, 1993; Salkind, 2010). Thus, I cannot infer that the intervention (a weekly alert on mobile application) changes resident reading behavior. I simply described residents' behavior in order to identify residents following alerts most closely and least closely as key informants for the qualitative phase 2.

Third, descriptive design described residents' point of view, but it did not allow to estimate the main barriers and facilitators to their sustainable participation in SE mediated by weekly alerts. It would be interesting to create a questionnaire and ask residents to rate the identified barriers and facilitators using a Likert scale (Likert, 1932).

Fourth, I described residents' views about their participation in SE. Potentially, it could be difficult to implement all resident recommendations. A future study should explore opinions of other stakeholders such as teachers, curriculum creators, and mobile app creators. This will help to uncover other barriers.

Fifth, I performed fieldwork and initial analysis of interviews on my own. Yet, I received methodological support from fellow students and my thesis committee. The guide for semi-structured interviews, coding manual, qualitative data analysis and results were discussed with my supervisor, co-supervisors and fellow researchers from ITPCRG at McGill.

Sixth, the current study as a part of a multi-phase program of research did not access the effectiveness of SE or any net benefits of using the IAM app or participation in SE. Nonetheless, effectiveness of the IAM app as a platform for SE will be evaluated using board examinations scores in multi-site cluster randomized controlled trial. This trial is now in progress.

# 8. CONCLUSION

The aim of this study was to test the technical aspects of the IAM app, such as the weekly alert. Both quantitative and qualitative findings showed that there were unforeseen pitfalls in SE mediated by weekly alerts on the IAM app. Quantitative results from the first phase showed that residents' participation in SE was not sustained throughout their first year of training. Qualitative results described numerous barriers to residents' persistence in SE mediated by weekly alerts: user-related barriers, insufficient information content, pitfalls in the mobile app design, pitfalls in the alert system, and insufficient support from the service provider. However, most of residents liked the idea of push notification. As well, they mentioned comfort with information technology and appreciated the IAM app as easy-to-use. Also, residents had a positive motivation to pass the examination and intention to use a mobile app that corresponds to their needs. They recommended to: provide relevant, comprehensive concise structured information; improve mobile app design; improve the alert system according to users' learning needs with the interactive gaming format; and provide proactive support with outreach.

In summary, predictors of residents' sustainable participation in SE mediated by weekly alerts appeared to fall into five dimensions: user-related factors, information content factors, mobile app design factors, alert system factors, and service factors. These finding were in corroboration with previous investigations exploring barriers and facilitators of SE. Thus, I may hypothesize that these dimensions form a construct of the SE Success Model. Also, from resident's perspective, key dimensions of the information system delivering SE (information content factors, mobile app design factors, alert system factors, and service factors) could be modified to address user-related barriers and facilitators.

The main contribution of this study is the understanding of residents' perspectives about their sustainable participation in SE. Further investigations should evaluate the SE Success Model. Results of the current study are taken into account in the creation of the new version of the IAM app. The effectiveness of the new version of the IAM app as a platform for SE will be assessed in a definitive trial of SE.

# 9. APPENDICES

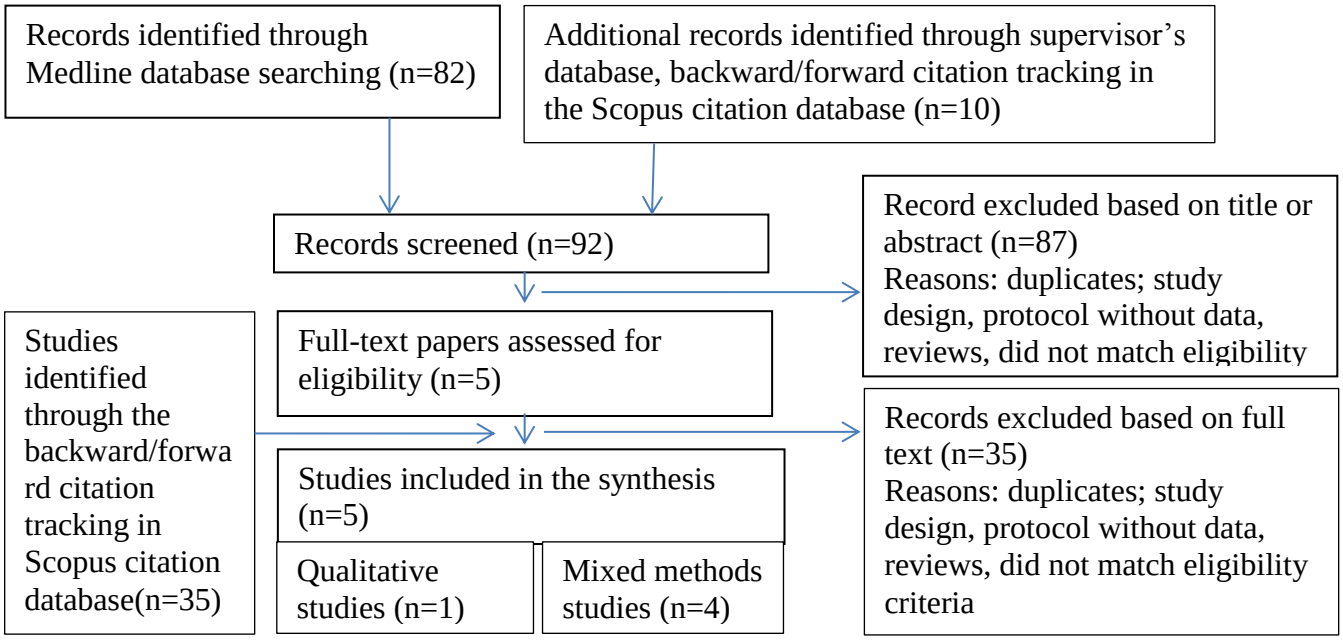
## 9.1 Appendix 1. Literature Review

### 9.1.1 Full 'Search strategy'

| Data base | Search strategy | | |
|---|---|---|---|
| Medline | Concept #1: Spaced education<br>1. spaced learning.mp.<br>2. spaced education.mp.<br>3. spacing effect.mp.<br>4. online spaced education.mp.<br>5. spaced teaching.mp.<br>6. spaced repetition.mp.<br>7. spaced practice.mp.<br>8. distributed practice*.mp.<br>9. distributed learning .mp.<br>10. retrieval practice*.mp.<br>11. testing effect .mp.<br>12. qstream .mp.<br>13. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 | Concept #2 Healthcare workers<br>14. health personnel/<br>15. education, professional/<br>16. pharmacist*.mp.<br>17. health practitioner*.mp.<br>18. internist*mp.<br>19. clerkship*.mp.<br>20. internship*.mp.<br>21. fellowship*.mp.<br>22. dentist*.mp.<br>23. surgeon*.mp.<br>24. occupational therapist*.mp.<br>25. rehabilitation therapist*.mp.<br>26. physical therapist*.mp.<br>27. physiotherapist*.mp.<br>28. resident*.mp.<br>29. medical student*.mp.<br>30. medical resident*.mp.<br>31. physician*.mp.<br>32. nurse*.mp.<br>33. doctor*.mp.<br>34. medical education.mp.<br>35. medical licensing exam*.mp.<br>36. healthcare professional*.mp.<br>37. health personnel*.mp.<br>38. health professional*.mp.<br>39. clinician* .mp.<br>40. 14 or 15 or 16 or 17 or | Concept #3: Online technology<br>41. firecracker*.mp.<br>42. anki.mp.<br>43. tablet*.mp.<br>44. device*.mp.<br>45. smart phone*.mp.<br>46. smartphone*.mp.<br>47. computer*.mp.<br>48. message*.mp.<br>49. cell phone*.mp.<br>50. cellphone*.mp.<br>51. e mail*.mp.<br>52. email*.mp.<br>53. learning management system*.mp.<br>54. course management system*.mp.<br>55. app*.mp.<br>56. web.mp.<br>57. internet.mp.<br>58. online.mp.<br>59. mobile.mp.<br>60. online systems/<br>61. mobile applications/<br>62. computer assisted instruction/<br>63. network*.mp.<br>64. 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63<br>**65. 13 and 40 and 64** |

| | | | |
|---|---|---|---|
| | | 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 | |

### 9.1.2 Flow diagram




### 9.1.3 Results of the individual studies

| Study | The results of the individual studies |
|---|---|
| 1. (Janssen et al., 2016). "A mixed methods approach to developing and evaluating oncology trainee education around minimization of adverse events and improved patient quality and safety". | Free-text comment: the expert feedback on cases, the competitive aspect of the course, the flexibility and manageability of the course format, cases covered scenarios that were less commonly considered issues in education and training, prefer receiving more cases, the cases were too easy, prefer receiving more cases. Interview: 1) enjoyment and engagement-"It didn't take very long to do so it wasn't a burden", could have been more engaging with revised content. 2) motivation for course completion - knowledge acquisition, interest in the topics covered in the course, the leaderboards and individual competition, gamified aspect of the course, the team based competition, competing with teams from around the world, a desire to help evaluate an online tool. 3) Impact on users' knowledge and confidence of the learning points: (high, low, no), the program is highly useful and relevant: (the applicability of the cases to user's clinical practice, easily see them-selves encountering the case scenarios in practice, |

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| | illustrating similarities and differences in cancer care globally), Content was a little too simplistic. 4) Program format: flexibility and the ability to answer cases at user's convenience, ability to completed the course on users' smart phones in between other activities, the user friendly interface (the appeal of the way the Qstream platform disseminates cases, the way the system prompted participants to complete cases (it would come through again if you didn't answer the question) that users may have forgotten about was very useful. 5) Course content: asked for more cases on chemo-therapy errors, drug interactions and other issues, desire for there to be more cases. |
| 2. (Blazek et al., 2016). "Spaced learning using emails to integrate psychiatry into general medical curriculum: Keep psychiatry in mind". | Participants recommended simplifying the format to look "less like a newsletter, eliminating the visual image which dominated screen-space on cell phone. Students disliked having to switch screens to view the answer explanations An incentive or the required participation and previewing the benefits of spaced learning to increase utilization.<br>massage theme : succinct, ''high yield,'' and ''easy to read'', simple format, ''organization and layout", simplifying the visual format of the emails, the clerkship-specific delivery so that students could learn ''how to address psych issues in every rotation.'' Case covering interdisciplinary problems, ''how to address psych issues in every rotation.'' the cases and questions as ''great for application and reinforcement.'' encourages thinking outside of rotation-specific problem, email for learning with an advanced notice. |
| 3.(Robinson et al., 2017). New Approaches to Continuing Medical Education: a QStream (spaced education) Program for Research Translation in Ovarian Cancer | The final thematic analysis yielded several themes, including knowledge change, content and format of the QStream as a learning platform, and perceived changes in referral patterns. Knowledge change: helped them update their knowledge about referring, disseminating new knowledge to colleagues, given enough confidence. Content and format of the QStream as a learning platform: answering the question, you're actually remembering it more than if you were just reading', welcomed the access the program on their phones and enjoyed the little time to complete, happily done more questions, easy access to our consultants and preferred easily ring up the genetic counsellors and ask them whether it's an appropriate referral. |
| 4.(Shaw et al., 2012) "Impact of online education on intern behavior around joint commission national patient safety goals: a randomized trial". | SE online cases authentic and engaging 'they made me feel interny' or, 'geared to my anxiety not to kill anyone this year and this program met my need! program just prior to commencing residency training raised the profile of patient safety, the content was memorable, The repeating nature of the SE methodology was considered positively 'I knew the cases were going to repeat, so I made sure I concentrated on getting them right the first time.' SE was more contextually relevant. However, not all interns felt SEs |

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| | intensive nature would be suitable for delivery of all types of education |
| 5. (Ramos, 2015) "Usability Assessment of a Mobile Application: Experience and Effects among Family Medicine Residents". | 5 themes: factors that influenced App use, the App's role, motivation for App use, use preference and the App's acceptability. Individual needs, learning strategies and push notifications were the factors that influenced the use of the App. However, proximity to exam dates sustained the use of the App. Role of app: support learning, give structure for learning, as reference of the key points, can help to study in group; motivation to use the app: habitude to use an app in general, as a way to signaling all the topics in advance, search on one note stimulate reading of all or other topic, awareness about all components of the program in order to know where to focus on; acceptability of the platform(app): design, correspondent with learning needs, availability oat the fingertips, useful. Barriers: malfunctioning of the system(app, platform), lack of all clinical information, user's far away from studying, interface issues, channels tab function), technical issues, alerts failure, and lack of technical support; platform devices differences. |

### 9.1.4 Study characteristics

| First author (year) | Title | Design | Participants | Intervention | Comparison | Study results | Details on SE intervention |
|---|---|---|---|---|---|---|---|
| 1. Janssen, A et. Al, 2016 Australia, Denmark, USA | A mixed methods approach to developing and evaluating oncology trainee education around minimization of adverse events and improved patient quality and safety | A mixed methods study (cross sectional study/ descriptive study) | 35 Oncology trainee (junior oncology doctors) 14 participants interviewed | The Qstream spaced learning platform | No | A total of 35 junior doctors registered to undertake the Qstream program, with 31 (88.57 %) successfully completing it. Analysis of the Qstream metrics revealed 76.57 % of cases were answered correctly on first attempt. The post-program survey received 17 responses, with 76.47 % indicating cases for the course were interesting and 82.35 % feeling cases were relevant. Finally, 14 participants consented to participate in semi-structured interviews about the program, with feedback towards the course being generally very positive. | -The Qstream spaced learning platform<br>- 8 short case- based scenarios with expert feedback were developed by a multidisciplinary advisory committee containing representatives from the international sites<br>- game-based approach (individual and team competition)<br>- Each participant received an email every 2 days |

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| | | | | | | | containing at least 2 cases<br>- If they answered a case incorrectly, it was re-sent<br>5 days later<br>-Once a case was answered correctly it was retired<br>- The course was completed once all questions had been retired. |
| 2. Blazek, 2016 USA | Spaced learning using emails to integrate psychiatry into general medical curriculum: Keep psychiatry in mind | A cluster-randomized trial. A Mixed Methods Study. | 174 members of the third-year medical student class (clerkship) at the University of Michigan Medical School. 26 participants interviewed. | Repeated series of emails with bulleted presentation of key points, followed by a MCQ, answer explanation and a reference | Did not receive email. | In a cluster-randomized trial over one academic year (intervention group n = 71, control group n = 61), scores on the knowledge quiz did not differ significantly. Students who actively engaged with the emails demonstrated significantly higher scores on the knowledge test. Email users valued the timing, format of delivery and application of psychiatric principles outside the psychiatric setting (PHC). Participants recommended simplifying the format and previewing the benefits of spaced learning to increase utilization. Delivering spaced learning through emails, within a curriculum designed to foster engagement, may provide an efficient means of addressing the widely-recognized but elusive goal of integrating teaching across medical disciplines. | - 1-year duration<br>-psychiatry clerkship<br>-series of 10 emails relating key psychiatric concepts targeted to the other core clerkships repeated over time intervals (bulleted presentation of key points, followed by a MCQ linked to an answer explanation and a reference). |
| 3. Robinson, 2017 Australi | New Approaches to ContinuingMedical | Pilot study/ Qualitative descript | 21/29 senior clinicians (five registrar | Spaced education program | No control group | Of the 21 participants who did commence the program, 18 (86 %) completed the program. Eleven participants agreed to be interviewed at | 3 Case-based scenarios with MCQ at spaced(one email/day) and repeated |

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| a | Education: a QStream (spaced education) Program for Research Translation in Ovarian Cancer | ive study | s, two nurses, four medical oncologists, four gynaecological oncology staff specialists, two gynaecological oncology fellows and one unstated) 12 participants interviewed | | | the completion of the program. Participants in the QStream program included five registrars, two nurses, four medical oncologists, four gynaecological oncology staff specialists, two gynaecological oncology fellows and one unstated. The final thematic analysis yielded several themes, including knowledge change, content and format (QStream as a learning platform) and perceived changes in referral patterns. | intervals(the latest guidelines for women with particular types of ovarian, fallopian tube and primary peritoneal cancer) -incorrectly answered question was resent 5 days later. -correctly answered question was resent 8 days later and retired after second correct answer. -Prompt reminder. -Link to further information. |
| 4. Shaw, 2012 USA | Impact of online education on intern behavior around joint commission national patient safety goals: a randomized trial | Mix Methods study (RCT/descriptive study) | 371 trainee (interns): surgical specialties (Surgery and OB-GYN) and medical specialities(Medicine, Anaes-thesiology,Emergen-cy Medici- | Spaced Education (SE) program | Traditional slides-based online training(SQ).online slide show followed by a quiz. | Both online learning programs improved knowledge retention. On four out of seven survey items measuring satisfaction and self-reported confidence, the proportion of SE interns responding positively was significantly higher ($p<0.05$) than the fraction of SQ interns. SE interns demonstrated a mean 4.79 (36.6%) NPSG-compliant behaviors (out of 13 total), while SQ interns completed a mean 4.17 (32.0%) ($p=0.09$). Among those in surgical fields, SE interns demonstrated a mean 5.67 (43.6%) NPSG-compliant | - 16 Clinically-relevant case-basedMCQ/immediate feedback. - Participants compare their performance with peers. -The spaced education item is repeated over 1-12 weeks (based on user's performance and question retired if it was answered correctly twice). |

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|---|---|---|---|---|---|---|---|
| | | | ne and Psychiatry Programmes) 53participants on SE/ 48 participants on SQ | | | behaviors, while SQ interns completed a mean 2.33 (17.9%) (p=0.015). Qualitative data indicates that SE was more contextually relevant than SQ, and significantly more engaging. Main themes: cases authentic and engaging, raised patient safety, SEs intensive nature. | |
| 5. Ramos, 2015 Canada | Usability Assessment of a Mobile Application: Experience and Effects among Family Medicine Residents | Usability/Case study | Family medicine residents (McGill University) | 1push notification every week for one of the clinical topics | No | -17 (85%) participants used the app.<br>-3 types of users: continuers (n=6),<br>Discontinuers (n=5) and non-users (n=4)<br>-69 of the priority topics were visited beyond the "Key Features" level.<br>-use increase as the exam date approached.<br>Cross-case analysis revealed 5 themes: factors that influenced App use, the App's role, motivation for App use, use preference and the App's acceptability | -6-month intervention<br>-standard curriculum<br>-open access to 99 priority topics<br>-alert to read one new topic each week |

## 9.2 Appendix 2. Ethics Approval

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April 2, 2015

Dr. Roland Grad
Department of Family Medicine
Jewish General Hospital
3755 Cote Ste-Catherine
Montreal, Quebec H3T 1E2

**RE: IRB Study Number A04-E18-15A**
*Can alerts from a smartphone application improve how residents prepare for their certification exam? A pilot study*

Dear Dr. Grad,

Thank you for submitting the above study for IRB review.

As this study involves no more than minimal risk, and in accordance with Articles 2.9 and 6.12 of the 2nd Edition of the Canadian Tri-Council Policy Statement of Ethical Conduct for Research Involving Humans (TCPS 2) and U.S. Title 45 CFR 46, Section 110 (b), paragraph (1), we are pleased to inform you that approval for the study, study instruments and consent form (March 2015) was provided by the IRB Co-Chair on April 2, 2015, valid until **April 2016**. The study proposal will be presented for corroborative approval at the next meeting of the Committee and a certification document will be issued to you at that time.

A review of all research involving human subjects is required on an annual basis in accord with the date of initial approval. The annual review should be submitted at least one month before **April 2016**. Please inform the IRB promptly of any modifications that may occur to the study over the next twelve months.

Sincerely,

Anita Gagnon, PhD
Co-Chair
Institutional Review Board

cc: A04-E18-15A

McGill

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May 10, 2016

Dr. Roland Grad
Department of Family Medicine
Jewish General Hospital
3755 Cote Ste-Catherine
Montreal, Quebec H3T 1E2

**RE: IRB Study Number A04-E18-15A**
*Can alerts from a smartphone application improve how residents prepare for their certification exam? A pilot study*

Dear Dr. Grad,

Thank you for submitting an application for Continuing Review for the above-referenced study.

The study progress report underwent review and full Board re-approval of the study was provided on May 9, 2016. The ethics certification renewal is valid until **April 10, 2017.**

The Investigator is reminded of the requirement to report all IRB approved protocol and consent form modifications to the Research Ethics Offices (REOs) for the participating hospital sites. Please contact the individual hospital REOs for instructions on how to proceed. Research funds may be withheld, and/or the study's data may be revoked for failing to comply with this requirement.

If any study modifications or unanticipated study developments occur prior to the next annual review, including study terminations, please notify the IRB promptly. Regulation does not permit the implementation of study modifications prior to IRB review and approval.

Regards,

Roberta Palmour

Roberta Palmour, PhD
Chair
Institutional Review Board

cc: A04-E18-15A

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April 3, 2017

Dr. Roland Grad
Department of Family Medicine
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3755 Cote Ste-Catherine
Montreal, Quebec H3T 1E2

**RE: IRB Study Number A04-E18-15A**
*Can alerts from a smartphone application improve how residents prepare for their certification exam? A pilot study*

Dear Dr. Grad,

Thank you for submitting an application for Continuing Review for the above-referenced study.

The study progress report underwent review and full Board re-approval was provided on April 3, 2017. The ethics certification renewal is valid until **April 9, 2018.**

The Investigator is reminded of the requirement to report all IRB approved protocol and consent form modifications to the Research Ethics Offices (REOs) for the participating hospital sites. Please contact the individual hospital REOs for instructions on how to proceed. Research funds may be withheld, and/or the study's data may be revoked for failing to comply with this requirement.

If any study modifications or unanticipated study developments occur prior to the next annual review, including study terminations, please notify the IRB promptly. Regulation does not permit the implementation of study modifications prior to IRB review and approval.

Regards,

Serge Gauthier, MD
Interim Co-Chair
Institutional Review Board

cc: A04-E18-15A

Hamilton Health Sciences

McMaster University

St. Joseph's Healthcare Hamilton

## Hamilton Integrated Research Ethics Board
## AMENDMENT REQUEST

**REB Project #: 14-502**
**Principal Investigator: Dr. Inge Schabort**

**Project Title: Usability testing of a mobile app for information delivery, information retrieval and data collection**

**Document(s) Amended with version # and date:**

- Consent Form - Participant Information Sheet/Consent Form Dated:15 June, 2015
- Protocol Amendment - Project Description Dated:15 June, 2015
- Other - IAM Alert and Screen Shots
- Other - Literature searches
- Other - Timeline
- Interview Guides - Interview Guide
- Survey - Baseline and Post-exam Surveys
- Letter of Support - Letter dated 28 January 2015
- Other - PI's Memo dated March 29, 2015 clarifying the amendment

### *Research Ethics Board Review*
***(this box to be completed by HIREB Chair only)***

[X] **Amendment approved as submitted**

[ ] **Amendment approved conditional on changes noted in "Conditions" section below**

[ ] **New enrolment suspended**

[ ] **Study suspended pending further review**

**Level of Review:**

[ ] Full Research Ethics Board
[X] Research Ethics Board Executive

**Conditions:**

The Hamilton Integrated Research Ethics Board operates in compliance with and is constituted in accordance with the requirements of: The Tri-Council Policy Statement on Ethical Conduct of Research Involving Humans; The International Conference on Harmonization of Good Clinical Practices; Part C Division 5 of the Food and Drug Regulations of Health Canada, and the provisions of the Ontario Personal Health Information Protection Act 2004 and its applicable Regulations; For studies conducted at St. Joseph's Hospital, HIREB complies with the health ethics guide of the Catholic Alliance of Canada

Raelene Rathbone

Suzette Salama PhD., Chair
Raelene Rathbone, MB, BS, MD, PhD, Chair

6/30/2015
Date

All Correspondence should be addressed to the HIREB Chair(s) and forwarded to:
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Project title: *Can a smartphone application improve how residents prepare for their certification examination? A pilot study*

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PARTICIPANT INFORMATION SHEET

**Introduction**

You are being asked to participate in this research project because you are a resident in the Family Medicine Residency program at McMaster. Please read this 'Information Sheet and Consent Form' carefully and ask as many questions as you like before deciding whether to participate.

As a resident, you will eventually sit for the board certification examination of the College of Family Physicians of Canada (CFPC). The CFPC encourages residents to use the key features of their 99 Priority Topics as a general guide to aid preparation for the board exam. This pilot study seeks to test a smartphone application containing clinical information on the key features of the 99 Priority Topics. Through this app for mobile devices, we seek to stimulate self-learning. The results of this study are needed to build the protocol for a future experiment to demonstrate the benefit of this mobile application on resident competence in family medicine, as shown by improved examination scores.

**Study Procedures**

If you participate, we will ask you to install the app. Then, we will track how frequently you access pages through the app to read and re-read clinical information provided on the app, but we will not track any web pages you access through the app. This data, along with your name, will be stored in the USA on a password protected commercial server managed by Rackspace. Data sent to the USA is open to access by regulatory bodies.

In addition, you may be contacted by the principal investigator or his assistant 1. To discuss any issues you have while using the app, and 2. For an interview following your certification exam in 2017.

In the analysis, we will examine your use of the app. Then, and anonymously, we will analyze your results on the certification exam. One member of our research team (Dr. Carlos Brailovsky) is authorized by the CFPC to obtain examination scores for all participants. This analysis will require you to provide permission to the CFPC to release your exam marks directly to Dr. Brailovsky. Examination scores will be released only after residency has ended.

**Potential Harms**

There are risks inherent in the transfer of data over the Internet if there is a security breach orattack from Internet-borne viruses, Trojans or other data-sniffing technologies.

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**Potential Benefits**
Study results will benefit the development of a protocol for a future randomized trial involving Canadian Family Medicine residents. This trial will seek to determine the effect of the app on resident knowledge.

**Will I be paid to participate in the study?**
You will not be compensated for your participation in this study.

**Will there be any costs to me in this study?**
No costs are anticipated due to participating in this study.

**Withdrawal**
Your participation in the present study is voluntary. You can withdraw from the study at any point in time without any negative consequences.

**Confidentiality**
If you agree to participate, your total confidentiality and anonymity in the study is guaranteed. Your name will be stored with your app usage data in a database on a password protected server at Rackspace. On this server, your name is required to be collected to troubleshoot app issues that you may experience. All study information will be used for academic purposes only. Unless authorized in writing, publication of the results of this study will be done anonymously for both the individuals and organizations involved. Study results will be published in a journal with a focus on medical education.

**Consent**
The study has been explained to me and my questions have been answered to my satisfaction. I agree to participate in this study. I do not waive any of my rights by signing this consent.

**Contact**
If you have any questions or concerns regarding your rights or if any adverse event should arise, please contact the the principal investigator, Dr. Roland Grad at roland.grad@mcgill.ca.

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CONSENT STATEMENT

*Participant*

I have read the preceding information thoroughly. I have had an opportunity to ask questions and all of my questions have been answered to my satisfaction. I agree to participate in this study. I understand that I will receive a signed copy of this form.

| Name | Signature | Date |
|---|---|---|

*Person obtaining consent:*

I have discussed this study in detail with the participant. I believe the participant understands what is involved in this study.

| Name, Role in Study | Signature | Date |
|---|---|---|

This study has been reviewed by Hamilton Integrated Research Ethics Board (HIREB). The HIREB is responsible for ensuring that participants are informed of the risks associated with the research, and that participants are free to decide if participants is right for them. If you have any questions about your rights as a research [participant, please call The Office of the Chair, HiREB at 905-521-2100 x 42013

## 9.3 Appendix 3. Qualitative Interview Guide

Can you tell me about your experience with the IAM app?

In general, what did you like? What did you dislike about this app?

Were there any factors that prevented you from using the app?

Was there anything that encouraged you to use the app?

Can you remember or summarize your main reasons for using this app?

**SPECIFIC QUESTIONS ON THE APP**

*Based on your experience, we will now review or summarize any specific positive and negative aspects of the app, and possible improvements.*

**Installation:** Tell me about your experience with the installation of the app such as difficulties, successes, any turning point and any suggestion for improvement**.**

**Routine:** Tell me about your experience with routine use of the app.

**Key Features:** Tell me about your experience with the screen that lists the key features of the app.

**Internal content:** What do you think about the clinical information in the app?

**External content:** Tell me about your experience with the links to external knowledge resources such as difficulties, successes and any turning point.

**Alert:** Do you receive alerts on the mobile application to read a new topic each week? Tell me about your experience with the alerts? Were there any factors that prevented you from reading the topic of the week after the alert? Was there anything that encouraged you to read the topic of the week after the alert? According to your previous experience, which factors can encourage you to read the specific topic after weekly alert? Do you have any suggestion for improvement of the alert system?

**Testing:** Did you receive open-ended test questions? IF YES-> Did you receive a feedback? Tell me about your experience with open-ended questions? Were there any factors that prevented you from submission of the answer to the question? Was there anything that encouraged you to submit the answer to the question? -Do you have any suggestion for improvement of the testing and feedback?

**Mistakes:** Since August 2015, did you either lose or break your smart phone, or somehow delete the app by mistake?

**SPECIFIC QUESTIONS ON INFORMATION USE / NON-USE (Houston, 2009)**

Did any diseases / health or psychologic conditions prevent you for using this app of reading the specific clinical topic after weekly alert?

Did any Geographical or temporal isolation prevent you for using this app of reading the specific clinical topic after weekly alert? (Ex: bad internet connection related to specific geographical location)

Let's think about our app as about information system, do you think that it was Inadequate or malfunctioning? (ex: Technical support, feedback) Do you have any suggestion for improvement?

Did any financial issue prevent you from using the app? For example data plan.

Was the reading of the app content openly encouraged by your colleagues, supervisors or other staff?

Did someone ever openly discourage you from reading app content / encourage you to read something else?

How would you describe your skills related to app as new technology use? I mean, did you have trouble using or downloading the app, in general, for example because you are "not a computer person"?

Attention shortfall. Did any emotion and mood conditions prevent you for using this app of reading the specific clinical topic after weekly alert? Did interacting with another information system (for ex: human, paper, other app or internet resources) prevented you for using this app or reading the specific clinical topic after weekly alert? Can you tell me about all the sources of information you use to study for your exam?

Information filtering: Did your work load prevent you from using the app or reading after a weekly alert? Did you find any misinformation or out of date information that prevented you for using this app of reading the specific clinical topic after weekly alert?

Would you like to add any other comment or suggestion that could be relevant to the goal of our study?

## 9.4 Appendix 4. Codebook

| Codes | Definition |
|---|---|
| User/Facilitators | User-related factors that facilitated reading after weekly alerts and persistence in the SE |
| Use/Barriers | User-related issues that made reading after weekly alerts or user persistence in SE impossible, difficult or problematic |
| Service/Facilitators | Description of positive experience or outcome related to service quality, as quality of support and service delivered by the mobile application provider. |
| Service/Barriers | Service-related issues, as quality of support and service delivered by the mobile application provider, that made the reading after weekly alerts impossible, difficult or problematic |
| Service/Strategies for improvement | Description of the recommended strategies for the service quality improvement from user perspective |
| Platform/Facilitators | Mobile platform-related factors that facilitated reading after weekly or persistence in the SE |
| Platform/Barriers | Mobile platform issues that made the reading after weekly alerts or user persistence in SE impossible, difficult or problematic |
| Platform/Strategies for improvement | Description of the recommended strategies for the platform improvement from user perspective |
| Alert system/Facilitators | Comments about alert system-related factors that facilitated reading after weekly alerts or user persistence in the SE |
| Alert system/Barriers | Alert system-related issues that made reading after weekly alerts or user persistence in SE impossible, difficult or problematic. |
| Alert system/Strategies for improvement | Description of the recommended strategies for the alert system improvement from user perspective |
| Information/Facilitators | Mobile platform content-related factors that facilitated reading compliance after each weekly alert or user persistence in the SE |
| Information/Barriers | Mobile platform content-related issues that made reading after weekly alerts or user persistence in SE impossible, difficult or problematic |
| Information/Strategies for improvement | Description of the recommended strategies for the mobile app-content improvement from user perspective |

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