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Using spaced education to deliver clinical information to medical residents: A mixed methods pilot study

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ABSTRACT

Spaced education (SE) is a learning strategy that can improve long-term knowledge retention. Inspired by the concept of SE, we conducted a mixed methods study of a smartphone application (app) as a platform of SE. Objectives were to: (phase 1 quantitative) estimate the extent to which weekly alerts on the app can stimulate medical residents to visit the app, (connection of phases) identify participants for a second qualitative phase, and (phase 2 qualitative) describe factors, from the resident perspective, which influence sustainable participation in SE, and describe strategies for improvement of the app. Method- ology and methods: phase-1 design was pre-experimental, phase-2 design was qualitative descriptive (deductive-inductive thematic analysis). Results: We observed a stimulating effect of weekly alerts for the first two months of the one-year study. Per participant, alert visits varied from 0 to 34 (mean = 1.7, SD = 4.5) and total page visits varied from 1 to 442 (mean = 28.3, SD = 61.4). Barriers and facilitators to sustainable participation in SE fell into five dimensions: user-related factors, information content factors, mobile app design factors, alert system factors, and service factors. Four strategies for app improvement were described. In conclusion, we propose five dimensions pertaining to potential predictors of sustainable participation in SE to deliver clinical information.

Keywords: Education, medical, education, graduate medical, general practice, family medicine, mobile applications, spaced education

1. INTRODUCTION

Given the rapidly changing body of medical knowledge, it is difficult for medical students and residents to retain information and achieve long-term knowledge retention in the context of medical

education (Augustin, 2014; Custers, 2010; Greb et al., 2009). Consequently, educators continue to seek innovative ways to improve learning and knowledge retention. Spaced education (SE) means studying information across two or more sessions separated in time (i.e., spaced apart or distributed). SE has improved long-term knowledge retention in numerous educational studies ranging from learning a new language, to mathematical concepts, to surgical skills training, and in a wide range of subjects: young children, cognitively impaired adults, and physicians (Yeh & Park, 2015). SE has positive effects on long-term knowledge retention in highly focused residencies, such as urology (Kerfoot, 2009). However, SE has not yet been studied in the context of family medicine residency. The successful development and implementation of any new instructional technology for medical learning, is a very challenging process that requires early evaluation of users' educational needs (Pereira et al., 2000).

To help family medicine residents prepare for their examinations, the Information Technology Primary Care Research Group (ITPCRG) at McGill University created a smartphone application including the Information Assessment Method (hereafter referred to as the IAM app) (Grad et al., 2017). The IAM app used SE as a strategy to reinforce long-term knowledge retention (Carpenter et al., 2012). Using the IAM app, SE was mediated by weekly alerts to promote reading of a new Priority Topic. The IAM app contained clinical information on the Key Features of the 99 Priority Topics in Family Medicine as a general guide to prepare for the certification examination of the College of Family Physicians of Canada (CFPC) (Allen et al., 2011). The IAM app presented information at three levels or pages: Topics, Key Features, and Clinical Information. The first level (Topics) presented a list of 99 Priority Topics. The second level (Key Features) displayed a list of Key Features for each topic, as established by the CFPC. The third level (Clinical Information) provided additional clinical information about each Key Feature.

The overall objectives of this pilot study were to describe the participation of family medicine residents' in SE in terms of app use, explore the factors that influenced sustainable participation in SE mediated by weekly alerts through the app, and describe strategies for app improvement from the resident perspective. Sustainable participation in SE was defined as regular reading in the app, after weekly alerts. Given the potential conceptual transferability of the results across all disciplines (educational and informational contexts), this study is relevant for multiple stakeholders interested in improving long-term knowledge retention: curriculum developers, educators, mobile app designers (informational and educational apps), and information professionals.

2. METHODOLOGY AND METHODS

The intervention consisted of weekly alerts on the mobile app as a mediator of SE. The app sent an alert to introduce a Priority Topic of the week such as ‘abdominal pain’. Upon viewing 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 followed by answer feedback. Test questions were available for ten of the 99 Priority Topics given the pilot nature of this study. The study used a sequential explanatory mixed methods research design (Fig. 1). The quantitative data collected and analyzed in Phase I informed data collection and analysis in Phase II. Phase II findings contributed towards deepening/broadening our understanding of Phase-one results (Creswell & Plano Clark, 2011; Ivankova et al., 2006; Ivankova & Stick, 2007).

2.1. Phase I

A pre-experimental study without control group (Sackett & Mullen, 1993; Salkind, 2010) was conducted to describe app use among family medicine residents and to identify participants for the qualitative phase (residents following alerts most closely and least closely – Phase II). Participants were recruited in July 2015 from all incoming first year family medicine residents at McMaster University in Hamilton, ON, Canada.

2.1.1. Data collection

Consenting residents completed a brief demographic questionnaire and received an email with a username and password to download the app from a web page created for the study. Phase I participants downloaded the IAM mobile application and started to receive a weekly alert. All page visits were recorded at a central server providing information on usage patterns (user ID, username, topic name, date and time when each resident visited priority topics). Data collection lasted one year (until August 24, 2016).

2.1.2. Quantitative analysis

After 1 year, for each resident we calculated the number of Key Feature pages visited per month, the total number of Key Feature pages visited (or total page visits), the number of topics of the week visited within one week of the alert (or alert visits), and the number of alert visits per month. 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.

2.2. Phase II

We conducted a qualitative descriptive study (Sandelowski, 2000) in order to describe why the method of SE worked well for some residents, while it did not for others. This section is informed by criteria for reporting qualitative studies (COREQ) (Tong et al., 2007). We used two models to guide interviews, analyze qualitative data and interpret results: the ‘Information Systems Success Model’ and the ‘Model of Compelled Nonuse of Information’ (Delone & McLean, 2003; Houston, 2009). The former describes the relationships between main critical dimensions of a successful information system. However, this model only reflects the information system dimensions and not user-related factors, thus does not encompass all potential barriers and facilitators of interest in this study. To address this issue, we combined it with the latter, which includes physical and psychological barriers.

2.2.1. Participants

The selection of participants for this phase was informed by Phase-one findings (residents following alerts most closely vs. least closely), thus connecting quantitative and qualitative phases (Creswell et al., 2003; Morgan, 1998; Tashakkori & Teddlie, 1998). Potential interviewees were purposefully selected as key informants based on their persistence in SE mediated by weekly alerts (i.e., high and low persistence). For each participant, consent was obtained, and an alias was used to protect confidentiality (Kaiser, 2009).

2.2.2. Qualitative data collection

The interview protocol was developed based on phase-one individual usage patterns (participants’ total page visits and alert visits with time and date stamp). Qualitative data were collected through individual semi-structured phone interviews using an interview guide (Whiting, 2008). Other questions emerged from the conversation. Interviews took place from January to April 2017 and lasted from 30 to 60 minutes. Participants were interviewed about their experience with the IAM app, and features that facilitated or hindered sustainable participation in the SE program. The interviews were recorded and transcribed verbatim. Interview data collection and analysis were carried out simultaneously in order to reach qualitative data saturation (Sandelowski, 1995). We sent interview invitations for potential participants until qualitative data saturation was reached (no new ideas emerged during analysis of the last few interviews).

2.2.3. Qualitative data analysis

Interview transcripts were imported into NVivo 11 software for organizing, managing, and coding data in a more efficient manner. We carried out qualitative thematic analysis with a hybrid

approach of deductive and inductive coding and theme development (Fereday & Muir-Cochrane, 2006). For deductive coding, the codes came from the above-mentioned models. Using inductive coding allowed new codes to emerge progressively during data analysis. Coding manual and coding results were discussed with supervisor, co-supervisors and colleagues (research trainees) until consensus was reached.

3. RESULTS

3.1. Quantitative results

Of 96 first year family medicine residents, 81 (84%) consented to participate in the study and completed a demographic questionnaire. Of those, 65 (80%) used the app (data included in analysis). In year one, the total number of Key Feature pages each resident visited (total page visits) varied from 1 to 442 (mode = 2; median = 13; mean = 28.3). Examination of the boxplot revealed the longer tail from the right of the box plot, median shifted toward the 1st quartile and presence of few outliers (Fig. 2). Histogram analysis confirmed the right skewed distribution (mode = 2), high frequency of low number of total page visits, and outliers with high number of total page visits (Fig. 3). The total page visits were clustered between 1–43 pages.

The number of Key Feature pages visited by all residents was 1840 over the year. Participants used the IAM app most frequently during the first two months of the study, e.g., 421 visits in August 2015 (Fig. 4). The number of Key Feature pages gradually dropped to 63 in November 2015; then, the number of monthly page visits was in the range of 25 to 91 up to August 2016. After one year, 52 weekly alerts were sent on 57 topics, as five alerts announced two topics. Thus, alert visits per user could vary from 0 to 57. The number of topics of the week each resident visited within one week of the alert (alert visits) varied from zero to 34. For these who used IAM, the mean (SD) was 1.7 (4.5) alert visits (mode = 0; median = 1; mean = 1.7). The box plot analysis revealed the long right tail from the right of the box, no left tail, and presence of outliers (Fig. 5). The histogram analysis confirmed the right skewed distribution (Fig. 6). Most alert visits clustered between 0–6 topics.

During the first month of the study, all residents performed 18 alert visits (Fig. 7). A maximal peak of 34 alert visits was observed in September 2015. This number dropped to 12 in October, and gradually declined to December 2015. From December 2015 to the end of our data collection, the number fluctuated in the range of one to eight alert visits per month (Fig. 8).

3.2. Qualitative results

Thirteen residents participated in a semi-structured interview. Nine (69%) were females, nine

(69%) were 26–28 years old, and eight (61.5%) had an Android mobile device. Table 1 presents interviewees' usage patterns. The next three tables present themes, sub-themes and illustrative quotes from interviews.

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

Facilitators of residents' sustainable participation in SE were any factors that facilitated regular reading after weekly alerts (Table 2). These facilitators were organized into five dimensions (main themes): user, information content, mobile app design, alert system, and service. User-related factors were related to family medicine residents themselves. 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.

Theme 1.1. User-related factors

Interviewees mentioned facilitators that were specifically related to their personal wishes, motivations, and skills. Interviewees had a positive motivation to pass the licensure examination. This motivation stimulated them to explore different information resources and to use the IAM app as a potential learning tool for examination preparation. All interviewees were comfortable with information technology. Some interviewees mentioned that paper-based learning and e-learning complement each other. Thus, they felt the IAM app would be suitable for delivery of medical education. From interviewees' perspectives, information technology was a valuable alternative method of learning that might improve their education.

Theme 1.2. Information content factors

Interviewees mentioned positive aspects of the information content of the IAM app. Nine interviewees expressed satisfaction with the information content, which was useful for exam preparation (sub-theme 1.2.1). Two interviewees appreciated having reliable information content from an authority (the Key Features of the 99 Priority Topics recommended by the CFPC).

Theme 1.3. Easy-to-use mobile app

One of the most commonly reported facilitators was ease of use of the mobile app. Interviewees mentioned that the initial installation was easy, and the IAM app was easily accessed at any time on a

personal mobile phone. Interviewees mentioned how they can spend free time productively using the app and said that they enjoyed the concise information structure. From interviewees' perspectives, reading and assimilation of information (learning) was facilitated. Also, interviewees liked the topic tracking (at the first page of the IAM app they can identify the day when they last visited each topic). This facilitated the completion of all topics.

Theme 1.4. Alert system factors

Interviewees appreciated weekly alerts as these reminded them about the IAM app and encouraged them to read Priority Topics. Some interviewees said that alert timing on a weekday or academic teaching day was convenient. One interviewee mentioned that quizzes on the topic of the week were helpful because she was able to test her understanding of the topic. This interviewee had made the highest number of alert visits.

Theme 1.5. Prompt service on request

Several interviewees were satisfied with the technical support. They emphasized that technical staff provided sufficient support on request.

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

These barriers refer to the factors that negatively affect residents' persistence in SE mediated by weekly alerts (Table 3).

Theme 2.1. User-related barriers

Interviewees complained about the lack of time caused by a heavy workload. Several interviewees indicated that they were busy specifically at the moment of the weekly alerts. Also, interviewees experienced information overload. This resulted in an adaptive mechanism of information filtering; they chose to focus on clinical information deemed relevant to their current clinical rotation to reduce cognitive overload. As a result, interviewees had their own learning pattern that didn't always fit with the schedule of weekly alerts. Several interviewees mentioned alert fatigue, and some deleted alerts without reading them. In three interviews, interviewees mentioned individual preference for other learning tools such as printed textbooks. Interviewees following alerts least closely had mobile device technical issues. Some switched to a new phone, and experienced difficulties with reinstallation of the app and insufficient technical support. For other interviewees, insufficient memory space on their

personal mobile device was a reason to delete and not reinstall the IAM app.

Theme 2.2. Insufficient information content

Although many interviewees evaluated the information content of the IAM app as useful for examination preparation, the app on its own was insufficient as a study tool. They were concerned by how comprehensive the information was. It was one of the main reasons why interviewees decided to use other information resources and gradually abandoned the SE approach. After a period of using the IAM app, some interviewees noticed a lack of structured clinical information for everyday clinical practice. Also, interviewees perceived the information content of the IAM app as incomplete regarding specialized clinical rotations. For the interviewee who performed the highest number of alert visits, a lack of updated guidelines was a reason for switching to other information resources. One interviewee mentioned lack of information about CFPC exam objectives.

Theme 2.3. Pitfalls in the mobile app design

A number of interviewees indicated pitfalls in the mobile app structure. The IAM app was specifically designed for topic reading; it presented information at three levels in the following order: “Topics”, “Key Features”, and “Clinical Information” with hyperlinks to access information from external websites. Two interviewees stated that it was inconvenient to find specific information for everyday clinical practice. Also, there was lack of a comprehensive search function. Interviewees 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. Other technical/programming issues were non-functioning external links and chart visualization. Though the initial installation was successful, interviewees indicated that it was more difficult than an average app. As a result, re-installation of the app was not always successful.

Theme 2.4. Pitfalls in the alert system

There were a few pitfalls in the alert system that hindered regular reading after weekly alerts. Interviewees first received a weekly alert 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. Interviewees described this aspect of the alert system as not obvious to them; thus, the majority did not benefit from quizzes. Some interviewees indicated that alert timing was inconvenient as it did not fit with individual preferences and learning schedule, and simply ignored alerts. Commonly, interviewees reported that topics of the week were irrelevant in the context of resident’s learning schedule; they would like to read

topics that were relevant regarding their current clinical rotation. Two interviewees had technical problems in receiving weekly alerts, and forgot about the IAM app.

Theme 2.5. Insufficient support from the service provider

Several interviewees reported that the support from the service provider (i.e., the designers of the IAM app) was insufficient to facilitate their participation in SE (e.g., a delay in renewal of an iTunes certificate). As a result, the IAM app was not functional for about a week, and interviewees had to reinstall the app. Another resident who was not able to receive weekly alerts and reinstalled the IAM app on her new phone, did not receive technical support.

3.2.3. Strategies for IAM app improvement

Interviewees were asked to describe how the IAM app as a platform for SE should be improved (Table 4). We asked about strategies to overcome barriers to their sustainable participation in SE (reading compliance after alerts).

Theme 3.1. Provide relevant, comprehensive concise structured information content

Information content of the IAM app was a key driver of participation in SE. Interviewees recommended comprehensive information content linked with every day clinical practice (addressing all specific questions outlined by CFPC). For example, interviewees recommended adding information about updated clinical guidelines. Information content must be useful for exam purposes and in everyday clinical practice. From the interviewee perspective, it is also important to strike a balance between information content that is concise and too detailed. Another important element is information about CFPC exam objectives and how the IAM app addressed these objectives. In summary, interviewees 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.

Theme 3.2. Improve mobile app design

Interviewees recommended improving the IAM app design by presenting information at different levels. Particularly, improvement should reflect availability of SE mediated by alert system with topics of the week, quizzes and feedback. One interviewee suggested outlines presenting each topic according to clinical tasks such as clinical history, physical examination, differential diagnosis, and treatment. Also, interviewees preferred a comprehensive search function rather than searching by topic title. To facilitate

installation and re-installation of the IAM app, interviewees suggested the app become available on the App or Play Stores. Given the need to update and re-install, one interviewee recommended to implement automatic updating. One interviewee recommended implementing an audio version of each Priority Topic or podcasts. Interviewees following alerts least closely recommended a need to improve the visual appearance of the app. They would prefer to see all information about one topic on one page with folders that expand and collapse. Some interviewees recommended tracking usage activity, to allow the IAM app to remain on the same page where the user stopped reading. One interviewee who followed alerts least closely had a personal preference for textbooks and e-textbooks. She recommended using more tables, diagrams, graphics, pictures, different headers and colors. Another interviewee proposed using closer line spacing, smaller letters and an attractive logo for the app.

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

Interviewees had different preferences but a common desire to adjust alerts according to their needs, such as a possibility to set the individualized alert time and frequency, matching topics of weekly alerts with the teaching curriculum or clinical rotations, and possibility to set alternative alerts via email or google agenda. Alternative alerts were recommended by one resident, who suffered from alert fatigue. Other interviewees who showed signs of alert fatigue recommended sending an additional alert for incomplete topics of the week. Also, interviewees suggested to use quizzes as a primary driver of the alert system and to send quizzes unconditional to the response to the alerts. Quizzes should be topic-specific and the same format as in the licensure examination. Several interviewees recommended implementing an interactive gaming format into alert system. They suggested using the following elements in the interactive game: quizzes, competition with other users, communication/interaction with other interviewees, performance tracking, and incentives. One interviewee 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. Another interviewee recommended offering new features on the app or any external incentives after completion of certain amount of learning tasks. Continuing medical education credit banking also was mentioned as a potential incentive. One interviewee 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. Interviewees who followed alerts most closely had a common recommendation to send alerts about updated clinical guidelines. One interviewee 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.

Theme 3.4. Provide proactive support with outreach

Four interviewees emphasized that proactive support with outreach would contribute to interviewees' persistence in SE. From the interviewees' perspectives, creators of the IAM app should be more proactive in promoting the IAM app: organize encounters with interviewees, recruit chief residents, organize a technical support line, send emails etc. The same strategy may be effective for early identification of users' problems. Interviewees recommended doing a little presentation in order to explain how the alert system is functioning. Also, some interviewees mentioned that if there was a real advertisement, a lot more people would use the IAM app. One interviewee mentioned an incentive that was related to outreach. If users of the IAM app had better exam scores, then creators should promote this fact in order to encourage interviewees to use the app.

4. DISCUSSION

Results described the participation of family medicine residents' in SE in terms of app use, explored the factors that influenced sustainable participation in SE mediated by weekly alerts through the IAM app, and recommended strategies for app improvement from the resident perspective. In the quantitative Phase-one, we observed a stimulating effect of weekly alerts for the first two months of the one-year study. Then, the effect of alerts from the app was much smaller than anticipated. A stimulating effect of alerts was observed at the beginning of the study and was not sustained.

In the qualitative Phase-two, numerous barriers were identified and helped explain why weekly alerts did not have a sustainable effect on use of the IAM app by residents. The identified barriers included: user-related barriers, insufficient information content, pitfalls in mobile app design, pitfalls in the alert system, and insufficient support from the service provider. Interviewees reported individual user-related barriers and a group of barriers reflecting quality dimensions of the IAM app. Also, interviewees revealed factors that facilitated initial participation in SE during the first two months of the study, which include: 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, interviewees who followed the alerts less closely complained about insufficient information content, insufficient support from the service provider, information filtering, and time constraints due to heavy workload. The main contribution of this work lies in the five dimensions of barriers and facilitators to resident participation in SE mediated

by weekly alerts: user-related factors, information content factors, mobile app design factors, alert system factors, and service factors (Fig. 9 and Table 5). Not surprisingly, strategies proposed by interviewees for improving the app address the last four dimensions in accordance with basic quality dimensions of our combined conceptual models. 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 resident's experience of service factors. Our quantitative and qualitative results support the combined models, in that quality dimensions consequently influence system use, user satisfaction, and net benefits of the information system. The quantitative results showed insufficient participation in SE and a low response to the weekly alert. Qualitatively, interviewees reported barriers at all four quality dimensions that had a negative effect on participation in SE mediated by a weekly alert. While a better understanding of user-related factors may be essential in the successful development and implementation of SE, interviewees pointed to other factors (information content factors, mobile app design factors, alert system factors, and service factors). Further discussion of results in line with residents' recommendations and previous literature on SE is presented in Fig. 10. 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 time constraints.

4.1. Strengths and limitations

The main strength of this study pertains to its innovative nature. To our knowledge, the IAM app is the first mobile application implementing SE in the context of family medicine residency training. Results can contribute to the successful development and implementation of future SE programs. Creators of novel educational 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 assessment. Another strength of the study is the two-phase mixed methods research design, with the qualitative Phase-two explaining the quantitative Phase-one results (the use of alerts from the IAM app being lower than expected).

However, this study faced at least three limitations. First, the IAM app was disabled for about one week, which is substantial in a one-year study; then, residents had to reinstall the app to continue SE, and interviewees indicated that it was a reason for drop-out. Second, we used a pre-experimental design for quantitative Phase I, which has threats to validity (absence of a control group and randomization) (Sackett & Mullen, 1993; Salkind, 2010). Third, the qualitative Phase II did not allow us to estimate the relative importance of perceived barriers and facilitators.

4.2. Future research and recommendation for practice

Results will facilitate the implementation of optimal SE in residency training. They inform the next phase of the IAM app project. We will test the new version of the IAM app and measure the effectiveness of SE using board examinations scores as the study outcome. In terms of practical application, results of this study are interesting for numerous stakeholders including curriculum developers, educators, mobile app designers (informational and educational apps), and information professionals (Fig. 10).

5. CONCLUSION

This pilot study tested SE within a mobile app, assessing the feasibility of delivering a weekly alert to residents in Family Medicine. Despite some pitfalls, most residents liked the idea of push notification and considered the IAM app as easy-to-use. They recommended to (1) provide relevant, comprehensive concise structured information; (2) improve mobile app design; (3) improve the alert system according to learning needs with an interactive gaming format; and (4) provide proactive support with outreach. These results contribute to the design of an innovative intervention involving an improved app to deliver SE to residents. A version of this new app, called the Family Medicine Study Guide, is presently being tested in a cluster randomized controlled trial in Canada.

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REFERENCES

- Allen, T., Brailovsky, C., Rainsberry, P., Lawrence, K., Crichton, T., Carpentier, M.P., & Visser, S. (2011). Defining competency-based evaluation objectives in family medicine: dimensions of competence and priority topics for assessment. *Canadian Family Physician*, 57(9), e331-340.
- Augustin, M. (2014). How to learn effectively in medical school: test yourself, learn actively, and repeat in intervals. *Yale Journal of Biology and Medicine*, 87(2), 207-212.

- Blazek, M.C., Dantz, B., Wright, M.C., & Fiedorowicz, J.G. (2016). Spaced learning using emails to integrate psychiatry into general medical curriculum: keep psychiatry in mind. *Med Teach*, 38(10), 1049-1055. doi: 10.3109/0142159x.2016.1150982.
- Carpenter, S.K., Cepeda, N.J., Rohrer, D., Kang, S.H.K., & Pashler, H. (2012). Using spacing to enhance diverse forms of learning: review of recent research and implications for instruction. *Educational Psychology Review*, 24(3), 369-378. doi: 10.1007/s10648-012-9205-z.
- Creswell, J., Plano Clark, V., Gutmann, M., & E Hanson, W. (2003). Advanced mixed methods research designs. In Tashakkori, A., & Teddlie, C., (Eds.), *Handbook on Mixed Methods in the Behavioral and Social Sciences*, pp. 209-240. Thousand Oaks, CA: Sage.
- Creswell, J.W., & Plano Clark, V.L. (2011). *Designing and conducting mixed methods research*. Los Angeles: SAGE Publications.
- Custers, E. (2010). Long-term retention of basic science knowledge: a review study. *Adv Health Sci Educ Theory Pract*, 15(1), 109-128. doi: 10.1007/s10459-008-9101-y.
- Delone, W.H., & McLean, E.R. (2003). The delone and mclean model of information systems success: a ten-year update. *Journal of Management Information Systems*, 19(4), 9-30.
- Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: a hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods International Journal of Qualitative Methods*, 5(1), 80-92.
- Grad, R., Pluye, P., Wong, E., Brailovsky, C., Moscovici, J.L., Kaczorowski, J., Rodriguez, C., Luconi, F., Rousseau, M., Karanofsky, M., Delleman, B., Kegel, S., Mercuri, M., Kluchnyk, M., & Schabert, I. (2017). Do Weekly Alerts From a Mobile Application Influence Reading During Residency? 1. doi: 10.22454/PRiMER.2017.243866.
- Greb, A.E., Brennan, S., McParlane, L., Page, R., & Bridge, P.D. (2009). Retention of medical genetics knowledge and skills by medical students. *Genetics in Medicine*, 11(5), 365-370. doi: 10.1097/GIM. 0b013e31819c6b2d.
- Houston, R.D. (2009). *A model of compelled nonuse of information*. (Doctoral dissertation), The University of Texas at Austin, Austin, TX. Retrieved from <http://hdl.handle.net/2152/6896>.
- Ivankova, N., Creswell, J., & Stick, S. (2006). Using mixed-methods sequential explanatory design: from theory to practice. *Field Methods*, 18(1), 3-20.
- Ivankova, N.V., & Stick, S.L. (2007). Students' persistence in a distributed doctoral program in educational leadership in higher education: a mixed methods study. *Research in Higher Education: Journal of the Association for Institutional Research*, 48(1), 93-135.
- Janssen, A., Shaw, T., Bradbury, L., Moujaber, T., Norrelykke, A.M., Zerillo, J.A., LaCasce, A., Co,

- J.P., Robinson, T., Starr, A., & Harnett, P. (2016). A mixed methods approach to developing and evaluating oncology trainee education around minimization of adverse events and improved patient quality and safety. *BMC Med Educ*, 16, 91. doi: 10.1186/s12909-016-0609-1.
- Jham, B.C., Duraes, G.V., Strassler, H.E., & Sensi, L.G. (2008). Joining the podcast revolution. *J Dent Educ*, 72(3), 278-281.
- Kaiser, K. (2009). Protecting respondent confidentiality in qualitative research. *Qualitative Health Research*, 19(11), 1632-1641. doi: 10.1177/1049732309350879.
- Kane-Gill, S.L., O'Connor, M.F., Rothschild, J.M., Selby, N.M., McLean, B., Bonafide, C.P., Cvach, M.M., Hu, X., Konkani, A., Pelter, M.M., & Winters, B.D. (2017). Technologic distractions (Part 1): summary of approaches to manage alert quantity with intent to reduce alert fatigue and suggestions for alert fatigue metrics. *Crit Care Med*, 45(9), 1481-1488. doi: 10.1097/ccm.0000000000002580.
- Kerfoot, B.P. (2009). Learning benefits of on-line spaced education persist for 2 years. *Journal of Urology*, 181(6), 2671-2673. doi: 10.1016/j.juro.2009.02.024.
- Morgan, D.L. (1998). Practical strategies for combining qualitative and quantitative methods: applications to health research. *Qualitative Health Research*, 8(3), 362-376. doi: 10.1177/104973239800800307.
- Pereira, J., Peden, J., & Campbell, K. (2000). Instructional technology in medical education: lessons learnt. *J Telemed Telecare*, 6(Suppl 2), S56-58.
- Ramos, D. (2015). Usability Assessment of a Mobile Application: Experience and Effects among Family Medicine Residents. (Master of Arts Master's thesis), McGill, Montreal. Retrieved from http://digitool.Library.McGill.CA:80/R/-?func=dbin-jump-full&object_id=135696&silo_library=GEN01 Available from McGill eScholarship@McGill database. (135696)
- Robinson, T., Janssen, A., Kirk, J., DeFazio, A., Goodwin, A., Tucker, K., & Shaw, T. (2017). New approaches to continuing medical education: a QStream (spaced education) program for research translation in ovarian cancer. *J Cancer Educ*, 32(3), 476-482. doi: 10.1007/s13187-015-0944-7.
- Sackett, P.R., & Mullen, E.J. (1993). Beyond formal experimental design: towards an expanded view of the training evaluation process. *PEPS Personnel Psychology*, 46(3), 613-627. doi: 10.1111/j.1744- 6570.1993.tb00887.x.
- Salkind, N.J. (2010). Encyclopedia of research design.
- Sandelowski, M. (1995). Sample size in qualitative research. *Research in Nursing & Health*, 18(2),

179- 183.

- Sandelowski, M. (2000). Whatever happened to qualitative description? *Research in Nursing and Health*, 23(4), 334-340.
- Shaw, T.J., Pernar, L.I., Peyre, S.E., Helfrick, J.F., Vogelgesang, K.R., Graydon-Baker, E., Chretien, Y., Brown, E.J., Nicholson, J.C., Heit, J.J., Co, J.P., & Gandhi, T. (2012). Impact of online education on intern behaviour around joint commission national patient safety goals: a randomised trial. *BMJ Qual Saf*, 21(10), 819-825. doi: 10.1136/bmjqs-2011-000702.
- Tashakkori, A., & Teddlie, C. (1998). *Mixed methodology: combining qualitative and quantitative approaches*. Thousand Oaks, Calif.: Sage.
- Tong, A., Sainsbury, P., & Craig, J. (2007). Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care: Journal of the International Society for Quality in Health Care*, 19(6), 349-357.
- Whiting, L.S. (2008). Semi-structured interviews: guidance for novice researchers. *Nursing Standard (Royal College of Nursing (Great Britain): 1987)*, 22(23), 13-19.
- Yeh, D.D., & Park, Y.S. (2015). Improving learning efficiency of factual knowledge in medical education. *Journal of Surgical Education*, 72(5), 882-889. doi: 10.1016/j.jsurg.2015.03.012.

TABLES AND FIGURES

Table 1 Phase 2: interviewees' extent of app use

Interviewee (alias)	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

Table 2 Facilitators of residents’ sustainable participation in SE mediated by weekly alerts on a mobile application

Themes	Sub-themes and quotes
Theme 1.1. User-related factors	Sub-theme 1.1.1. Positive motivation to pass the examination “Well, I want to pass my exam, so I will gather any materials to do it well.”-Bob Sub-theme 1.1.2. Comfort with information technology “So, if I’m just looking on app or accessing something on the computer, it helps.”-Dalila
Theme 1.2 Information content factors	Sub-theme 1.2.1 Information useful for examination preparation “I liked the 99 topics that rather will be on the exam.”-Lia Sub-theme 1.2.2. Reliable information from an authority “I like that they used the Key Features that were directly from the college.”-Julia
Theme 1.3. Easy-to-use Mobile app	Sub-theme 1.3.1. Easy initial installation “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.”-Lia Sub-theme 1.3.2. Easy accessible learning tool “You can access the information anytime. . . I also find myself using the app when I was sitting ever in a waiting room or in the airport.”-Julia Sub-theme 1.3.3. Concise information structure of the IAM app platform “I really like the way you put it together, concise and then you have a link to specific page. It’s not like million different things.”-David Sub-theme 1.3.4. Topic tracking “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
Theme 1.4. Alert system factors	“I liked the reminders that popped up with the specific Priority Topic [. . .] without the reminder I probably wouldn’t even go into the app.”-Anna Sub-theme 1.4.1. Convenient alert timing on weekdays or days of academic teaching “Pop up on the Wednesday that was good because that’s an academic day”-Anna Sub-theme 1.4.2. Availability of quizzes related to topics of the week “I did like that it has questions, so you could test your knowledge after reading the topic.”-Lisa Theme 1.5. Prompt service on request

“I frequently got a response back right away from one of your study support staff.”-
Julia

Table 3 Barriers of residents' sustainable participation in SE mediated by weekly alerts on a mobile application

Themes	Sub-themes and quotes
Theme 2.1. User-related barriers	Sub-theme 2.1.1. Lack of time from workload "I was busy with work and it kept giving me the alert. I was feeling guilty because I am not studying."-David Sub-theme 2.1.2. Information filtering "When I'm on obstetrics, I'm learning obstetrics, when I'm in emergency I'm thinking about that. I found that there was too much information and I needed to start targeting my studying."-Lia Sub-theme 2.1.3. Alert fatigue "If there are too many notifications on the phone, I just cleared it, and then I just forgot it."-Anna Sub-theme 2.1.4. Individual preference for other learning tools "I do not like that it's always on my phone. I would prefer to use my laptop."-Sandra 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 "I got a new phone and I emailed to see if I can download the App on my new phone, but 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 "I did not have enough space on my device and I completely deleted it [IAM app]."-Eva
Theme 2.2. Insufficient information content	"I was very concerned by how comprehensive the information was for each topic."-Lara Sub-theme 2.2.1. Lack of structured clinical information for every day practice. "I want to read up information for a patient that I see in my clinic."-David Sub-theme 2.2.2. Clinical information was incomplete regarding specialized clinical rotations. "The information we need in the rotation is a lot more specific and in more detail."-Lia Sub-theme 2.2.3. Lack of updated clinical guidelines. "In second year, I noticed that there were new guidelines that were not offered by the app."-Lisa Sub-theme 2.2.4. Lack of information about CFPC exam objectives

	“I didn’t know what I should expect from the CPFC exam. I didn’t understand the role of Key Features and how I would need to study them.”-Julia
Theme 2.3.	Sub-theme 2.3.1. Pitfall in mobile app structure
Pitfalls in the mobile app design	“It’s a little bit hard. You need to click through different things and you are not absolutely sure where you can find the information. For day to day practice it’s not that I would use.”-Tommy Sub-theme 2.3.2. Technical/programming issues “When I minimize the app, it won’t stay in the subject. It will kick me out to the main menu.”-Bob Sub-theme 2.3.3. Installation was more difficult than an average app “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. You have to go to your setting and authorize because it’s untrusted program.”-David
Theme 2.4.	Sub-theme 2.4.1. Unobvious functioning of the alert system
Pitfalls in alert system	“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.”-Tommy Sub-theme 2.4.2. Inconvenient alert timing “It was mainly schedule related. It [alert] generally popped up during a round presentation. If I was in clinic, it discouraged certainly.”-Julia Sub-theme 2.4.3. Topic of the week was irrelevant in the context of resident’s learning schedule “If I was on pediatrics or internal medicine then I would rather use my time to learn about internal medicine or pediatrics.”-David Sub-theme 2.4.4. Technical problems of receiving weekly alerts “I didn’t have the weekly reminders. I forgot that the app was there.”-Sara
Theme 2.5.	
Insufficient support from the service provider	“I wasn’t getting the notifications. I think I had email to figure it out. I didn’t get any reply.”-Sara

Table 4 Strategies for IAM app improvement

Themes	Sub-themes and quotes
Theme 3.1. Provide relevant, comprehensive concise structured information	Sub-theme 3.1.1. Comprehensive information content linked with every day clinical practice “I would like to use the app that not only helps with exam purposes, but also with clinical use.”-Sara Sub-theme 3.1.2. Balance between concise and complete “I think it has to be a balance between being too concise versus too detailed because if I’m studying for the exam I want to make sure I’m learning everything I need to know.”-Eva Sub-theme 3.1.3. Introduce CFPC exam objectives “Slides on how the exam is structured and how this app is in accordance with those objectives.”-Julia
Theme 3.2. Improve mobile app design	Sub-theme 3.2.1. Use intuitive mobile app structure Sub-theme 3.2.1.1. Mobile app structure reflecting app functions “If for example there is a little menu that says: 99 topics, feedback then immediately I’ll get the idea of the app and that there are different things that I can do. That’s bit more intuitive.”-Tommy Sub-theme 3.2.1.2. Information content structure useful for every day clinical practice “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.”-Tommy Sub-theme 3.2.2. Implement comprehensive search function “I wouldn’t search for abdominal pain [topic title], but I would search for example for blood pressure targets.”-Tommy Sub-theme 3.2.3. Do installation via App or Play Store “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 “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 podcast

“Put in the audio version. So, when you are driving you could be learning as well.”-

Lara

Sub-theme 3.2.6. Improve visual appearance

Sub-theme 3.2.6.1. One-page-topic

“My preference is to see everything on one page and scroll through it.”-Tommy

Sub-theme 3.2.6.2. Tracking usage activity

“I just want the screen to stay on the same page.”-Sandra

Sub-theme 3.2.6.3. Attractive visual objects

“If there were more diagrams, clinical pictures, different headers and colors and visualizations.”-Eva

Theme 3.3

Improve the

alert system

according to

users’ learning

needs, with the

interactive

gaming format

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

Sub-theme 3.3.1.1. Individualized alert timing and frequency

“Some people may want more frequent alerts or may want less. If you could change it, I’ll feel less pressure.”-Eva

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

“May be if you could categorize topics. If I’m going to my obstetric rotation, I would read about obstetrical care.”-Eva

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

“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

“So, having another reminder sometime midweek or at the time of the weekend, if I hadn’t done it that week.”-Anna

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

“I think they need to send the questions to everybody not just the person who read the topic.”-Bob

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

Sub-theme 3.3.4.1. Quizzes

“I would like to have a more interactive app, like a game with quizzes at the end.”-Eva

Sub-theme 3.3.4.2. Competition with other users

“. . . and you can compare scores, and get high scores.”-Eva

Sub-theme 3.3.4.3 Communication/interaction with other residents

“If people can make comments and suggestions. The interaction with your friends and make it more like a game.”-Eva

Sub-theme 3.3.4.4. Performance tracking

“If the app telling me that I read 1% of it. It could encourage me to go back and finish it.”-Eva

Sub-theme 3.3.4.5. Incentives

“Incentives for completing a certain amount of reading, motivate by external incentives.”-Lara

Sub-theme 3.3.5. Send alerts about updated clinical guidelines

“If an alert was about updated information, new guidelines, I would review it, most definitely.”-Bob

Theme 3.4.
Provide
proactive
support with
outreach

“If they had a real advertisement, a lot more people would have used it. You know if it was mentioned on academic half day.”-Dalila

Table 5 The five dimensions in line with the literature

Dimensions	Previous studies
User-related factors	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 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)
Information content factors	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 that 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).
Platform design factors	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). 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 from 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 et al., 2008).

Alert system factors

We 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). In the specialty of Oncology, junior doctors liked a system that prompted them to answer questions (Janssen et al., 2016). Moreover, an earlier usability study of the IAM app showed that interest in push notifications and technical issues leading to failure of push notifications impacted the use of the application (Ramos, 2015). Also, residents from this 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 learning strategy (Blazek et al., 2016; Ramos, 2015; Robinson et al., 2017). In other work, gamification with individual competition motivated participants to continue SE mediated by emails (Janssen et al., 2016; Shaw et al., 2012).

Service factors

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).

Fig. 1. Visual model for mixed methods sequential explanatory design procedures.

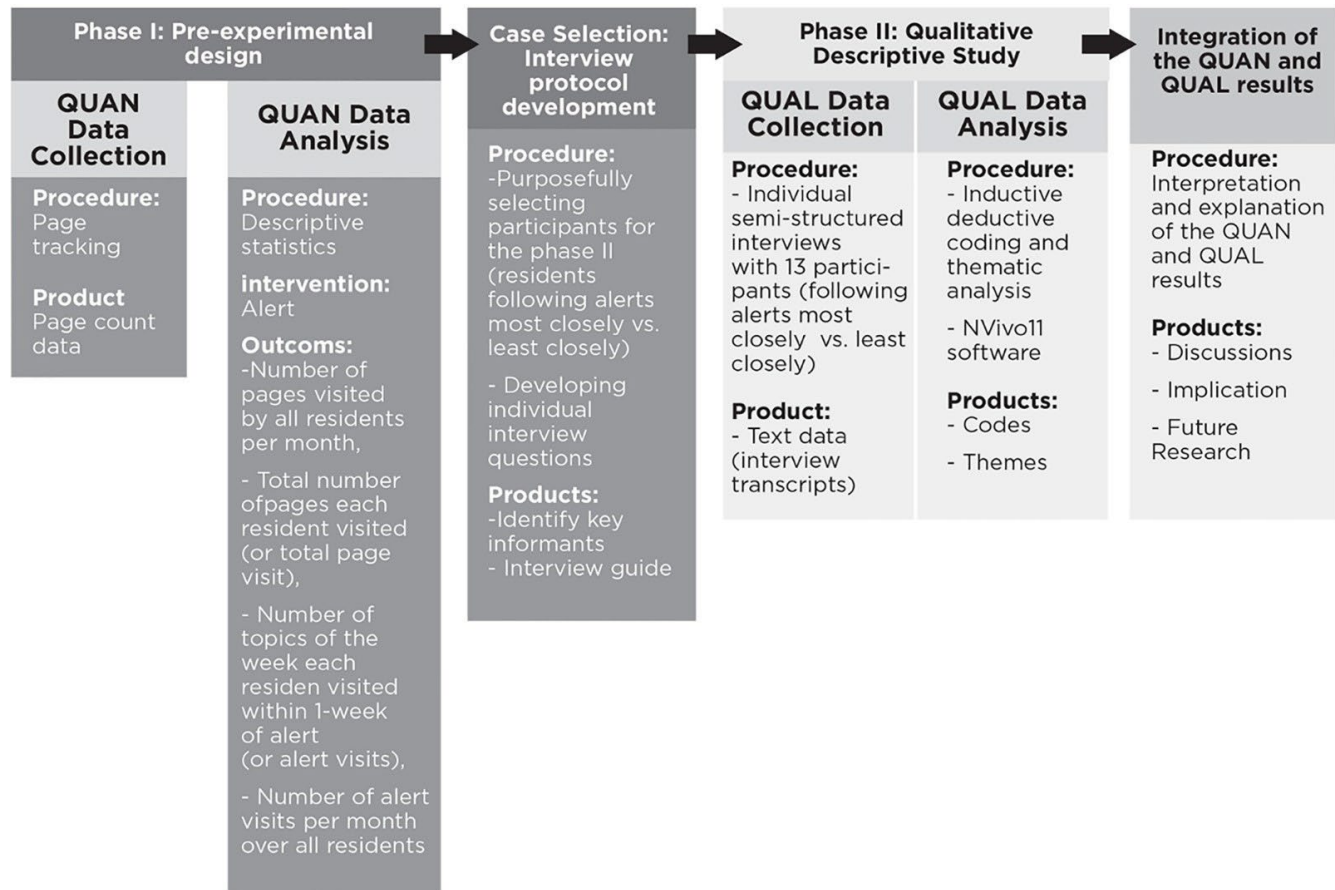


Fig. 2. Boxplot of the total number of pages each participant visited.

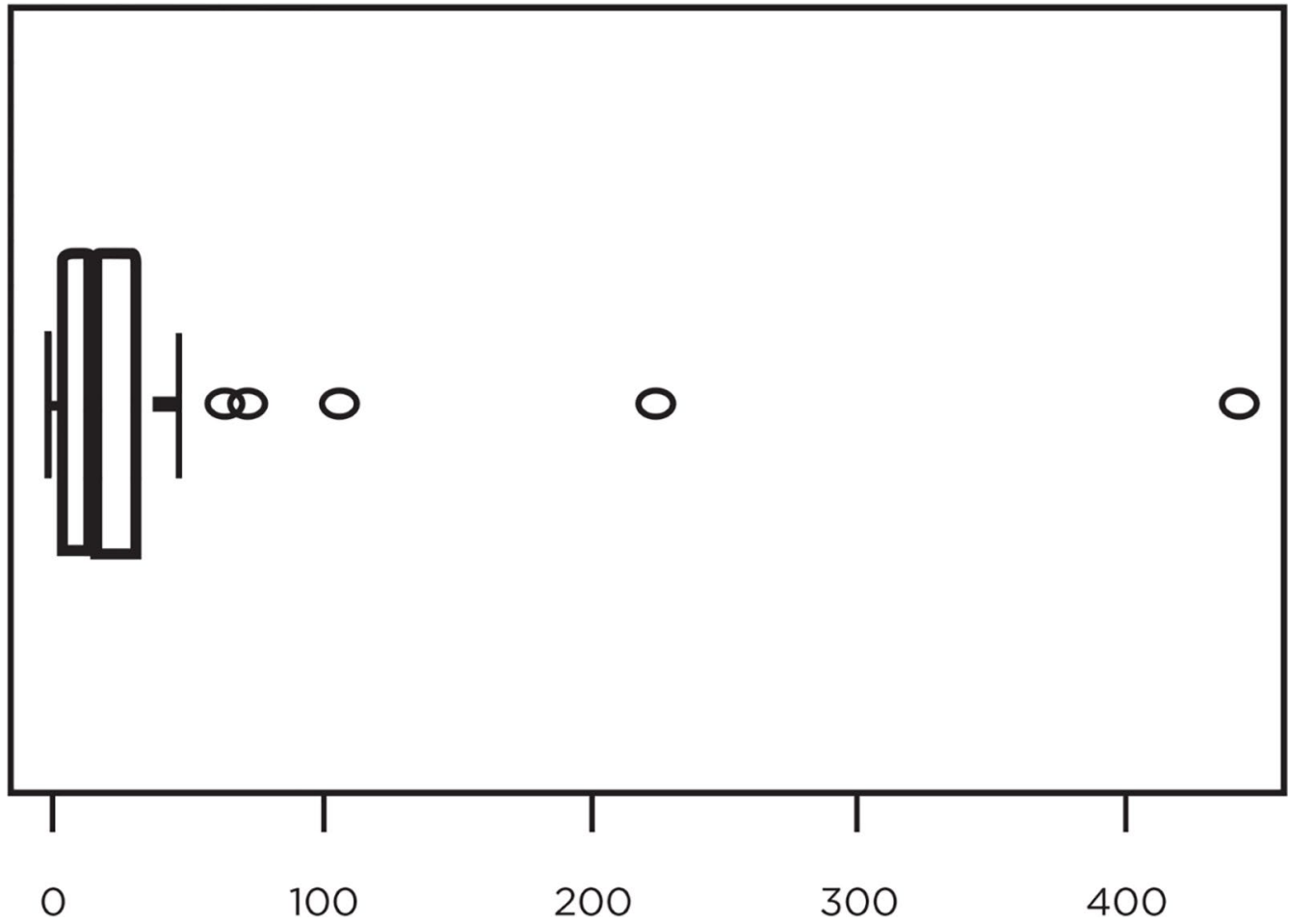


Fig. 3. Histogram of the total number of pages each participant visited.

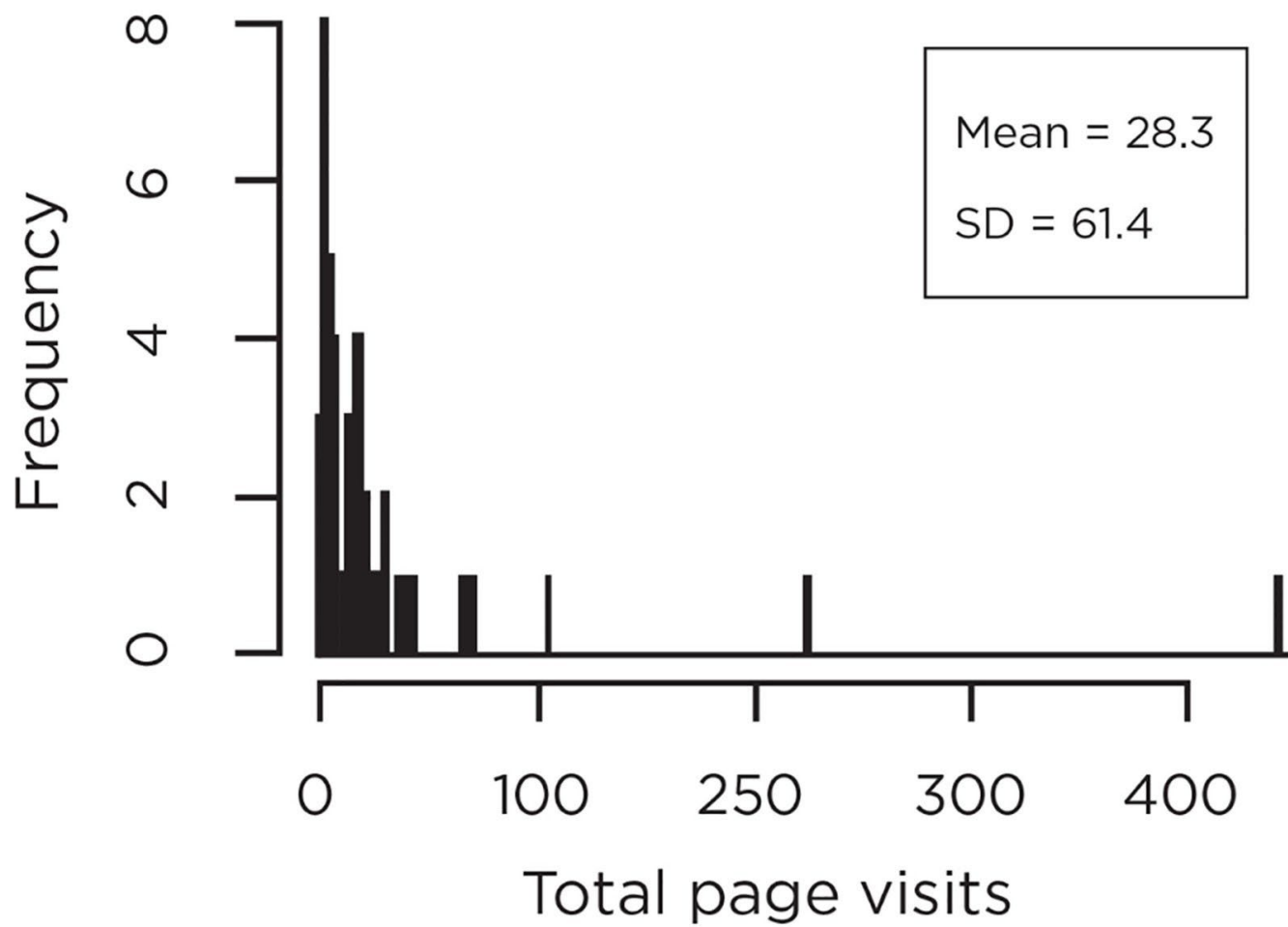


Fig. 4. Total pages visited by all residents (per month).

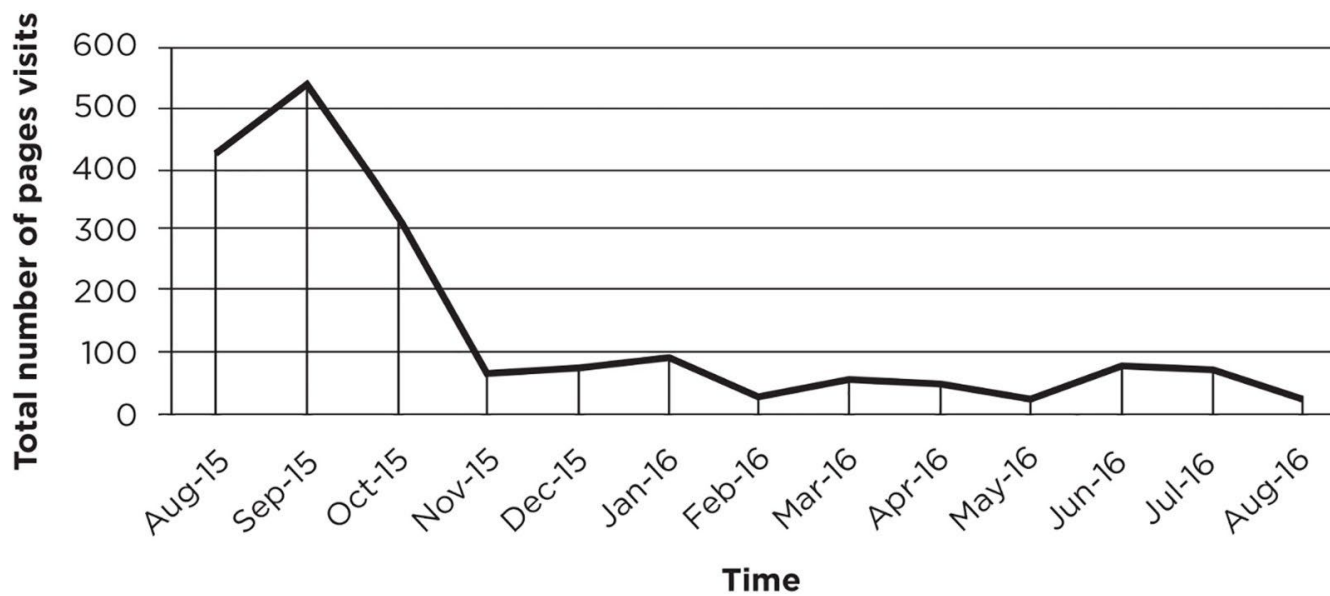


Fig. 5. Box plot of the number of topics of the week each resident visited within 1-week of the alert (or alert visits).

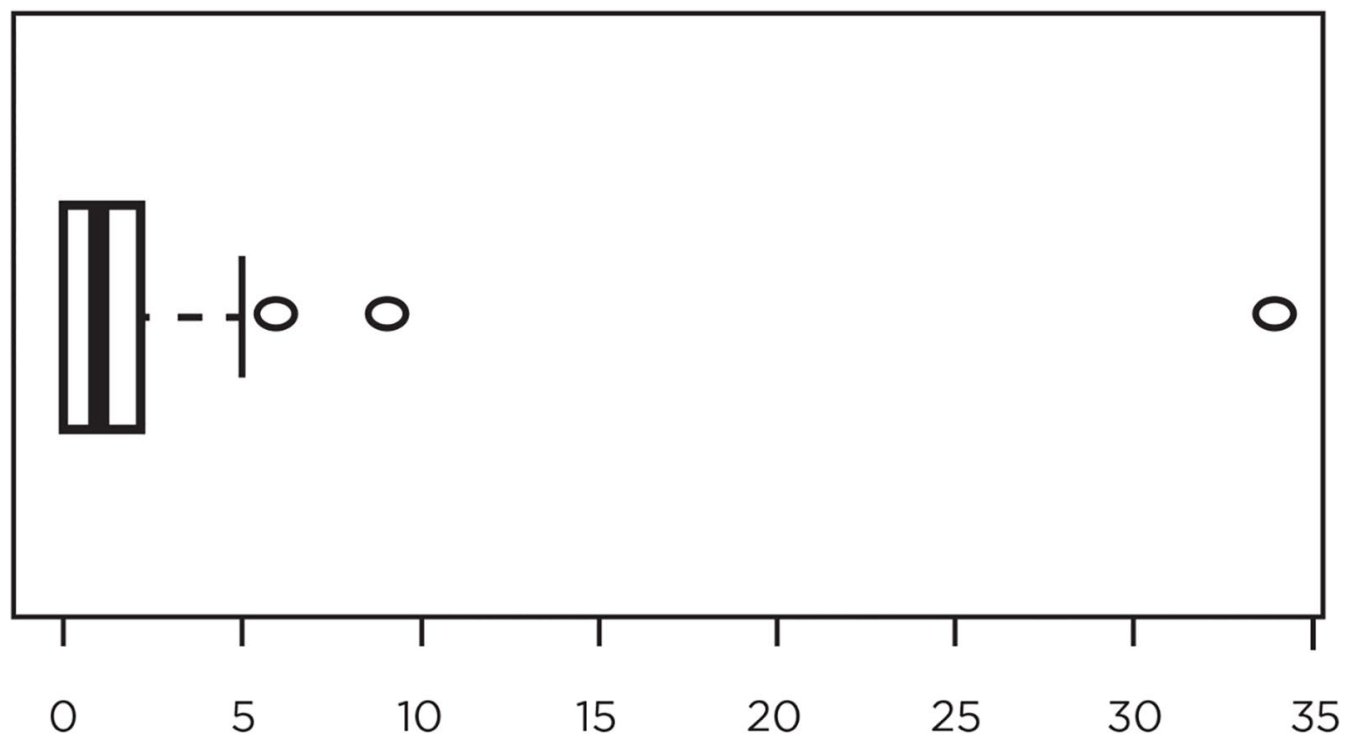


Fig. 6. Histogram the number of topics of the week each resident visited within 1-week of the alert (or alert visits).

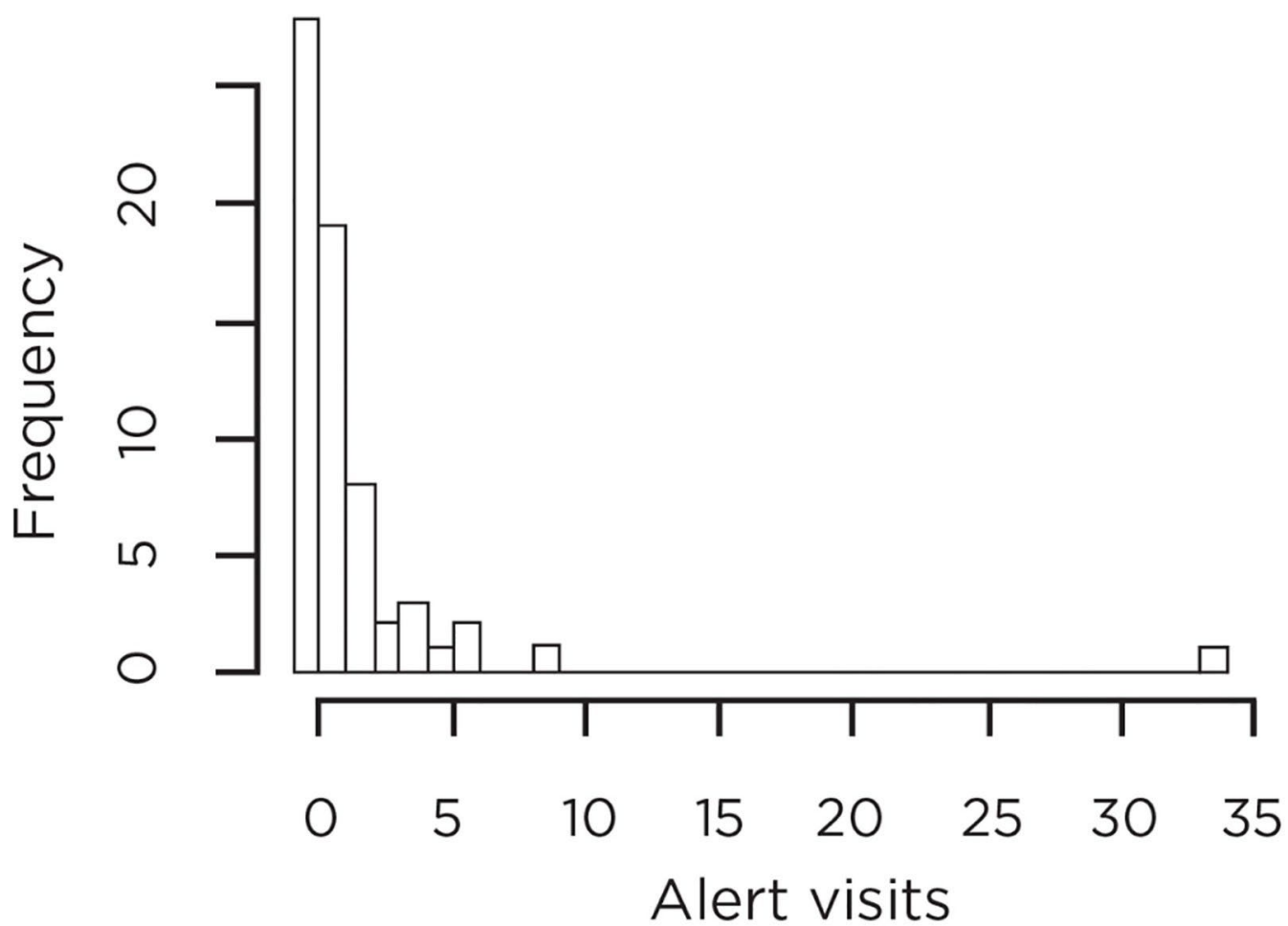


Fig. 7. Number of alert visits per month.

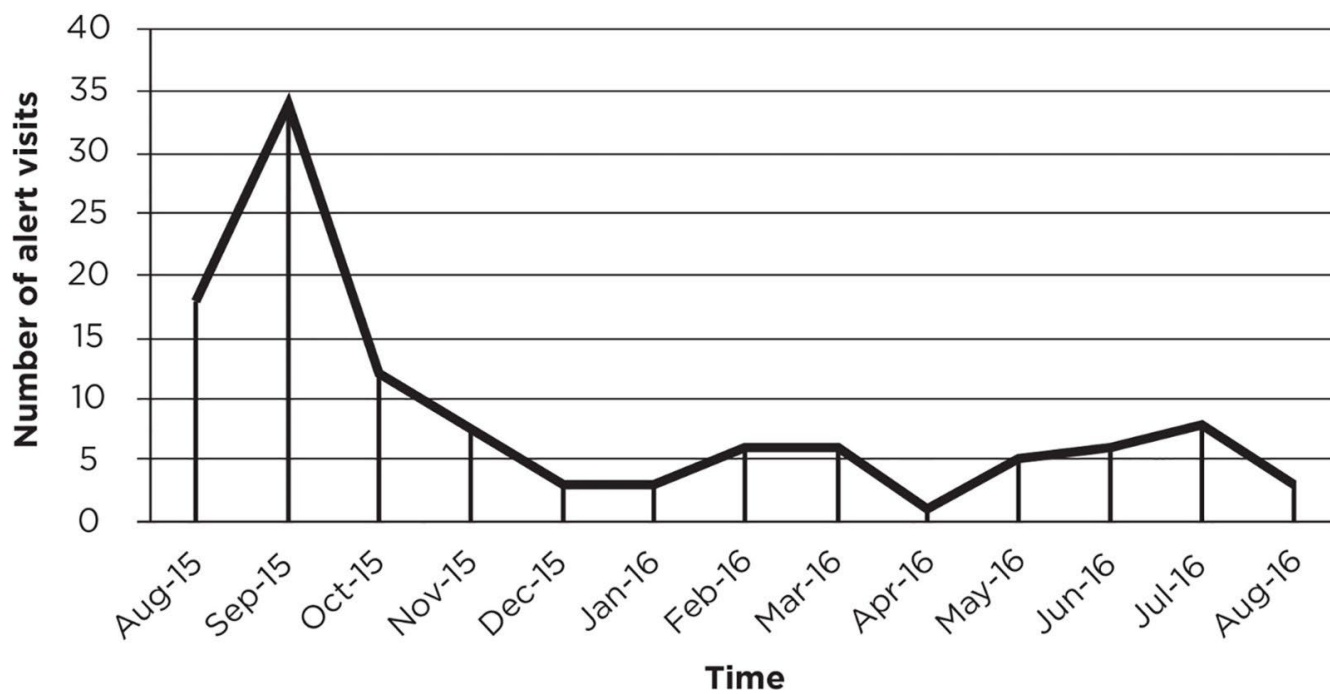


Fig. 8. Individual usage pattern of each resident during 1 year.

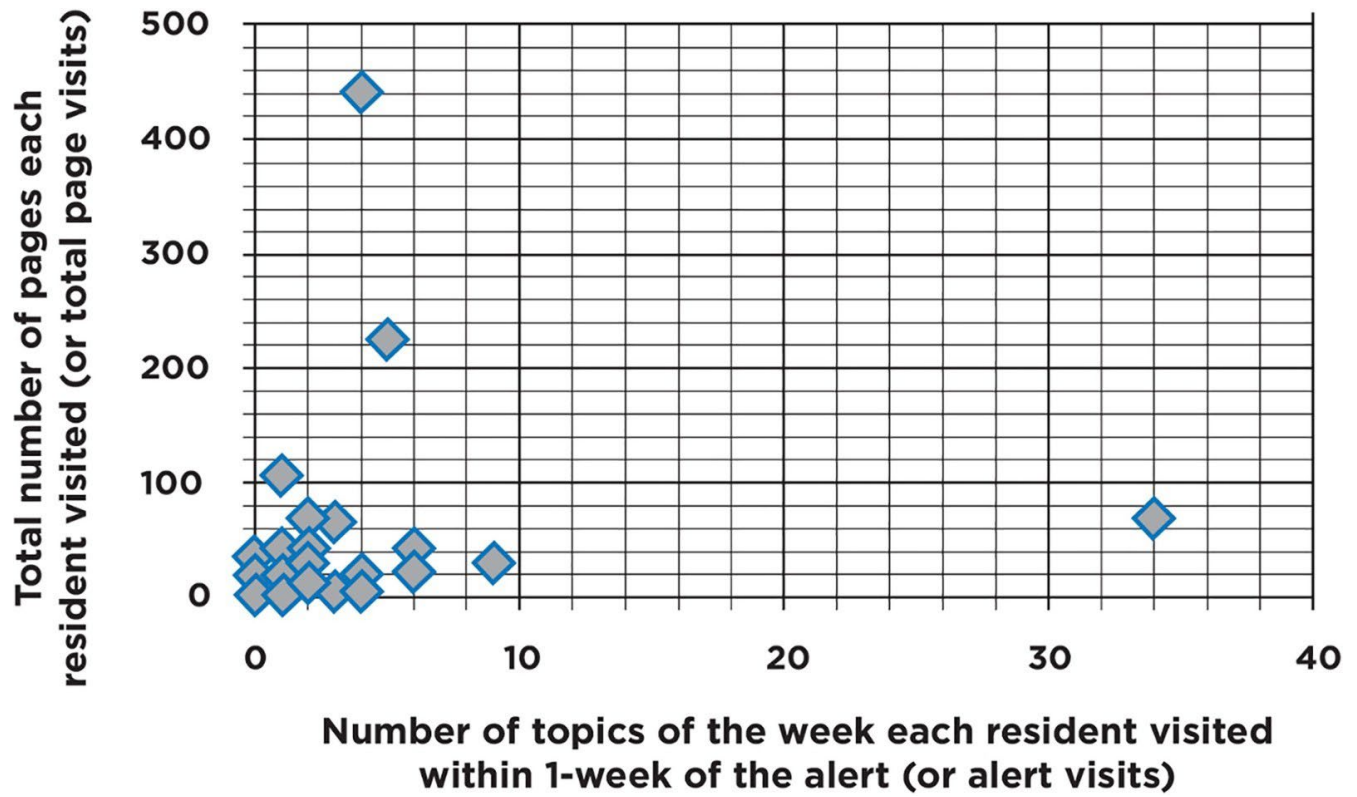


Fig. 9. SE success model.

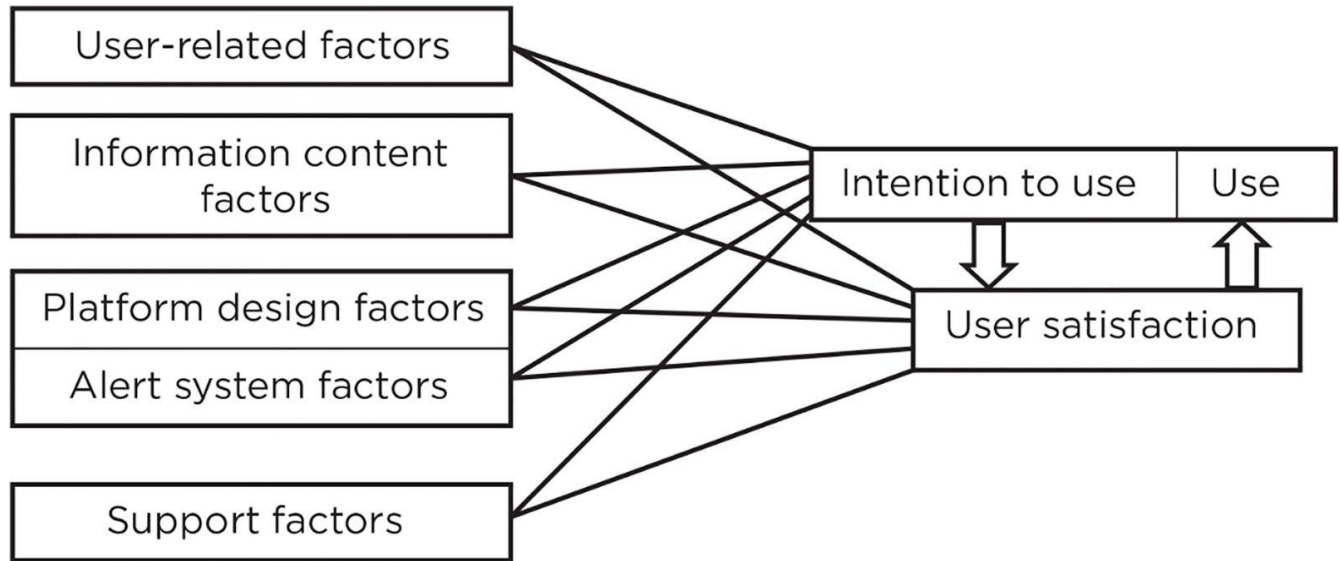


Fig. 10. Six practical recommendations.

- **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**