



PACARD: A New Interface to Increase Mobile Learning App Engagement, Distributed Through App Stores

Journal of Educational Computing

Research

0(0) 1–28

© The Author(s) 2018

Reprints and permissions:

sagepub.com/journalsPermissions.nav

DOI: 10.1177/0735633118756298

journals.sagepub.com/home/jec



Xuan Lam Pham¹ and Gwo Dong Chen²

Abstract

This study proposed to enhance mobile learning engagement with PACARD (Personalized Adaptive CARD-based interface) that combines several technologies including card-based interface, personalized adaptation, push notifications, and badges. To evaluate our proposal, we distributed a mobile learning application (app) called *English Practice* on the Google Play store, and 63,824 online users were recruited to join the experiment. Six metrics of app engagement (app retention, session length, session count, total time consumption, average duration per day, and uninstall rate) were logged and analyzed. Results are presented in three parts. First, PACARD increased the number of user sessions, duration of use, and retention of app. Second, investigating PACARD also provided detailed reports about users, including their habits and behaviors, thus providing greater understanding of PACARD use. Third, PACARD improved learning achievement. Because of the large number of participants, this study's findings are reliable and widely applicable. PACARD is easy to implement and tailor to most mobile devices and mobile learning apps on the market. Indeed, it benefits educators and mobile app developers as well as learners themselves.

¹Department of Computer Science, School of Information Technology in Economics, National Economics University, Hanoi, Vietnam

²Department of Computer Science and Information Engineering, National Central University, Zhongli, Taiwan

Corresponding Author:

Xuan Lam Pham, Department of Computer Science, School of Information Technology in Economics, National Economics University, No. 207 Giai Phong Road, Hai Ba Trung District, Hanoi, Vietnam.

Email: lampx@neu.edu.vn

Keywords

mobile learning app, engagement, card-based design, app store, personalized, adaptive

Introduction

Today, mobile applications (apps) are popular tools for learning, especially for self-study (Apple, 2015; Chiong & Shuler, 2010; Godwin-Jones, 2011). Consequently, many schools have created their own mobile apps distributed in stores (the Google Play store or the Apple app store) or deliver learning content via apps such as iTunes and YouTube (Chiong & Shuler, 2010; Rossing, Miller, Cecil, & Stamper, 2012). According to the Global Education Apps Market 2015–2019 report (Technavio, 2015), currently, more than 3.17 million apps are available in various stores, of which approximately 15% are categorized under education. However, enterprises and educators may encounter many problems when developing mobile learning apps to distribute in stores. Low engagement is a common issue that educational apps face (Bosomworth, 2015; Pachler, Bachmair, & Cook, 2009; Panel, 2005; Sharples, 2006). More specifically, many apps are used only once and then eventually deleted by users even though the apps are good learning apps, which have been designed with primary input from educators and curriculum developers or have been shown in educational research to be effective learning tools (Hoch, 2014). Therefore, increasing engagement is important for educators or researchers who want to introduce their learning apps to the real world and make them closer to their real end users. The literature survey showed that the webpages and blogs of developers and mobile apps experts provide guidelines for how to increase app engagement in stores, but the information is generic and not specific for education apps. In the available published educational studies, there is a gap. Therefore, in this study, we fill this gap with the proposed interface model PACARD (Personalized Adaptive CARD-based interface) that can be used to increase app engagement by targeting long-term study with a pedagogical theory.

First, PACARD was based on a card-based interface, which simulates flashcards in the real world. This method is much more effective than passively studying material (Edge, Searle, Chiu, Zhao, & Landay, 2011; Hong, Hwang, Tai, & Chen, 2014; Leitner, 1972; Wozniak & Gorzelanczyk, 1994). When we use flashcards, our brain absorbs and retains the information found on the back of the cards following the tip provided on the front. This active process exercises our memory, which, in turn, stimulates memorization. In particular, cards should be reviewed in periodic intervals, such as daily, then weekly, and then monthly, to strengthen active memory. PACARD provides mechanisms to make

sure that learned content is represented to learners at periodic intervals (Pham, Chen, Nguyen, & Hwang, 2016a).

Second, PACARD uses a card-based interface that can overcome the biggest disadvantage of mobile devices (small screen size) because the card-based design is flexible enough to appear properly on various screen sizes and to be structured for users' preferences (Adams, 2015; Cutter, 2015; Lake, 2014; Pham et al., 2016a).

Third, PACARD provides a personalized adaptive learning experience: PACARD can provide tailored learning material for individual learners and bring the best advantages of mobile devices to users (Adams, 2015; Cutter, 2015; Klementi, 2015; Pham et al., 2016a; Sanchez & Branaghan, 2011).

Fourth, PACARD integrates notifications and badges which is an effective method for attracting users to return to the application (Albert, 2015; Charleer, Klerkx, Odriozola, Luis, & Duval, 2013; Hamari, 2017; Marcellino & Santamaria, 2012; Tvarozek & Brza, 2014).

To evaluate the proposal's effectiveness, a mobile application called *English Practice* has been developed wherein the card-based interface PACARD was implemented. We used the method of *research in large through the app store* (Böhmer & Krüger, 2014; Ferreira, Kostakos, & Dey, 2012; Miluzzo, Lane, Lu, & Campbell, 2010). This method is suitable for evaluating online tools or apps distributed through store. Experiments with 63,824 participants were conducted through online application delivery via the Google Play store. Participants were formed into two groups: an experimental group using *English Practice* with PACARD enabled and a control group with PACARD disabled. Our three research questions were:

1. What are the differences between the experimental group and the control group in app engagement (app retention, session length, session count, total time consumption, average duration per day, and uninstall rate)?
2. What characterizes users' learning behavior on PACARD?
3. What are the differences in learning achievement between the experimental group and the control group?

Literature Review

Mobile Learning Apps and Distributions on the App Stores

Nowadays, mobile technology is gaining popularity (Zydney & Warner, 2015). For instance, the release of Apple iPhone in 2007 and the launch of Apple app stores in 2008 promoted a huge increase in the number of mobile applications. The growth in mobile apps has shown no signs of slowing, with as many as 15,000 new apps being released each week (Rakestraw, Eunni, & Kasuganti, 2013). Android and iOS are the two most popular mobile platforms where

mobile apps are distributed via apps store. They control 98.4% of all mobile smartphone activations in the fourth calendar quarter of 2015 (Rossignol, 2016). Moreover, smartphones with added-on computing capabilities and bigger screen size have morphed into mini-computers that go a long way toward solving the issues arising from early efforts in mobile learning (Godwin-Jones, 2011). With incorporated apps, mobile technology has many advanced features such as always-on connectivity, geolocalization, and the ability to record and to create content, among many others, which makes mobile apps ideal for ubiquitous learning (Ally & Tsinakos, 2014; Tsai, Shen, Tsai, & Chen, 2017).

The NMC Horizon Report (2017 Higher Education Edition) indicated that mobile devices play a pivotal role in new teaching paradigms, enable learners to access materials anywhere, and create new opportunities for students to connect with course content. Mobile apps, for example, allow two-way communication in real time, helping educators efficiently respond to student needs (Adams Becker et al., 2017). With built-in analytics and adaptive learning platforms, apps can provide more opportunities for monitoring and tracking various steps within the context of hands-on learning activities so that the learning environment becomes more supportive of the creative process (Adams Becker, Freeman, Giesinger Hall, Cummins, & Yuhnke, 2016). Apps can be applied into the classroom environment, and its content can be customized to meet the individual learning needs of all students (Shuler, 2009).

Although many teachers or learners use apps daily, understanding what an app is and having a context for how apps have evolved will help build the users' conceptualizations of apps (Cherner, Dix, & Lee, 2014). An app is essentially a small computer program that can be quickly downloaded on a mobile device (Cherner et al., 2014; Lucey & Laney, 2012; Pilgrim, Bledsoe, & Reily, 2012). Most apps are programmed to run on either the iOS or Android operating system (Godwin-Jones, 2011; Shuler, Levine, & Ree, 2012). Many apps appear to have the potential to enhance learning opportunities for young users at school and at home (Pelton & Francis Pelton, 2011). Moreover, teachers visiting the Apple app store or Google Play can quickly become overwhelmed when seeking to select the most effective app for their instructional needs (Chiong & Shuler, 2010; Walker, 2011).

Regarding the classification of apps, Cohen, Hadley, and Frank (2011) proposed three types of educational apps: creating apps, gaming apps, and eBook apps. Whereas Goodwin and Highfield (2012) pointed out that each app was viewed and classified according to its pedagogical design features based on a classification scheme originally devised to analyze interactive multimedia. Thus, app classification was instructive, manipulable, and constructive (Goodwin & Highfield, 2012). However, educational apps are also categorized as *skill based*, *content based*, and *function based* according to their purpose, requirements, and use (Cherner et al., 2014).

Recently, researchers have raised concerns about education and learning-based apps, such as in studies on language (Godwin-Jones, 2011), science (Zydney & Warner, 2015), math (Riconscente, 2011), and children (Goodwin & Highfield, 2012; O'Hare & Cinekid, 2014). However, few researchers have addressed the problem of mobile learning apps, especially the problem of low user engagement and distraction.

Problems of Mobile Learning Applications Distributed by Stores: Low User Engagement and Distraction

Since the Apple store and the Google Play store have become popular mobile app distribution platforms, the number of mobile apps has been growing rapidly. However, not all these apps distributed by stores are successful. Based on data from Quettra's research, the average app loses 77% of its daily active users within the first 3 days after the install and 90% of its daily active users after 30 days (Chen, 2015). One reason is the high number of attractive apps and games on users' smartphones. A recent study showed that many mobile learning apps find themselves competing against Twitter, Instagram, Angry Birds, and so on for learners' attention (Buzzsprout, 2015). That is to say, users are very easily distracted (Pachler et al., 2009; Sharples, 2006). Many apps are forgotten and abandoned even before users discover all their great features. In 2014, depending on the type of app, 9% to 23% of all installed apps have been opened only once, while only 39% of all apps have been opened more than 11 times (Hoch, 2014). Furthermore, if an app is opened only once in 7 days, there is a 60% chance it will never be opened again (Kosir, 2015). Additionally, Panel (2005) reported that educational apps were classified as those with the lowest retention (see Figure 1). People around the world currently spend time playing games, searching for information, socializing, reading the news, and so on, rather than using mobile technology to learn (Bosomworth, 2015).

To investigate why engagement with mobile learning apps is low and how to solve this problem, we refer to the lifecycle of a mobile app in Figure 2.

As can be seen in Figure 2, the lifecycle of a learning app distributed in the Apple app store begins after the app is downloaded and installed (1 and 2). Next, users can open the app (3) and start using it (4). During each session, users normally use the app for a short period and then switch to a different app (6) or turn off the phone (7). If the app is useful, the user may keep it on his or her phone and use daily; otherwise, the user uninstalls it (9). Based on the lifecycle of a mobile learning app, the following metrics need to be considered: the percentage of users who retained the app (app retention) and average use time per day, session length, session count, total time consumption, average duration per day, and uninstall rate (Adler, 2014; Farago, 2012; Kothari, 2016; Rhodes, 2016; Tolub, 2016). The first five metrics need to be increased while the uninstall rate needs to be decreased. According to previous studies, the

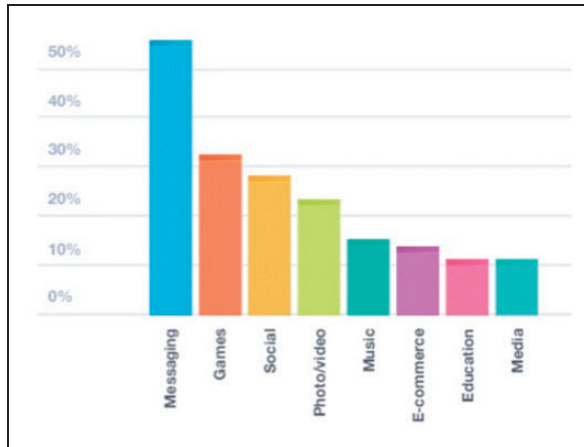


Figure 1. Average retention rate after 1 month by app category.

following are ways for improving learning app engagement based on these metrics:

- *Release app updates* (new features) to secure users' attention (Lele, 2015; Zinevych, 2014). New updates can provide new learning content, refresh the material, or add new functionalities.
- *Use supported tools for long-term learning* to engage users. Make users stay longer with the app (Pham & Chen, 2015).
- *Integrated evaluation tools*, such as quizzes, can keep learners engaged as these tools are always a motivator to study harder (TalentLMS, 2014).
- *Use the power of social media* to the fullest to increase engagement (Lele, 2015). It can increase members' rate of acquisition and retention and drive revenue (Fenech, 2015; Lele, 2015; Wang & Fesenmaier, 2003).
- *Use push notifications* to reach users and grab their attention (Kumulos, 2015; Levy & Kennedy, 2005; Localytics, 2014).

PACARD: A New Solution to Increase Engagement in Mobile Learning Apps

To increase engagement in mobile learning applications, PACARD focuses on the following factors:

- *Interface*: Card-based interface tailored to various screen sizes of mobile devices (phone, tablet, and smartwatch).

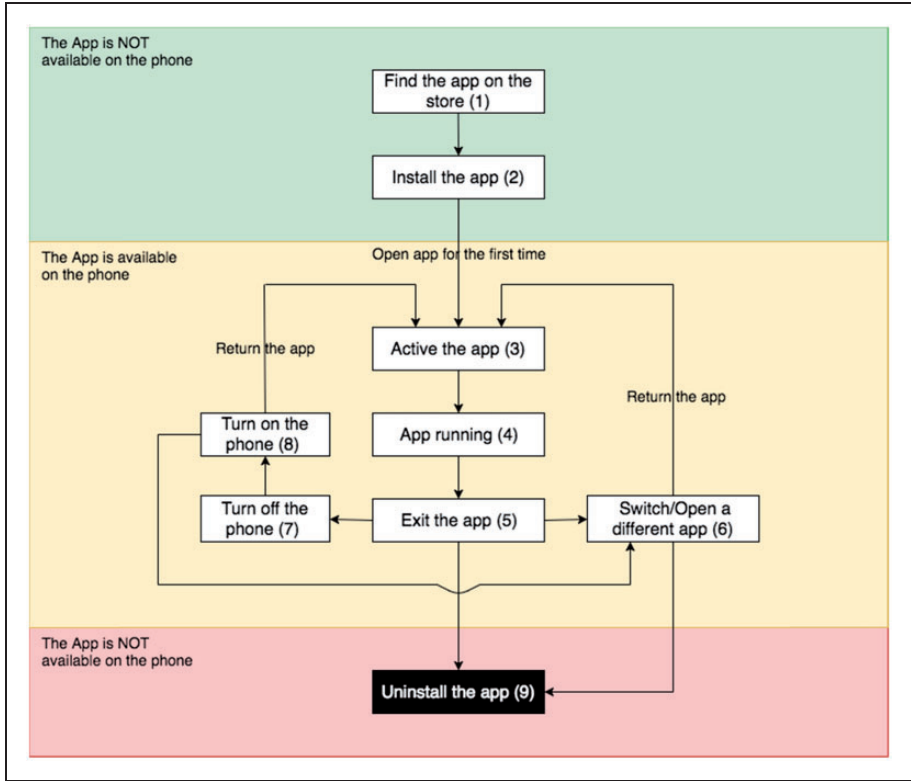


Figure 2. The lifecycle of a mobile learning apps.

- *Content delivery:* Integrated spaced repetition learning strategies and personalized adaptive technology to enhance active recall of learned items.
- *Interactive:* Notification and badge to attract more returning learners.

Interface—Card-Based Design for Various Screen Sizes

Cards are the most flexible layout formats for creating consistent experiences (Cao, 2015) because they can fit various screen sizes. Our interface takes advantage of that for improving user experience. In particular, PACARD is designed to display on mobile phones as well as on tablets that have a larger screen (see Figure 3). On tablet screens, the PACARD layout has two columns of cards. On mobile phone screens, each card has variable height based on its content; furthermore, the cards' widths also vary based on each column's width. Displaying cards on smartwatches is also of concern. In fact, designing



Figure 3. Screen shots of PACARD on different screen sizes.

an interface for smartwatches is substantially different from designing for mobile phones or tablets because it has limited screen size. Hence, smartwatches display a compact version of a card, only one card is displayed at a time, and users swipe vertically to navigate from one card to another. Smartwatches can connect to the user's smartphone (normally via Bluetooth) to synchronize data (Jackson, 2015). Learning progress and cards will automatically be transferred to the smartwatch when the application is opened.

Content Delivery

Spaced repetition combined with card-based design. Spaced repetition is used because it is a useful learning strategy (Baddeley, 1997; Ellis, 1995; Hong et al., 2014; Hulstijn & Hulstijn, 2001; Wozniak & Gorzelanczyk, 1994). The combination of spaced repetition with card-based design creates an interface that can help learners review learning content by calculating optimal intervals between reviews for each individual card and prepare a list of cards the learner should review each day to retain their information (Pham & Chen, 2015). Spaced repetition software engages learners in an active reviewing process since it always expects them to provide an answer (Cable, 1996; Flashcardlearner.com). Based on evidence currently available, it seems fair to suggest that spaced repetition can help increase engagement and support lifelong learning. Moreover, both spaced repetition and card-based design are fit for micro learning. The micro principle recommends fitting learning content into fragmented time slots, which are likely to be the majority of opportunities for users to access learning. Developing micro content items as small, self-contained, and granular learning objects suitable for mobile

delivery fits the micro principle (Edge et al., 2011; Gassler, Hug, & Glahn, 2004; Leene, 2006).

Personalized adaptive. A personalized adaptive mobile learning app tailors learning content and interactions to match learners' abilities and mobile technologies' needs use. It identifies an individual's profile and history since it is designed to provide appropriate learning patterns, attributes, and interactions based on learners' profiles (Snapwiz, 2013; Zare, 2011). Therefore, it would be expected to enhance learner engagement (Clarke & Miles, 2003; Newmann, 1989). Personalization helps provide the user a unique, relevant experience. The more aligned the experience is with a user's needs and preferences, the more likely a user is to continue using the app (Clarke & Miles, 2003; Kosir, 2015). Snapwiz, the creator of cloud-based adaptive and personalized learning platforms, released a paper (Snapwiz, 2013) indicating that adaptive learning and collaborative learning have best engaged students and enhanced learners' ability to retain and understand information. Moreover, among mobile learning systems, researchers have indicated that adaptive learning systems can contribute positively to students' learning outcomes (Dreyer & Nel, 2003). Thus, it is essential to focus on developing efficiently adaptive mobile learning applications that can provide tailored learning material for individual learners and take the best advantage of mobile devices available to users.

Interactive

Push notification. Some studies have shown the effectiveness of push notifications on user retention (Fenech, 2015; Lele, 2015; Warren, Meads, Srirama, Weerasinghe, & Paniagua, 2014). In most cases, notifications increased session counts, time consumption, and retention of the app (Pham, Chen, Nguyen, & Hwang, 2016b).

In this study, we integrated into PACARD a push notification mechanism that sends learners reminders at intervals to review learning content (cards; see Figure 4).

However, as everything has two sides, push notifications have some disadvantages, for instance, being a source of much disruption to ongoing tasks (Cutrell, Czerwinski, & Horvitz, 2001; Czerwinski, Horvitz, & Wilhite, 2004; Iqbal & Horvitz, 2007, 2010) and potentially increasing the uninstall rate (Pham et al., 2016b). Thus, in this study, we conducted an observation to obtain more understanding of PACARD's effectiveness concerning the uninstall rate (Study 2).

Badges

Badges is one effective way to attract the user back to the application (Albert, 2015; Charleer et al., 2013; Hamari, 2017; Marcellino & Santamaria, 2012; Tvarozek & Brza, 2014). Badges come in two kinds: *notification* and *reward*.

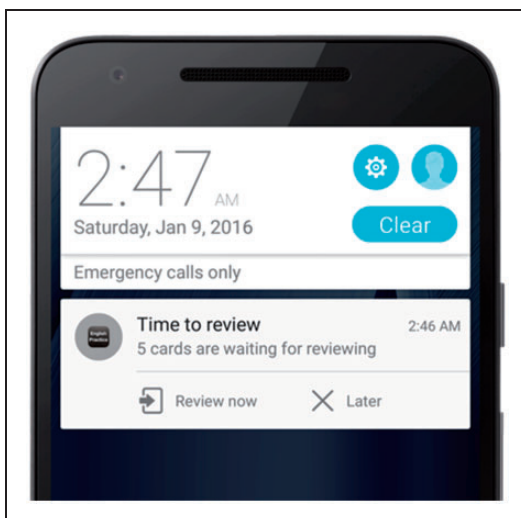


Figure 4. Notification for the *English Practice* application.

The *notification badge* shows the number of items or tasks that have not been read or completed within apps. Badges may be numerals, graphics, text, animations, or any combination thereof and may be displayed in different locations relative to their corresponding information (Marcellino & Santamaria, 2012). Badges can display inside (in-app badge) or outside (icon badge) the app. For example, the badge count in an icon of a to-do list app shows the number of upcoming or immediate items that need attention. Badge count in the “inbox” folder of an email app indicates the number of unread messages. By showing the number of unread notifications via a badge count, users are more inclined to tap on the app to see what they missed (Albert, 2015). For PACARD, badge count can indicate the number of cards that should be reviewed. This is expected to encourage users to open the app and return to PACARD to review missing learning items on cards. Figure 5 illustrates how our app used an out-app badge (icon badge) and an in-app badge.

Reward badges are certifications for having completed a certain task, designed to provide users a sense of accomplishment. Recent studies have shown that badges can increase learning engagement (i.e., Hamari, 2017; Law, 2015; Munson & Consolvo, 2012; Tvarozek & Brza, 2014). Badges can also inform learners individually about their progress and increase awareness and reflection (Charleer et al., 2013). Anderson, Huttenlocher, Kleinberg, and Leskovec (2014) deployed badges as incentives for engagement in a Massive Open Online Course and confirmed that making badges more salient produced increased forum engagement. Badges create clear goals, enjoyable challenges, and encourage people to continue using apps. Overall, it seems reasonable to assume that

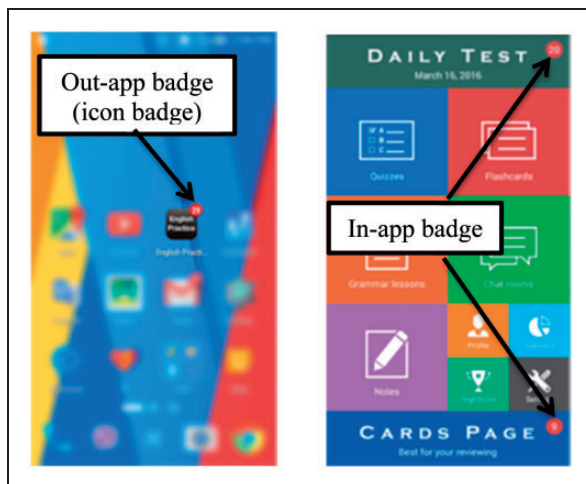


Figure 5. Display of an in-app and an out-app (icon) badge.

badges can increase engagement. Reward badges can be awarded to users who perform the following tasks:

- Practicing cards a set number of times
- Creating a set number of cards
- Recalling successfully a set number of cards
- Sharing a set number of cards

Figure 6 illustrates that reward badges are designed with an easily identifiable image related to the semantics of the badge (review, create, recall, and share). A medal for badges indicates different levels of achievement (bronze, silver, and gold). For example, if learners want to get *Silver Practice* and *Bronze Share* badge, they need to practice cards more than 500 times and share more than 20 cards via Chat rooms module or social network.

PACARD's Implementation on Mobile Apps

A common mobile app or mobile often has many screens. The PACARD interface can be added as an extra screen for displaying learning items, as demonstrated in Figure 7.

PACARD's design makes it possible to integrate it into any type of mobile app. Additionally, PACARD can help users remember learning content and increase memory retention and engagement (Pham et al., 2016a). Besides appearing like a separate screen (see Figure 8), PACARD is also integrated

	Practice	Createe	Recall	Share
Bronze	 100+	 10+	 50+	 20+
Silver	 500+	 50+	 250+	 100+
Gold	 2000+	 200+	 1000+	 400+

Figure 6. Designs of various reward badges.



Figure 7. Implementation of PACARD on mobile apps.

into another screen, such as a chat screen (see Figures 9 and 10). This integration allows users to review learning items when chatting and to share cards with peers via the chatting box.

Learning content is presented in a stream of cards. The PACARD module works as a learning assistant that tracks and represents all content in card format for conventional reviewing.

The *English Practice* app allows users to practice English by chatting with other users (see Figure 9). In this function, we integrated PACARD as a drawer screen (can be shown or hidden by users). Then, it allows users to review

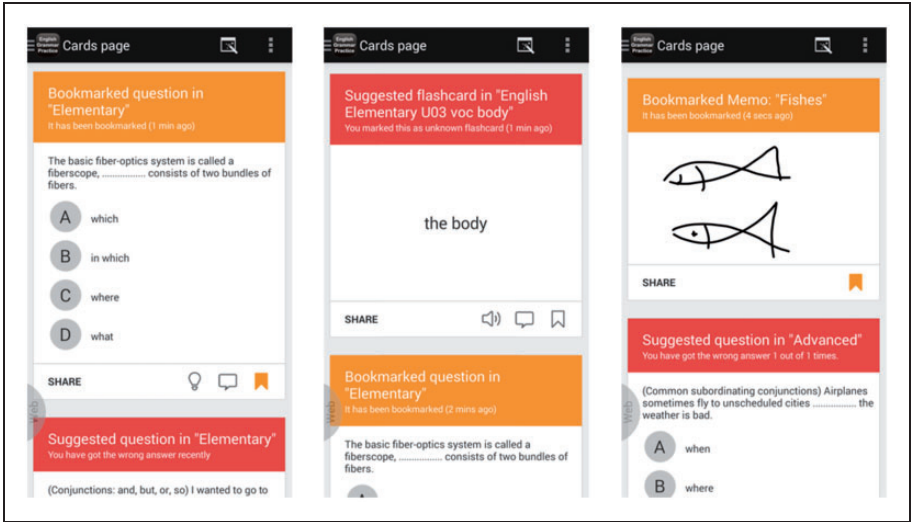


Figure 8. Cards on PACARD.

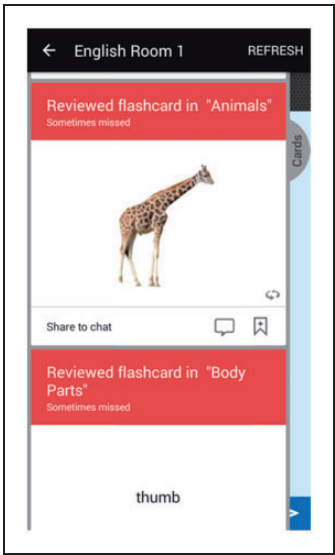


Figure 9. Chat screen.

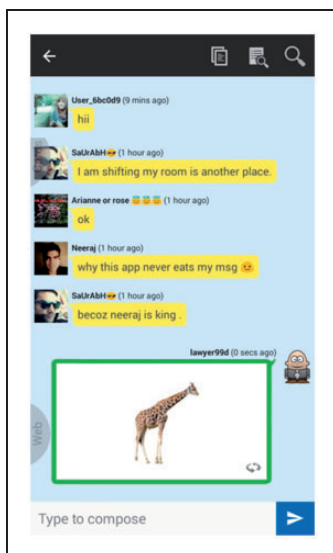


Figure 10. PACARD on chat screen.

learning content while chatting (see Figure 9). Moreover, with PACARD, users can share cards via the chat box (see Figure 10), and they can discuss content or teach another user, based on shared cards.

Study Design

Software: English Practice App

Published on Google Play on March 24, 2012, the *English Practice* app's learning content includes 254 grammar lessons, 3,996 quiz questions, and 150 sets of flashcards (Link on Google Play Store: <https://play.google.com/store/apps/details?id=com.jquiz.english>). A chat room was integrated into the app, allowing learners to interact and practice their English with others. Additionally, the application allows learners to create personal notes (including text and multimedia notes) that are also treated as learning content, which is pushed on PACARD. Here are some statistics on the app so far:

- First day release: March 24, 2012
- Total number of downloads (to October 1, 2016): 1,181,152
- Number of ratings (to October 1, 2016): 15,500
- Average rating score (to October 1, 2016): 4.3 out of 5
- Number of app reviews (to October 1, 2016): 3,600

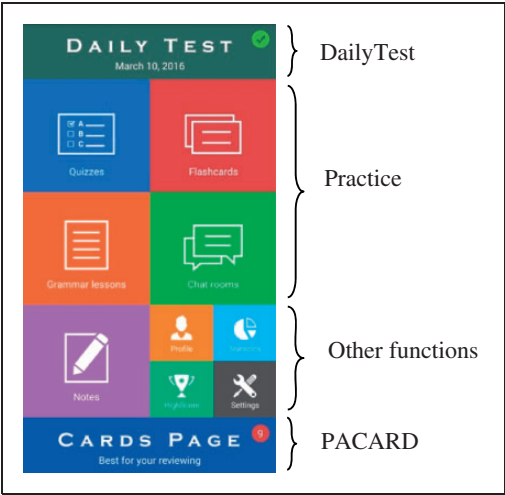


Figure 11. Main menu of the *English Practice* app.

Figure 11 shows the main menu of the *English Practice* app. PACARD has been implemented into the *English Practice* app since January 24, 2014. PACARD is designed to be simple and friendly, so learners and teachers do not need any training step to use it. A screen with six tips was shown to help users understand the features of PACARD when the users entered the app for the first time. Due to the limited space of each card block’s size, the most appropriate item format appearing on the card should be a question–answer, personal note, text, or short abridgment of one particular topic easily visible in small pieces. In *English Practice* app, PACARD is the design model of a function called *cards page*. In other words, *cards page* is a friendly name for PACARD, wherein card-based *interface*, *content delivery*, and *interactive* methods mentioned in the previous section are implemented. System architecture, learning activity, and card design are presented in detail in the previous study (Pham et al., 2016a).

Participants

Over 3 months, the *English Practice* application received 49,495 new downloads from the Google Play store, and 95,430 users updated the app. According to the Google Analytic report, in 3 months, there were about 170,000 active users. They were mainly distributed in Asia (56%) and Europe (21%). Their gender was 56% male and 44% female. In addition, nearly half of the participants were in either the 18 to 24 or 25 to 34 age-group. Most users use mobile, only 12% use tablet (see Table 1). Each user had a unique identity and a notification was

Table 1. Summary of the Characteristics of All Users.

Age	18–24 (44%); 25–34 (31%); 35–44 (17%); others (8%)
Gender	Male (56%); Female (44%)
Continent	Asia (56%); Europe (21%); Africa (12%); Americas (10%); Oceania (1%)
Device	Tablet (12%); Mobile (88%)

shown to ask him or her to join our study. All connected data were stored and could be exported and analyzed. Using participants online like this helped us to obtain a more diverse participant sample than would be possible in traditional (offline) research. This method prevented experimenter demand effects and helped us reduce the cost of conducting research. However, it can be difficult to obtain qualitative feedback from participants (Chittaro & Vianello, 2016).

Methodology and Studies

In this study, we used the method *research in large through the app store*. This method is suitable for evaluating online tools and apps distributed through stores. Guidelines for *research in large through the app store* have recently been published for conducting studies using app store data (i.e., Böhmer & Krüger, 2014; Ferreira et al., 2012; Miluzzo et al., 2010).

From about 170,000 active users (according to Google Analytics), we received 63,824 records (from 63,824 users) since many users were offline or refused to participate in the study. The participants were randomly divided into the control group and the experimental group. The PACARD interface was available only in the experimental group. Figure 12 shows more clearly how PACARD was integrated in the app.

Figure 12 was partly explained in Problems of Mobile Learning Applications Distributed by Stores: Low User Engagement and Distraction section. From this figure, we can see that PACARD is integrated and has two parts (the foreground and the background). The foreground (the PACARD interface) is an interface with the cards that display the learning content. The background works as a service to calculate the right time for push notifications (to remind users to return to the app) as well as to display badges. These features were not available in the control group since PACARD was used only by the participants in the experimental group.

Four studies were conducted:

- Evaluation of PACARD’s effectiveness on app retention, uninstall rate, and average use time per day (Study 1): A total of 63,824 users were observed for 60 days, 30,639 using the app with PACARD (experimental group) and 33,185 using the app without PACARD (control group). We compared app

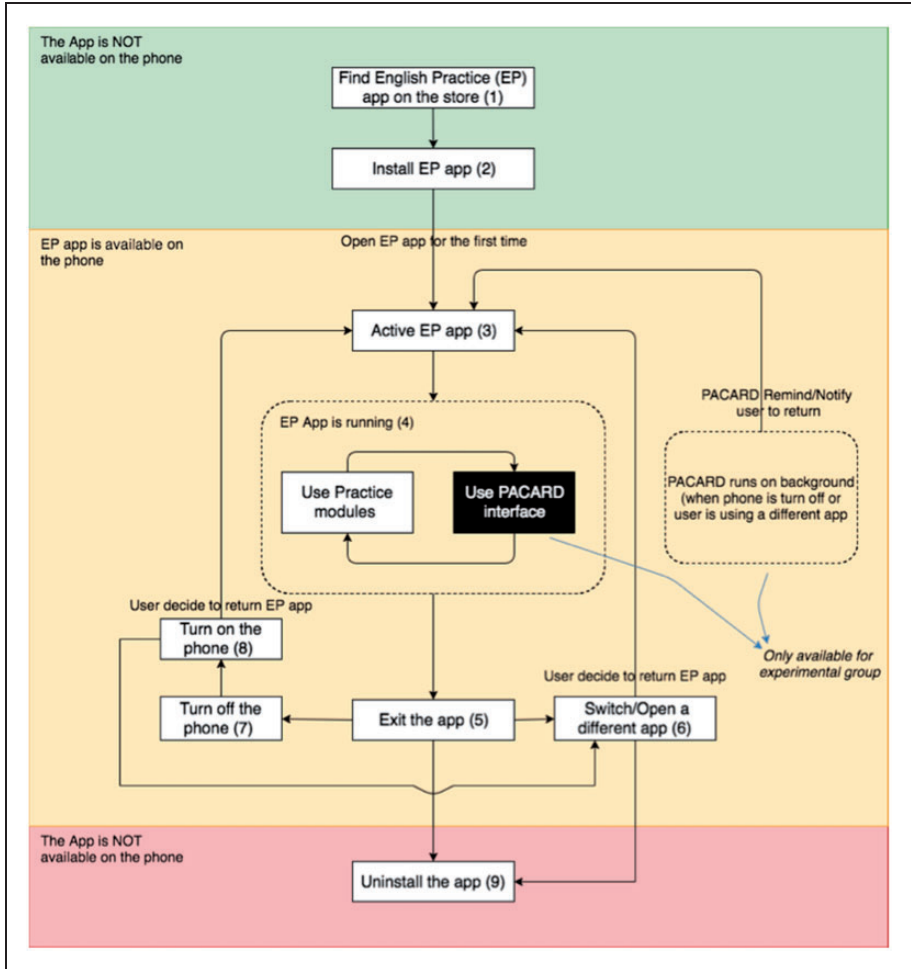


Figure 12. Integrating PACARD into the app.

- retention between the two groups in the first 30 days. Moreover, in the next 30 days, we enabled PACARD for the control group and observed changes of uninstall rate and average use time before and after enabling PACARD.
- Evaluation of PACARD’s effectiveness on app engagement metrics: Session length, session count, and total time consumption (Study 2): We used a *t*-test for evaluation. To avoid the occurrence of users rushing through the study, we calculated how long each participant spent on each function and removed all unreliable records. After filtering, 6,736 participants satisfied our conditions (time consumed on the application was more than 30 minutes).

Of those participants, 3,519 used the application version with PACARD (experimental group) and 3,217 used the application without PACARD (control group).

- Analysis of connected log files to understand user behaviors (Study 3): From experimental participants (Study 2), 3,519 logged files were analyzed to discover which functions of PACARD were most frequently used.
- Evaluation of PACARD’s effectiveness on learning achievement (Study 4): In this study, we evaluated PACARD’s effect on learners’ achievement based on the number of mastered cards.

Results and Discussion

Evaluation of PACARD’s Effectiveness on App Retention, Uninstall Rate, and Average Time per Day (Study 1)

As shown in Figure 13, the experimental group had significantly longer retention than the control group. Particularly, 61.4% of experimental group users remained a day after downloading the application, while the number for the control group was 46.2%. Day 2 retention of the experimental group decreased slightly to 50.2%, but the control group decreased to 35.8%. Similarly, retention of the experimental group went from a respectable 45.8% (Day 7) to 14.5% (Day 30), while it plummeted from 29.8% (Day 7) to 3.6% (Day 30) in the control group.

Regarding uninstall rate and average time per day, we observed users in the control group for 60 days. In the first 30 days, these users ($N = 33,165$) used *English Practice* without PACARD. At the 31st day, the PACARD function was automatically enabled. Figure 14 shows how the uninstall rate and use time changed:

Regarding uninstalls, as shown in Figure 14(a), on the 31st day when PACARD was enabled, the number of uninstalls rose sharply from the average 370 ($SD = 19.6$) per day to 535 per day. Possibly, the PACARD push notification got the attention of some users who were not aware they were keeping the

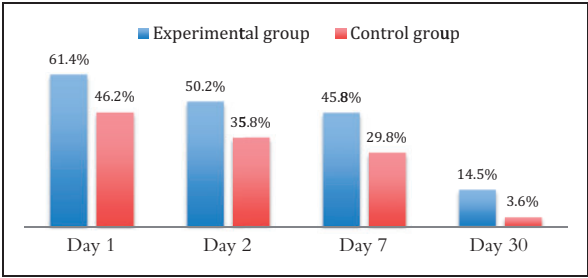


Figure 13. Comparison of app retention between experimental and control groups.

English Practice app without using it. Then, many users decided to remove it after a period of disuse. However, after the 31st day, the figure returned to its previous rate. More specifically, the uninstallation rate decreased dramatically from the peak of 535 times per day to the average of 377 ($SD=13.2$) times per day during the next 30 days. Figure 14(b) makes it obvious that after enabling PACARD, average use time increased from 9.7 minutes per day ($SD=0.53$) to 11.2 minutes per day ($SD=0.30$). Moreover, the number remained steady after that.

These numbers revealed that with push notification and badges, PACARD indeed attracted more attention from users. In particular, notifications warn users who have not used the app for a while to remove it. They also notify users to return to the app for reviewing learning content on the PACARD interface. This finding aligns with that of Pham et al. (2016b) who showed that push notifications can increase learner engagement.

Evaluation of PACARD’s Effectiveness on Session Count, Session Length, and Total Time Consumption (Study 2)

Table 2 makes it apparent that users in the experimental group had a higher number of sessions ($M=9.67$, $SD=9.7$) than those in the control group

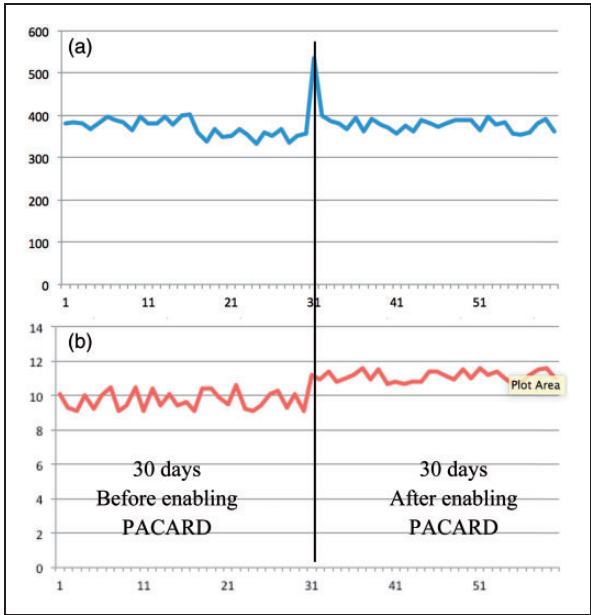


Figure 14. Uninstall and average use time changes before and after enabling PACARD. (a) Uninstall rate (Users/day), (b) Use time (Minutes/day).

Table 2. Comparison of Three Metrics Between Experimental and Control Groups.

Metrics	Group	N	Mean	SD	t	df	p
Session count	Experimental	3,519	9.67	9.7	5.95	6594	2.8e-09**
	Control	3,271	8.28	8.4			
Session length (seconds)	Experimental	3,519	829	1,403	0.04	6600	.968
	Control	3,271	831	1,472			
Total time consumption (seconds)	Experimental	3,519	6,028	7,249	3.84	6787	.00013**
	Control	3,271	5,355	6,996			

* $p < .05$. ** $p < .01$.

($M = 8.28$, $SD = 8.4$, $p = 2.8e-09 < .001$). However, session length between experimental and control groups showed no difference. Users in the experimental group spent more time with the app ($M = 6,028$ seconds, $SD = 7,249$) than those in the control group ($M = 5,355$ seconds, $SD = 6,996$, $p = .00013 < .001$). This result indicates that experimental group participants returned to the app more times as a result of PACARD having notifications that remind users to continue using the app to review learning items. The increasing number of user returns to the app for activities prompted by notifications led to increased total time consumption.

We also compared the application with and without badges, finding that the ratio users press to return to the application (in each 12 hours) is higher than 5.9% ($p = .03 < .05$). This means that badges (both in-app and out-app badges) are one effective strategy persuading users to return to the application. Unfortunately, the icon badge is not a standard android user interface. It is supported only on some phones. Badges on the icon display vary and are determined by different phone brands (e.g., Samsung, HTC, and Asus). Because of that, icon badges may not be easily integrated.

Analysis of Connected Log Files to Understand User Behaviors (Study 3)

As mentioned in PACARD's Implementation on Mobile Apps section, the four types of cards are quiz, flashcard, lesson, and note. Our previous studies (Pham et al., 2016a) have shown that quiz cards are most used, followed by flashcard and lesson, with notes ranked last. For each type of card, users can use varied functions, for instance, share, comment, view hint, text to speech, hint, scroll, and flip. Use frequencies of these functions are shown in Table 2.

From statistics in Table 3, we see that the Flip function is most used (21%), followed by Scroll and Hint (15% and 14%, respectively). Bookmark (7%) and Comment (5%) were not so popular. Share and Swipe (3% and 1%,

Table 3. Statistics for Use Functions on Each Type of Card.

Function	Available (times)	Used times	Frequency used (%)
Flip	1,319,633	270,238	21%
Scroll	21,042	3,200	15%
Hint	760,125	100,563	14%
Text to speech	597,228	50,637	9%
Bookmark	1,357,346	80,921	7%
Comment	1,357,346	60,241	5%
Share	1,357,346	30,671	3%
Swipe	1,357,346	10,921	1%

respectively) were even less used. The possible reason that the Flip function is most used may be that flashcards are two sided, and users need to flip the card to see the other side. In addition, users must also flip quiz cards to see the previous answers and other information. The Scroll function available only in Lesson cards is thus available only in 21,043 cards; lesson content, usually more than one page long, needs the Scroll function (frequency used: 15%). Allowing users to view help for quiz questions, the Hint function is frequently used (14%) since users may face difficult questions. In addition, after answering a quiz question, users often click Hint to see an explanation for a question. Other functions such as Comment (5%), Bookmark (7%), and Text to Speech (9%) are used with average frequency. Particularly, Swipe card—to mark a card—has been little used. Users may remain unaware of its availability, possibly because this function is not presented as a button.

PACARD’s Effectiveness on Learning Achievement (Study 4)

Users themselves mark “mastered” cards as mastered items; in other words, users believe they fully understand and have achieved those cards’ knowledge. Normally, users mark cards as mastered items when they have encountered them several times. Besides that, the system automatically prompts users to “master” a card if they became “familiar” with the card three times continuously. For example, the “familiar” definition is applied when users select a correct answer for a card that contains a multiple choice question or when learners obtain meaning from a flashcard. Once the card is indicated as “mastered,” it no longer appears on PACARD. However, users can retrieve those cards later from their mastered card box or in the Daily Test.

As shown clearly in Table 4, experimental users ($M = 11.86$, $SD = 19.8$) had significant higher numbers of mastered cards than the control group ($M = 9.09$,

Table 4. Comparison of Users’ Mastered Learning Items.

Group	N	Mean	SD	df	t	p
Experimental	3,519	11.86	19.8	5290	6.0933	1.184e-09**
Control	3,271	9.09	12.0			

* $p < .05$. ** $p < .01$.

$SD = 12, p < .001$). In other words, experimental users achieved more knowledge than control users, whether from multiplechoice questions, articles, flashcards, or their personal notes. This finding revealed that PACARD indeed promoted users’ learning achievement. From our previous PACARD study (Pham et al., 2016a) that estimated its influence on users’ retention based on average percentages of successfully recalled items in Daily tests, results demonstrated that students maintained gained knowledge better with PACARD. Two possible reasons may explain the difference between experimental and control users on mastered card items. First, PACARD’s learning content delivery is based on spaced repetition and personalized adaptive; this has been proven to enhance active recall (Pham et al., 2016a). Second, experimental users tended to spend longer with *English Practice* app. PACARD reminds learners about items that remain *missed or unsolved*; therefore, students might be encouraged to continue finding solutions for these items. In short, the experimental group devoted more time to reviewing items on PACARD and consequently mastered more cards.

Conclusions

This study proposed PACARD as a solution for educators or developers who wish to enhance mobile learning application engagement. PACARD, primarily based on a *card-based interface*, which is *personalized adaptive*, is easy to implement and tailor to most mobile devices and mobile learning apps on the market. Indeed, it benefits educators and mobile app developers as well as learners themselves. PACARD’s badge icons and the push notification mechanism trigger learners’ attention and attract them to return to the app more frequently and increase session length and daily use time, thus raising total time consumption. Adoption of push notification improved user retention by reminding users of the app’s existence and encouraging its use. Afterward, users archived more knowledge (mastered more learning items) and learned better, thus proving that PACARD benefits the user’s learning process. Overall, PACARD enhanced app engagement, which is better for sustaining learning time leading to higher learning achievement.

By using Google app store distribution, this study reached a large number of actual-user participants from various backgrounds and countries. Because they used the mobile app in their natural habitat, this study’s findings are reliable and

widely applicable. This research was conducted through the app store and its associated analytics. In addition to traditional research methods, app store analytics research has many advantages, but there are some limitations as when this method is used. In particular, in this study, it was difficult to obtain qualitative feedback from online participants. Therefore, for future study, we may conduct a qualitative study from offline users.

Besides its advantages, PACARD owns all the disadvantages of card-based design. In particular, representing learning materials as pieces caused fewer logical associations among cards. This means that PACARD cannot present the relationship between cards. Moreover, hierarchy is not the emphasis on card-based design. Thus, searching through cards adds an extra step compared with a themed layout. Consequently, when users are looking for one specific piece of information, scanning through cards can be annoying.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

- Adams Becker, S., Cummins, M., Davis, A., Freeman, A., Hall Giesinger, C., & Ananthanarayanan, V. (2017). NMC horizon report: 2017 higher education edition. *Austin, Texas: The New Media Consortium*. Retrieved from <https://www.nmc.org/publication/nmc-horizon-report-2017-higher-education-edition/>
- Adams Becker, S., Freeman, A., Giesinger Hall, C., Cummins, M., & Yuhnke, B. (2016). *The NMC/CoSN horizon report: 2016 K-12 edition*. Austin, TX: The New Media Consortium.
- Adams, P. (2015). *Why cards are the future of the web*. Retrieved from <https://blog.intercom.io/why-cards-are-the-future-of-the-web/>
- Adler, B. (2014). *The 8 mobile app metrics that matter*. Retrieved from <http://info.lytics.com/blog/the-8-mobile-app-metrics-that-matter>
- Albert, D. (2015). *Pushing push—Have notifications come of age?* Retrieved from <https://www.sitepoint.com/pushing-push-notifications-come-age/>
- Ally, M., & Tsinakos, A. (2014). *Increasing access through mobile learning*. Vancouver, Canada: Commonwealth of Learning.
- Anderson, A., Huttenlocher, D., Kleinberg, J., & Leskovec, J. (2014). *Engaging with massive online courses*. Paper presented at the 23rd international conference on World wide web, Seoul, Korea.
- Apple. (2015). *iPad in education*. Retrieved from <http://www.apple.com/education/ipad/apps-books-and-more>

- Baddeley, A. D. (1997). *Human memory: Theory and practice*. Exeter, England: Psychology Press.
- Böhmer, M., & Krüger, A. (2014). A case study of research through the app store: Leveraging the system UI as a playing field for improving the design of smartphone launchers. *International Journal of Mobile Human Computer Interaction (IJMHCI)*, 6(2), 32–45.
- Bosomworth, D. (2015). Mobile marketing statistics 2015. *Smart Insights site*. Retrieved from <http://www.plenuminvest.dk/docs/mobile-marketing-statistics-2015.docx>
- Buzzsprout. (2015). *Mobile learning: Why tech savvy educators are turning to podcasts*. Retrieved from <https://www.buzzsprout.com/blog/2015/01/15/mobile-learning>
- Cao, J. (2015). *How cards are taking over Web design*. Retrieved from <http://thenextweb.com/dd/2015/06/16/how-cards-are-taking-over-web-design/>
- Caple, C. (1996). *The effects of spaced practice and spaced review on recall and retention using computer assisted instruction* (PhD dissertation). Raleigh, NC: North Carolina State University.
- Charleer, S., Klerkx, J., Odriozola, S., Luis, J., & Duval, E. (2013). *Improving awareness and reflection through collaborative, interactive visualizations of badges*. Paper presented at the 3rd Workshop on Awareness and Reflection in Technology Enhanced Learning (ARTEL13), Paphos, Cyprus.
- Chen, A. (2015). New data shows losing 80% of mobile users is normal, and why the best apps do better. Retrieved from <http://andrewchen.co/new-data-shows-why-losing-80-of-your-mobile-users-is-normal-and-that-the-best-apps-do-much-better/>
- Cherner, T., Dix, J., & Lee, C. (2014). Cleaning up that mess: A framework for classifying educational apps. *Contemporary Issues in Technology and Teacher Education*, 14(2), 158–193.
- Chiong, C., & Shuler, C. (2010). *Learning: Is there an app for that? Investigations of young children's usage and learning with mobile devices and apps*. New York, NY: The Joan Ganz Cooney Center at Sesame Workshop.
- Chittaro, L., & Vianello, A. (2016). Evaluation of a mobile mindfulness app distributed through on-line stores: A 4-week study. *International Journal of Human Computer Studies*, 86, 63–80.
- Clarke, J., & Miles, S. (2003). *Changing systems to personalize learning: Introduction to the personalization workshops*. Providence, RI: Education Alliance at Brown University.
- Cohen, M., Hadley, M., & Frank, M. (2011). Young children, apps & iPad. *U.S. Department of Education Ready to Learn Program*, 200, 5–10.
- Cutrell, E., Czerwinski, M., & Horvitz, E. (2001). Notification, disruption, and memory: Effects of messaging interruptions on memory and performance. *Proceedings of the IFIP Conference on Human-Computer Interaction (INTERACT 2001)* (pp 263–269). Tokyo, Japan: IOS Press.
- Cutter, J. D. (2015). *Card based design: How mobile is shaping the future of online content*. Retrieved from <http://graphicdesign.com/news/card-based-design-how-mobile-is-shaping-the-future-of-online-content>
- Czerwinski, M., Horvitz, E., & Wilhite, S. (2004). *A diary study of task switching and interruptions*. Paper presented at the Proceedings of the SIGCHI conference on Human factors in computing systems, Vienna, Austria.

- Dreyer, C., & Nel, C. (2003). Teaching reading strategies and reading comprehension within a technology-enhanced learning environment. *System*, 31(3), 349–365.
- Edge, D., Searle, E., Chiu, K., Zhao, J., & Landay, J. A. (2011). *MicroMandarin: Mobile language learning in context*. Paper presented at the proceedings of the SIGCHI conference on human factors in computing systems, Vancouver, BC, Canada.
- Ellis, N. C. (1995). The psychology of foreign language vocabulary acquisition: Implications for CALL. *Computer Assisted Language Learning*, 8(2–3), 103–128.
- Farago, P. (2012). App engagement: The matrix reloaded. *Flurry Insights*. Retrieved from <http://www.flurry.com/bid/90743/App-Engagement-The-Matrix-Reloaded>
- Fenech, T. (2015). *The 9 Keys to taming promiscuous app users and increasing user retention*. Retrieved from <https://www.helpshift.com/blog/the-9-keys-to-taming-promiscuous-app-users-and-increasing-user-retention/>
- Ferreira, D., Kostakos, V., & Dey, A. K. (2012). Lessons learned from large-scale user studies: Using android market as a source of data. *International Journal of Mobile Human Computer Interaction (IJMHCI)*, 4(3), 28–43.
- Flashcardlearner.com. *What is spaced repetition?* Retrieved from <http://www.flashcardlearner.com/articles/what-is-spaced-repetition/>
- Gassler, G., Hug, T., & Glahn, C. (2004). *Integrated micro learning—An outline of the basic method and first results*. Paper presented at the International Conference on Interactive Computer Aided Learning (ICL 2004), Villach, Austria.
- Godwin-Jones, R. (2011). Emerging technologies: Mobile apps for language learning. *Language Learning & Technology*, 15(2), 2–11.
- Goodwin, K., & Highfield, K. (2012). *iTouch and iLearn: An examination of “educational” apps*. Paper presented at the early education and technology for children conference, March 14–16, Salt Lake City, UT.
- Hamari, J. (2017). Do badges increase user activity? A field experiment on the effects of gamification. *Computers in Human Behavior*, 71, 469–478.
- Hoch, D. (2014). *App retention improves—Apps used only once declines to 20%*. Retrieved from <http://info.localytics.com/blog/app-retention-improves>
- Hong, J.-C., Hwang, M.-Y., Tai, K.-H., & Chen, Y.-L. (2014). Using calibration to enhance students’ self-confidence in English vocabulary learning relevant to their judgment of over-confidence and predicted by smartphone self-efficacy and English learning anxiety. *Computers & Education*, 72, 313–322.
- Hulstijn, J. H., & Hulstijn, J. H. (2001). *Intentional and incidental second language vocabulary learning: A reappraisal of elaboration, rehearsal and automaticity: Cognition and second language instruction*. Cambridge, England: Cambridge University Press.
- Iqbal, S. T., & Horvitz, E. (2007). *Disruption and recovery of computing tasks: Field study, analysis, and directions*. Paper presented at the Proceedings of the SIGCHI conference on Human factors in computing systems, San Jose, California, USA.
- Iqbal, S. T., & Horvitz, E. (2010). Notifications and awareness: A field study of alert usage and preferences. *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work, CSCW 2010* (pp. 27–30). Savannah, GA: ACM.
- Jackson, W. (2015). *Pro android wearables: Building apps for smartwatches*. Berkely, CA: Apress.

- Klementi, K. (2015). *Cards as the new creative canvas in web design*. Retrieved from <http://blog.templatemonster.com/2015/01/14/cards-as-the-new-creative-canvas-in-web-design/>
- Kosir, D. (2015). *5 methods for increasing app engagement & user retention*. Retrieved from <http://clearbridgemobile.com/5-methods-for-increasing-app-engagement-user-retention/>
- Kothari, N. (2016). *The 9 key metrics for measuring user engagement for ecommerce apps*. Retrieved from <https://mofluid.com/blog/the-9-key-metrics-for-measuring-user-engagement-for-ecommerce-apps/>
- Kumulos. (2015). *Push notifications—5 best ways to maximize engagement*. Retrieved from <https://www.kumulos.com/2015/11/12/push-notifications-5-best-ways-to-maximize-engagement/>
- Lake, C. (2014). *15 delicious examples of card-based web design*. Retrieved from <https://econsultancy.com/blog/64646-15-delicious-examples-of-card-based-web-design/>
- Law, P. (2015). *Digital badging at The Open University: Recognition for informal learning*. Paper presented at the The Open and Flexible Higher Education Conference 2014: New Technologies and the Future of Teaching and Learning, Krakow, Poland.
- Leene, A. (2006). Microcontent is everywhere. *Proceedings of the microlearning conference 2006* (pp. 20–40). Innsbruck, Austria: Innsbruck University.
- Leitner, S. (1972). *So lernt man lernen: Der Weg zum Erfolg* [How to learn to learn: The Way to Success]. Freiburg, Germany: Herder.
- Lele, S. (2015). *8 Tips for boosting app retention: Create an app for the long run*. Retrieved from <http://blog.personagraph.com/8-tips-for-boosting-app-retention-create-an-app-for-the-long-run>
- Levy, M., & Kennedy, C. (2005). Learning Italian via mobile SMS. In K.-H. Agnes & T. John (Eds.), *Mobile learning: A handbook for educators and trainers* (pp. 76–83). Oxon, England: Routledge.
- Localytics. (2014). *Push messaging drives 88% more app launches*. Retrieved from <http://info.localytics.com/blog/push-messaging-drives-88-more-app-launches-for-users-who-opt-in>
- Lucey, T. A., & Laney, J. D. (2012). *Reframing financial literacy: Exploring the value of social currency*. Charlotte, NC: IAP.
- Marcellino, C., & Santamaria, J. (2012). Managing notification service connections and displaying icon badges: Google Patents No. US 8135392 B2 United States.
- Miluzzo, E., Lane, N. D., Lu, H., & Campbell, A. T. (2010). *Research in the app store era: Experiences from the cenceme app deployment on the iphone*. Paper presented at the First Workshop on Research in the Large at UbiComp, Copenhagen, Denmark.
- Munson, S. A., & Consolvo, S. (2012). *Exploring goal-setting, rewards, self-monitoring, and sharing to motivate physical activity*. Paper presented at the 6th International Conference on Pervasive Computing Technologies for Healthcare, San Diego, CA, USA.
- Newmann, F. M. (1989). Student engagement and high school reform. *Educational Leadership*, 46(5), 34–36.
- O'Hare, E., & Cinekid, C. (2014). *Mobile apps for children*. Retrieved from <http://www.cinekid.nl/projects/research>

- Pachler, N., Bachmair, B., & Cook, J. (2009). *Mobile learning: Structures, agency, practices*. New York, NY: Springer Science & Business Media.
- Panel, M. (2005). *Trends report: The new standards for mobile app retention*. Retrieved from <https://mixpanel.com/blog/2013/11/04/trends-report-the-new-standards-for-mobile-app-retention/>
- Pelton, T., & Francis Pelton, L. (2011). *Design principles for making meaningful mathematics apps*. Proceedings of Society for Information Technology & Teacher Education International Conference (pp. 2199–2204). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).
- Pham, X. L., & Chen, G. D. (2015). PACARD: A personalized adaptive card-based interface that enable learners to access and recall learning element efficiently. Paper presented at the 23rd international conference on computers in education (ICCE 2015) (pp. 245–255), Hangzhou, China.
- Pham, X. L., Chen, G. D., Nguyen, T. H., & Hwang, W. Y. (2016a). Card-based design combined with spaced repetition: A new interface for displaying learning elements and improving active recall. *Computers & Education*, 98, 142–156.
- Pham, X. L., Chen, G. D., Nguyen, T. H., & Hwang, W. Y. (2016b). *Effects of push notifications on learner engagement in a mobile learning app*. Paper presented at the IEEE International Conference on Advanced Learning Technologies (ICALT 2016), Austin, TX, USA.
- Pilgrim, J., Bledsoe, C., & Reily, S. (2012). New technologies in the classroom. *Delta Kappa Gamma Bulletin*, 78(4), 16–20.
- Rakestraw, T. L., Eunni, R. V., & Kasuganti, R. R. (2013). The mobile apps industry: A case study. *Journal of Business Cases and Applications*, 9, 1.
- Rhodes, W. (2016). *28 metrics that matter for your app*. Retrieved from <https://savvyapps.com/blog/mobile-app-analytics>
- Riconscente, M. (2011). *Mobile learning game improves 5th graders' fractions knowledge and attitudes*. Los Angeles, CA: GameDesk Institute.
- Rossignol, J. (2016). *iOS and android capture combined 98.4% share of smartphone market*. Retrieved from <http://www.macrumors.com/2016/02/18/ios-android-market-share-q4-15-gartner/>
- Rossing, J. P., Miller, W. M., Cecil, A. K., & Stamper, S. E. (2012). iLearning: The future of higher education? Student perceptions on learning with mobile tablets. *Journal of the Scholarship of Teaching and Learning*, 12(2), 1–26.
- Sanchez, C. A., & Branaghan, R. J. (2011). Turning to learn: Screen orientation and reasoning with small devices. *Computers in human behavior*, 27(2), 793–797.
- Sharples, M. (2006). *Big issues in mobile learning*. Paper presented at the Report of a workshop by the Kaleidoscope Network of Excellence Mobile Learning Initiative, University of Nottingham, England.
- Shuler, C. (2009). *iLearn: A content analysis of the iTunes app store's education section*. New York, NY: The Joan Ganz Cooney Center at Sesame Workshop.
- Shuler, C., Levine, Z., & Ree, J. (2012). *iLearn II: An analysis of the education category of Apple's app store*. Paper presented at the The Joan Ganz Cooney Center at Sesame Workshop, New York, USA.

- Snapwiz. (2013). *Improving student engagement by integrating adaptive and collaborative learning technologies*. Retrieved from <http://ww1.prweb.com/prfiles/2013/10/22/11256816/Improving-Student-Engagement-white-paper.pdf>
- TalentLMS. (2014). *e-learning concepts, trends, applications*. Retrieved from <http://www.talentlms.com/elearning/elearning-101-jan2014-v1.1.pdf>
- Technavio. (2015). *Global education apps market—Market study 2015–2019*. Retrieved from <http://www.technavio.com/report/global-education-apps-market-market-study-2015-2019>
- Tolub, Y. (2016). *Mobile app analytics: The 12 most important metrics to measure*. Retrieved from <http://www.uxmatters.com/mt/archives/2016/08/mobile-app-analytics-the-12-most-important-metrics-to-measure.php>
- Tsai, C.-W., Shen, P.-D., Tsai, M.-C., & Chen, W.-Y. (2017). Exploring the effects of web-mediated computational thinking on developing students' computing skills in a ubiquitous learning environment. *Interactive Learning Environments*, 25, 762–777.
- Tvarozek, J., & Brza, T. (2014). *Engaging students in online courses through interactive badges*. Paper presented at the international conference on e-learning (p. 89). Spain: University of La Laguna.
- Walker, H. (2011). Evaluating the effectiveness of apps for mobile devices. *Journal of Special Education Technology*, 26(4), 59–63.
- Wang, Y., & Fesenmaier, D. R. (2003). Assessing motivation of contribution in online communities: An empirical investigation of an online travel community. *Electronic Markets*, 13(1), 33–45.
- Warren, I., Meads, A., Srirama, S., Weerasinghe, T., & Paniagua, C. (2014). Push notification mechanisms for pervasive smartphone applications. *IEEE Pervasive Computing*, 13(2), 61–71.
- Wozniak, P., & Gorzelanczyk, E. J. (1994). Optimization of repetition spacing in the practice of learning. *Acta Neurobiologiae Experimentalis*, 54, 59.
- Zare, S. (2011). Personalization in mobile learning for people with special needs. *International conference on universal access in human-computer interaction. Applications and Services* (pp. 662–669). Berlin, Germany: Springer.
- Zinevych, S. (2014). *How a content-rich mobile app can boost your customer retention*. Retrieved from <http://publ.com/blog/2014/09/24/how-a-content-rich-mobile-app-can-boost-your-customer-retention/>
- Zydney, J. M., & Warner, Z. (2015). Mobile apps for science learning: Review of research. *Computers & Education*, 94, 1–17.

Author Biographies

Xuan Lam Pham, PhD, is working as a lecturer in School of Information Technology in Economics, National Economics University, Vietnam. Recently, he is doing research to explore and solve problems of mobile learning.

Gwo Dong Chen is a full professor at the Department of Computer Science and Information Engineering, National Central University. His research interest is Human Computer Interaction for technology-enhanced learning. He is trying to develop new mechanisms and representation methods for textbooks in the digital age.