A Mobile Strategy for Self-Directed Learning in the Workplace

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ABSTRACT

Traditional approaches to workplace training often treat learners as equally prepared, drive them through too much content in too short a time, and conclude before ensuring retention. These departures from ideal instructional practice have a common cause—the need to fit learning activities into constrained episodes such as classroom presentations and e-learning courses. Fortunately, advances in mobile technology, learning science, and artificial intelligence are making it possible to deliver learning experiences in less constrained conditions, with reduced risk of overload, and better alignment with an individual's mental and situational readiness to learn.

We developed a mobile strategy that leverages these advances to support adult learning, and implemented this strategy in PERLS, a mobile application that recommends bite-sized learning materials—or microcontent—through a deck of electronic cards. An intelligent algorithm tracks progress and recommends content based on principles of self-regulated learning, goal-setting, and adult learning motivation. Essentially, PERLS aims to engage users in becoming better self-regulated learners on the job.

In this paper, we describe the PERLS mobile learning strategy and results of an evaluation of user satisfaction with the technology and pilot testing of several instruments for continuous improvement. The mobile app was deployed to support training of Defense Support for Civil Authorities (DSCA). By drawing from observations, online usage data, learning outcome measures, and surveys of learner characteristics and attitudes, this paper provides evidence of the feasibility of using this approach to enhance self-directed learning activity among military personnel.

ABOUT THE AUTHORS

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A STRATEGY FOR TECHNOLOGY-ENHANCED SELF-LEARNING

Traditional approaches to instruction present a challenge for working adults, who usually have many demands on their time and engage in learning intermittently. Classroom and electronic courses attempt to work within these limits by delivering intense learning experiences over a defined time interval. This strategy makes learning activities efficient and easy to schedule, but it tends to overwhelm learners with too much content in a short period, and then concludes without ensuring retention. To help adults learn effectively despite limits on available time, we have developed a mobile strategy based on shifting portions of a learning task to brief, opportunistic intervals, which are more plentiful for busy adults than are longer, pre-planned intervals. This differs from traditional approaches to learning in that it is largely self-directed and substitutes most long duration content with a collection of short duration *microcontent* (Hug et al., 2006)

We implemented this strategy in PERLS—a mobile, PERvasive (i.e. anytime/anywhere) Learning System. PERLS is designed to make it easy for learners to quickly dip into learning material whenever an opportunity arises, and then move back to whatever activity they were engaged in previously. For example, a user might quickly find and select an item of microcontent while waiting in line or taking a break from a lengthy work task. The application functions as a personal assistant that tracks learners' progress and suggests content based on learners' interests, progress, and availability. It uses a process model of self-regulated learning (SRL) for both tracking and recommending. For instance, a user might be casually exploring one topic, intensely studying a second, and sustaining prior learning on a third. PERLS uses artificial intelligence algorithms to estimate a user's current SRL phase, and recommend phase-appropriate microcontent.

A curator acquires and manages microcontent with a web-based curation user interface (UI). Sources include long form e-courses, which are transformed into small content units to support study and retention objectives; online repositories, including content siloed inside other applications (Freed, Folsom-Kovarik, & Schatz, 2017); dynamic sources, such as blogs and news sites, that supply fresh content for long term user engagement; users, who can supply content of high value to a small population; and training personnel to adapt legacy content and create original microcontent to meet emerging organizational needs.

In this paper, we describe PERLS, starting with the Self-Regulated Learning (SRL) model that serves as a conceptual foundation for the mobile learning strategy instantiated in the app. We then describe results of a recent study that explores the use of PERLS for sustainment of Joint Knowledge Online (JKO) e-course training in Defense Support for Civilian Authorities (DSCA) during disasters, as well as preparation for advanced classroom-based DSCA training provided in a 3-day residential course by USNORTHCOM. The study fulfills two purposes: (1) evaluating the desirability and usability of PERLS between episodes of formal instruction (a Level 1 Evaluation) (Kirkpatrick, 1975); and (2) developing data collection instruments to support continuous improvement of the app's system performance, user experience, and learning once it is deployed at scale.

A MODEL OF SELF-REGULATED LEARNING

PERLS (Pervasive Learning System), developed under ADL's Personal Assistant for Learning program, is a mobile app supporting adult self-regulated learning. Self-regulated learning (SRL) complements formal course-based instruction, emphasizing "autonomy and control by the individual who monitors, directs, and regulates actions toward goals of information acquisition, expanding expertise, and self-improvement" (Paris & Paris, 2001). For adults, self-learning is the predominant form of learning, with average time spent ranging from 200–650 hours per year (Livingstone, 1999), accounting for at least 70% of total learning effort (Kim et al., 2004).

Although self-learning can incorporate e-courses and other kinds of pre-packaged instruction, it falls mainly to the learner to find relevant content (Pirolli & Card, 1999) and plan learning activity by recognizing learning needs,

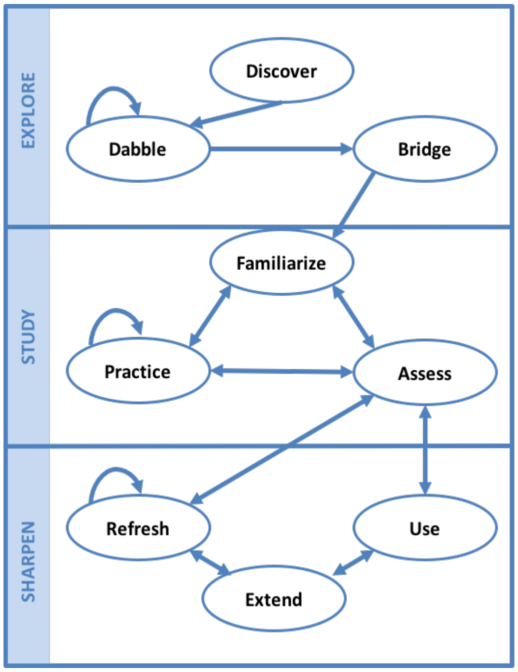

Figure 1. PERLS Self-Regulated Learning Model

setting goals, acquiring resources, monitoring progress, detecting and remedying problems, (Boekearts, Pintrich, & Zeldener, 2005; Zimmerman & Schunk, 2011). Each such challenge represents an opportunity for technology-enhanced learning, and collectively, a reason to use context-aware recommendation and other related technologies useful for personalizing the learning experience.

PERLS' model of the learning process (Figure 1) involves three main phases – Explore, Study, and Sharpen – each associated with a set of activity types or "sub-phases." The Explore phase starts with Discovery, where the learner becomes aware of a topic and why it might be important to learn more. Learners who are naturally curious, perceptive, and social will tend to become aware of important topics in a timely way. Others may struggle, and benefit from technology that supports Discovery. Dabbling is undemanding interaction with topic materials, consistent with a low level of commitment to long-term learning. Content is typically brief and easy to absorb, providing the learner with an opportunity to assess or nurture motivation, gain confidence, and become oriented to the basic terms and ideas in the topic domain. Bridging is preparing for intensive, high commitment learning, by, e.g., defining goals, setting time and effort expectations, and identifying learning resources.

Learners may progress past Exploration and transition to the Study Phase, indicating a commitment to gain a competency, complete a course, or achieve some other goal. Study activities include Familiarization to obtain a foundation of knowledge, Practice to develop skills, and Assessment to establish a starting point and measure goal progress. Formal instruction is a special case of Study since learners might achieve their goals by formal or informal methods. After achievement, learners transition to Sharpen Phase sustainment activities including Refreshing for retention, Extension to stay current and build on prior learning, and Using what they have learned to enhance fluency. In each phase and activity, some learners are largely self-sufficient while others can benefit from technological support.

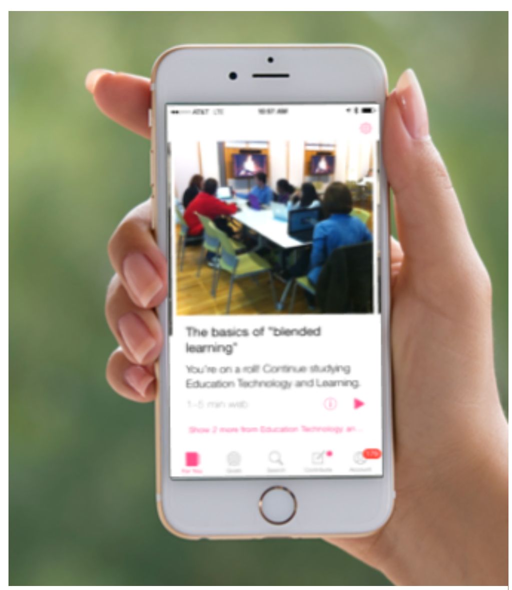

Figure 2. PERLS uses a card-based UI

HOW PERLS SUPPORTS SELF-LEARNING

Self-learning differs from formal instruction in how and when people engage with learning content. For example, pre-study exploration and post-study sustainment lengthen the timeline of learning compared to a self-contained course. Effective support technology must be engaging and habit-forming so that self-learners use it regularly during learning trajectories that can last months or years. And because self-learning takes place in the context of the learner's daily activities, support technology will be used more reliably if users can take advantage of unplanned time slots, whenever and wherever these occur. Thus, it should be easy to use, quick to start, and provide microcontent suitable for brief time slots.

Modern mobile apps use a range of user experience design approaches to meet these criteria. PERLS adopts a card-based approach (Figure 2), where each card displays a content or action recommendation, and a "swipe" gesture is used to advance to the next recommended item. Some recommendations cover topics that are unfamiliar to the learner, but potentially relevant. Others cover topics of the learner has recently reviewed or studied. In other words, recommendations span SRL phases as well as topics. The recommendation engine ranks each topic for degree of interest based on user behavior data, user goals, interests of similar users, and organizational requirements. Content on high interest topics are then evaluated for fitness to the learner's current SRL phase for that topic. For example, if the learner is Dabbling in a topic, then brief, entertaining, low difficulty content such as news articles will be rated as high fitness. Lectures and complex skill practice tasks will be rated as low fitness, even if overall topic interest is high. Content on high interest topics with high fitness are prioritized and presented early in the recommendation sequence

In line with Knowles's (1984) first principle of adult learning – "There is a need to explain the specific reasons things are being taught" – PERLS generates a human-readable explanation for each recommendation based on a taxonomy of motivation types. For example, one recommendation might advance a declared mastery goal, while another might be explained as a trending interest among peers, an organizational learning requirement, or as highly rated by people who shares the user's interest on a given topic. Explanations are shown on the card as text "sell points" to help persuade the learner to accept the recommendation and to enhance their awareness of learning needs.

PERLS recommends different kinds of content to address different self-learning needs (Freed et al., 2017). For example, standalone, short duration documents, videos, and podcasts are well-suited to Dabbling and other low intensity learning phases. Study phase recommendations may include complex, sequenced, and lengthy content, possibly including skill practice activities and traditional long-form material. Event notifications, multiple choice "quiz cards," and "action cards," which suggest actions such as setting an explicit learning goal, are used for phase-specific needs not easily addressed with standard formats. PERLS also recommends content native to other applications (Freed, Folsom-Kovarik, Schatz, 2017), some requiring switching to a difference device.

DSCA STUDY

We evaluated PERLS in a range of DoD training contexts, each illuminating different aspects of the described mobile strategy for self-learning support. Here we describe a study in the area of Defense Support for Civilian Authorities (DSCA), defined as:

> "Support provided by U.S. Federal military forces, National Guard, DoD civilians, DoD contract personnel, and DoD component assets, in response to requests or assistance from civil authorities for special events, domestic emergencies, designated law enforcement support, and other domestic activities. Support provided by National Guard forces performing duty in accordance with Reference (m) is considered DSCA, but is conducted as a State-directed action also known as civil support." (Dept. of Defense Directive 3025.18)

DSCA training proceeds in up to three phases. Phase 1, a 6-hour e-course offered by Joint Knowledge Online (JKO), is taken by several thousand DoD and National Guard personnel each year. Phase 2 is a 3-day residential course designed to ready participants to plan and execute DSCA operations. USNORTHCOM runs this course 13 times per year, reaching approximately 850 of 1200 people seen as needing this training. Participants are expected to have completed the JKO e-course within the last year. Phase 3 is informal sustainment, with information made available to course graduates by email and a Facebook Group.

DSCA instructors describe unmet needs at and between each of these phases. The study focused on needs arising between phases 1 and 2—in particular, remediation and sustainment of knowledge from the 6-hour e-course in preparation for the residential course. Through the following six research questions, the study formally evaluated a key aspect of user experience, specifically, users' attitudes about the app's desirability and usability (Question 1) and pilot tested a set of instruments for the app's continuous improvement, including system performance instrumentation (Questions 2 and 3), expanded metrics of user experience (Questions 4 and 5), and learning measurement (Question 6):

RQ-1. Will users report that PERLS is desirable and usable?
RQ-2. Does PERLS software perform well with up to 30 users (e.g., adequate speed, few crashes)?
RQ-3. Will using PERLS be associated with increased self-directed learning activity?
RQ-4. Will using PERLS be associated with increased self-reported perceptions of learning readiness?
RQ-5. Will using PERLS be associated with increased self-reported motivation for self-directed learning?
RQ-6. Will using PERLS be associated with better learning outcomes?

METHODOLOGY

Participants

A sample of convenience was recruited from personnel of the active or reserve military services, state National Guard units, and Federal Emergency Management Agency (FEMA) who were eligible to enroll in the DSCA Phase 2 In-Residence course in June 2017. A total of 61 participated in the study (47 males), divided among the following three groups: 25 assigned to study with the PERLS technology (mobile app), 21 assigned to study with a web course (web course) and 15 who did not use any technology to study (control). Participants were engaged in the research in accordance with human subjects' regulations. All were required to have taken the 6-hour JKO DSCA e-course within the previous year, and most (65%) had participated in a live DSCA training exercise within the previous 3 months. Most participants in all three conditions were between the ages of 31 and 50, and 91% in the two treatment conditions had more than 10 years of experience in the military, National Guard, or FEMA. Nonparticipants were mostly senior officers with greater than 10 years of military service.

Study Conditions

There were three conditions: Participants using the PERLS mobile app for self-directed study in the four weeks preceding the Phase II In-Residence course (n = 25), participants using a 1-hour "refresher" webcourse provided by Joint Knowledge Online (JKO) for self-directed study (n = 21), and a control condition that did not employ any technology for self-directed study (n = 15). Participants in the PERLS conditions could use the app on either a loaner iPod (n = 9) or their personal iPhones (n = 16). They could access up to 126 learning objects of Phase 1 DSCA content during the first 3 weeks of the study, increasing to 150 learning objects in the final, fourth week. They could also access 43 quizzes and 14 "tips" about how to prepare for DSCA events. In the JKO webcourse condition, participants each received a unique URL link by email to the JKO stand-alone 1-hour Phase I DSCA refresher course.

The sample was not assigned to condition randomly since it was most practical and cost-effective to offer installation of PERLS mobile app through an in-person session at one site, in this case, U.S. Northern Command (NORTHCOM) in Colorado Springs, CO. Consequently, there were some key differences between the participants in the two treatment conditions. Most mobile app condition participants (96%) reported in the presurvey that they worked for NORTHCOM, which is the national DSCA training site and which serves as combatant command for all DSCA events in the continental U.S. These participants reported somewhat different goals from the comparison condition, such as wanting to develop DSCA training curricula, plan training exercises, and coordinate national emergency responses. By contrast, webcourse condition participants worked in different locations, and generally wanted to learn DSCA to support their work as regional emergency preparedness officers, battalion commanders, transportation personnel, and military liaison officers. In addition, webcourse participants were more likely than PERLS mobile app participants to have participated in a DSCA training exercise (38% vs 12%), implying greater prior knowledge and greater confidence.

Several factors limited our ability to fully test the described mobile self-directed learning strategy. Participants in the PERLS condition were not permitted to carry mobile devices at work, limiting opportunities for brief unscheduled learning activities. Those who did not own an iPhone, or preferred not to have PERLS installed on their personal device, were loaned an iPod Touch. Several reported in interviews that they did not like carrying an extra device, and chose to leave it at home, further limiting use of unplanned windows of opportunity for learning. Finally, the mobile app included only DSCA-related content, whereas many apps employing a similar user interaction design (e.g. for news) mix content on multiple topics to spur more frequent interaction and help users to develop habits of engagement. Several participants emphasized in interviews that, absent any habit or explicit prompts to use the app, they forgot about it for long periods.

Data Collection Instruments

Two sets of data collection instruments were used. The first (Set 1) supported a Kirkpatrick Level 1 evaluation of user experience, which was the primary focus of the study. The second (Set 2) focused on system performance, user mindset, and learning outcomes, and was included for validation against participant interviews, with the aim of supporting continuous evaluation and improvement of PERLS in future studies and in operational use.

SET 1: USER EXPERIENCE ASSESSMEMT INSTRUMENTS

System Usability Scale (SUS). This was a 10-item survey asking for rating of the mobile app's usability. Scores from this instrument are standardized on a 100-point scale providing an overall usability rating.

PERLS Usability and Desirability Survey. This was a 13-item survey, including 12 questions on a 1-5 scale about specific features of the PERLS mobile app, and 1 requesting a short response describing their overall experience using PERLS.

Self-Directed Learning Technology Usability Focus Group Protocol. This was a 7-question interview protocol to elicit information on how participants used their assigned self-directed learning technology (mobile app, webcourse) to prepare for the Phase II course, what navigational strategies they used to find learning content, what content formats they preferred for learning, what feedback and motivational support features they preferred, and whether they would recommend their assigned learning technology to others.

SET 2: CONTINUOUS IMPROVEMENT INSTRUMENTS

These instruments were all being tested for future use. Some were automated system measures (e.g. of system performance and technology usage). Some were more psychological measures, used to check how well pre-existing, validated instruments would measure the efficacy of PERLS. The validity of these instruments was checked in various ways including statistical tests and interviews with participants.

Online System Performance Metrics. The PERLS system was set up to log basic data on system performance from both the software client and server (e.g., response speed, crashes) and a bug-reporting system was built into the app that allowed users to take screenshots of problems and send emails to developers.

Online Technology Usage Data. Participant usage of both the mobile app and webcourse technologies was tracked through online analytics. PERLS collected timestamped xAPI log data on each user action and every app action visible to the user, a total of more than 13,000 events in all. Google Analytics was used to track webcourse activity at a coarse level, since it was not possible to track at the level of individual webcourse pages.

PreSurvey of Learning Readiness and Participant Background. This was an 11-item survey instrument that gathered background demographics (age, sex), DSCA experience levels, years served in the military, and level of Internet access. Two existing instruments were adapted to estimate motivation impacts of the two technologies (PERLS and the web course). Two items from Bandura's Children's Self Efficacy Scale (CSES) (Bandura, 2006; for instrument validity information, see Usher & Pajares, 2008) were used to evaluate learners' perceptions of confidence and self-efficacy. One item asked participants to rate their self-efficacy on six DSCA tasks. The other asked participants to rate their self-efficacy on eight tasks of self-regulated learning. An abbreviated version of the Instructional Materials Motivation Survey (IMMS) (Keller, 1987; for instrument validity information, see Loorbach, Peters, Karreman, & Steehouder, 2015) was adapted to assess the impact of design and mode of delivery on motivation. In this instrument, motivation to learn is characterized four dimensions: Attention, Relevance, Confidence, and Satisfaction (ARCS), and the questions focus on how features of the delivery mode affect those motivational elements. The survey included 12 standard questions about a participant's degree of motivation in terms of these four motivational constructs, as well as a 13th question we added to differentiate Confidence applying DSCA knowledge in training exercises vs. Confidence for actual disaster events. The survey also included one question about rating the level of technical difficulties encountered with the Phase 1 JKO web course and a short response question asking participants to identify their DSCA Phase II learning goals.

PostSurvey of Learning Readiness. This 10-item survey included some of the same motivational measures as the presurvey to measure change from presurvey to postsurvey: self-efficacy items on DSCA knowledge and self-regulatory learning and the ARCS item. It also asked about additional DSCA-related experiences they may have had during the period covered by the study, technical problems they experienced with their assigned self-directed learning technology, their level of Internet access, and contextual factors affecting their overall experience with the learning technology.

DSCA Pretest Proxy. To reduce the testing burden on participants, the study partners and research team agreed to use the Phase I 6-hour course tests that all participants had taken to qualify for the Phase II In-Residence course as a pretest proxy. Two issues limited the effectiveness of the qualifying test as a pretest proxy. First, participants took this test at different times in the preceding 12 months, so differences in retention were a confounding factor. Second, the JKO course software automatically selects test items randomly from up to three alternatives for each of 29 DSCA learning objectives, so each participant was essentially taking a different test. Differences in difficulty among test items present a second confound.

DSCA Posttest. This was a 23-item assessment focused on 23 out of 29 possible learning objectives drawn from the JKO DSCA Phase I test bank. Six objectives and their associated items were removed because the PERLS mobile app content either did not include complete information on the DSCA content (e.g., role of Coast Guard, Army Corps of Engineers, National Guard) or represented content not tested in the JKO pre-survey (e.g., two learning objectives on National Response Framework). Among the 23 remaining test items, 9 addressed learning objectives associated with Preparedness, 9 addressed learning objectives of Incident Management, and 5 addressed the learning objectives of DSCA.

Procedures

Researchers administered the *Learning Readiness PreSurvey* to PERLS condition participants in person, and then provided each with their assigned technology – either the PERLS mobile app on the participant's personal iPhone, PERLS on a loaned iPod Touch, or access credentials to the online webcourse. PERLS users were provided with written and verbal instructions on how to log in, report problems, and get help if needed, and were advised to try to spend a few minutes a day using the app. Webcourse participants were remotely located, and directed via email reminders and weblinks to the *Learning Readiness PreSurvey* and, on completion of the survey, were linked to a dedicated URL for their own personal instance of the JKO 1-hour DSCA refresher webcourse. *System performance metrics* were gathered continuously in PERLS and intermittently via Google Analytics in the webcourse condition. PERLS users also submitted bug reports (e.g., screenshots and emails describing problems). During the testing phase, PERLS engineers made two changes to the client (app) code and server code, and one change in instructional content. After the 4-week study period, researchers downloaded *Online Technology Usage Data* logs from PERLS servers and Google Analytics from the JKO webcourse. Later, on the first day of the phase 2 residential course, researchers administered several survey and assessment instruments, starting with the *Learning Readiness PostSurvey* and the *DSCA Posttest* to participants in all three conditions. Participants in the mobile app condition additionally completed the *PERLS Usability and Desirability Survey* and the *SUS*. Finally, over the first two days of the course, researchers recruited participants from both the mobile app and webcourse conditions to participate in several *Self-Directed Learning Technology Usability Focus Group*s before, after, and during lunch breaks, and presented participants in the mobile app and webcourse conditions with $10 coffee shop gift cards.

Analysis

For the evaluation of user experience, analysts summarized the ratings and open-ended comments from the usability survey, SUS, selected postsurvey items, and the PERLS focus group data. With respect to instrumentation for continuous improvement, analyses were conducted as follows: To gauge system performance, they summarized logged data and user generated problem reports, and checked via survey items on technical problems and focus groups on the accuracy of the automated reports. To examine system usage, they compared the number of usage sessions between the mobile app and webcourse conditions and characterized the duration and content of learning activity in the PERLS app. They checked these metrics against reports in the focus groups. For the expanded user experience analysis, researchers statistically verified the equivalence of the presurvey self-efficacy and self-regulated learning ratings and the ARCS ratings among the three groups and then statistically tested for differences in the postsurvey mean score ratings among the three groups. For accuracy and background, they checked focus group data. For the learning analysis, analysts conceptually aligned the JKO pretest data with the DSCA posttest by removing 6 non-aligned items from the pretest for all participants. The analysts statistically verified the equivalence of the pretest scores among the three groups, and then statistically tested among the three groups the change scores from pretest and posttest and the differences in mean JKO posttest scores. They conducted an item difficulty analysis of both the pretest and posttest items (difficulty was measured as a percentage of respondents answering correctly).

RESULTS

Main Study: PERLS usability and desirability (RQ-1)

Focus group participants ($N = 31$) expressed almost universally positive reactions to PERLS and to learning in brief intervals with microcontent: *The short content:* "I liked the idea of something with short segments;" "I was able to get through the cards quickly. They were descriptive enough to capture my attention and help me understand the key concepts;" "I like the small stuff. If I have a couple minutes, I can just flip through." *The potential portability:* "I would like to access it at work." *The potential to track learning progress:* "I liked the green check marks," which appeared as an overlay on each completed learning object. They liked PERLS as a complement to the longer form military training coursework: "I liked these for review;" "I wish I'd gotten it sooner after taking Phase I because the … [content] … is hard to remember. This would have helped reinforce that learning." By contrast, the participants in the webcourse group mostly complained about their experience: "My main motivation was finishing;" "I just clicked through to get it over;" "It's pain we all have to go through." However, they did praise the sequenced nature of the content presentation: "I like to know when I'm done with a section. I also like the quizzes that help me verify that I know the content."

Users of the mobile app gave an above average overall rating of 77.28 out of 100 on the System Usability Scale (SUS). Scores from 65-69 are considered average for commercial applications. Most participants (63%) agreed or strongly agreed with the statement "I think that I would like to use this system frequently." This is higher than expected for a training application, and a strong indicator that PERLS users can reap the benefits of continuous learning engagement such as improved needs awareness and improved retention. Participants reported few technical problems with the mobile app, though slightly more than were reported with the JKO 6-hour and 1-hour webcourses.

As noted, nearly all users reported frustration that they could not easily use the app at work due to restrictions on access to personal smartphones on military installations. For example, there was a notable difference in the rating of Internet access between the two groups in the study, with only 58% in the mobile app group reporting "high" access at both work and home as compared to 81% in the webcourse group. In focus groups, participants reported they could easily access the webcourse from their workplace.

Participants made numerous suggestions for enhancing PERLS usability and usefulness. By far, the most common suggestions were to make PERLS more accessible – i.e. to make it available on both mobile and non-mobile devices so they could use it at work, and to make it function when no network connection is available. Other leading suggestions focused on providing better sequencing of learning object recommendations, means for visualizing available content, paths through the content space, progress along those paths, more varied media in learning materials, improved self-quizzing capability.

Responses to the usability survey indicated that users found it easy to *discover* important content in the mobile app (M = 1.92, SD = .91) and to *study* content in the mobile app (M = 2.00, SD = .91) with 1 = very easy and 5 = very difficult. They gave similar high "ease of use" scores for the microcontent and quizzes. They gave an average score to the mobile app for improving their overall sense of preparedness for Phase II (M = 2.84, SD = 1.1). Learners reported liking the app, but lacking sufficient online access or time to use it as much as they intended.

Continuous Improvement Study Research Questions (RQ-2 to RQ-6)

This section reports on the findings from the second part of the study aimed at developing instruments to drive continuous improvement in PERLS without validation from user interviews.

System Performance (RQ-2)

The system dashboard showed uninterrupted, low-latency performance throughout the 28 days of the study (no slowdowns, crashes, loss of data, or service disruptions). Two app updates and the addition of 24 learning objects to the DSCA content corpus proceeded without incident. Of the 19 issues reported by users, 15 identified content problems (e.g. the need to spell out an acronym, or increase font size), 2 were feature requests, and 2 identified minor bugs. Post-study interviews validated the dashboard data, revealing no significant system performance issues, but many previously unreported requests for new features. All key app functions were accessed by users without explicit instruction, and completed without confusion or interruption.

Usage (RQ-3)

As shown in Table 1, most participants used their assigned self-directed learning technology without prompting at least once over the 4-week testing period prior to the Phase II DSCA In-Residence Course. An independent-samples t-test was conducted to compare the number of sessions per user in each of the two self-directed learning conditions. There was a significantly higher number of use sessions for the mobile app (M = 6, SD = 4) compared to the webcourse (M = 2, SD = 2), t (42), 4.61, $p < .0001$. We could not obtain precise measure of total duration of usage for the webcourse, but since the webcourse was designed to be a 1-hour learning experience, we have entered 60 minutes as a proxy. Focus group interviews confirmed that this 1-hour estimate was consistent with user activity.

Table 1. Total usage of PERLS or web course for self-directed learning

	%Participants using Technology Unprompted	# of Sessions M (SD)	Total Minutes of Learning M (SD)
Mobile app (n = 23/25)	92%	6(4)*	72' (57')
Webcourse (n = 19/21)	90%	2(2)	60'

* t = 4.61, p < .0001

On average, PERLS mobile app users spent slightly more time learning (72 in PERLS vs. 60 minutes in webcourse), which could be attributed to learners' greater willingness to engage in or browse the PERLS microcontent. However, PERLS users covered less breadth of material (100% in the webcourse vs. 29%, in PERLS, based on 10% coverage in weeks 1-3 and 19% in week 4; see Table 2). Some difference in breadth of coverage was considered likely based on the different instructional strategies employed. In particular, the webcourse was designed to move the learner steadily and sequentially through all specified material in a fixed (1 hour) period, while the mobile app let learners decide for themselves what content best aligned with their needs, interests, available time and attention span, but did not guarantee coverage. The large difference in breadth of material covered could result from any of several factors including: difference in time spent internalizing information in the course-structured vs. self-directed

Table 2. Patterns of PERLS usage

PERLS Usage	Weeks 1-3 M(SD)	Week 4 M(SD)
% of Total Learning Objects (LOs) Browsed	13%(15%)	22%(16%)
% of Total Learning Objects (LOs) Played	10%(13%)	19%(15%)
Mean Minutes per Session	11'(5')	
Mean Minutes per Day	16'(12')	
Mean Minutes per Week	38'(39')	

Note: Total LOs was 126 in weeks 1-3; 150 in week 4

conditions, difference in amount of time spent transitioning in and out of learning activities, or participants in the mobile condition strongly prioritizing the content they find most interesting or relevant. Since many course participants described the web course as "drinking from a fire hose," it seems likely that time spent internalizing mobile content was a large factor.

PERLS usage spiked in the first and, especially, fourth weeks of the study—corresponding to the initial week of the study and the week immediately preceding the Phase 2 course. As indicated in Table 2, on average, users looked at almost twice as many recommendations (cards) and completed almost twice the number of learning objects in the final week of the study as they did in the previous three weeks combined. A closer look (see Table 3) indicates that there were several overall usage patterns. A large number of participants ("crammers") used PERLS almost exclusively in the final week. A smaller group ("explorers") used it primarily in the first week. And a final small group ("continuous learners") used it throughout the study.

Table 3. PERLS Usage over Time

Week	# of Users	Minutes of Usage M (SD)
1	15	23'(17')
2	9	19'(19')
3	5	33'(58')
4	16	55'(42')

Attitude Metrics: Readiness and Motivation to Learn (RQ-4 and RQ-5)

Researchers reviewed how participants in both self-directed learning conditions rated their post-survey self-efficacy conducting six DSCA tasks. Initial analysis showed both these groups gave themselves significantly higher ratings than participants in the control condition [F (2, 57) 3.40, p = .04]. However, when the 13 participants who engaged in a DSCA training exercise during the study period were removed from the sample, the difference became statistically insignificant, although the positive trend for preferring the 1-hour webcourse and the mobile app as compared to the full 6-hour webcourse condition was still reflected in the three group mean ratings: (Webcourse M = 5.61 (1.97); PERLS M = 4.62 (2.41); Control M = 3.99 (1.89). A statistical test of the change in self-efficacy ratings from presurvey to postsurvey in the two self-directed learning conditions indicated only the webcourse condition significantly improved. This result was statistically significant both with all study participants [t (20) 4.28, p <.0001] and when those who participated in a DSCA training exercise during the study period were removed ([t (12) 3.32, p <.006]. These results countered expectations that the PERLS app would improve self-efficacy and confidence, as this instrument detected no change. The explanation for this outcome could be several things. First, as many PERLS users requested increasing the number of assessment questions provided by the app, it is possible that increasing feedback would increase confidence. Second, the focus group participants noted that PERLS alerted them to gaps in their knowledge-—an important trigger for adult learning (Marsick & Watkins, 2001)—while the webcourse provided a more supportive learning experience, possibly falsely enhancing a sense of confidence and stimulating boredom—an explanation consistent with focus group feedback and studies into judgments on learning (JOL) (Koriat & Bjork, 2005) and studies into boredom's negative effects on online self-directed learning behavior (Baker, D'Mello, Rodrigo, & Graesser, 2010).

Perceptions of self-regulated learning skill did not significantly improve from presurvey to postsurvey in either treatment condition nor did it differ among all three conditions. However, specific aspects of the self-regulatory skill improved significantly consistent with features of the two self-directed learning technologies. For instance, learners using the mobile app reported a significant improvement in getting themselves to "study DSCA outside work" and using "military and FEMA resources to get DSCA information," while webcourse learners reported significant improvement in arranging "a place to study DSCA without distractions" and remembering "information presented in DSCA online courses." Based on feedback during the focus groups, we speculate this result may be related to webcourse participants' perception that they were required to set aside dedicated time to complete their studying. By contrast, mobile app users described taking time to study over breakfast, while playing with the family dog, standing in line at a store, or late at night before going to bed. All participants in all three conditions reported statistically similar above-average levels of readiness to learn in Phase 2 [M = 7.56 (2.58) (mobile app); M = 8.48 (1.40) (webcourse); M = 7.93 (2.2)]. These results indicate that the app and webcourse technologies influenced self-perceived self-regulatory skill in the context of specific self-regulatory routines. Future instrumentation should be amended to identify and assess the effect of specific routines.

On the ARCS survey items, participants gave slightly higher ratings of motivation to learn from both the mobile app and the webcourse as compared to the 6-hour course but a four-way analysis of variance test showed these differences were not significant. PERLS users exceeded webcourse users in rated "satisfaction," while webcourse users indicated higher attention, relevance, and confidence. Though not statistically significant, these results were consistent with comments made in focus group interviews. In particular, interviewed PERLS users indicated much higher enthusiasm and satisfaction with their user experience than did web course users. One-hour web course users seemed reassured by the simple linear structure of the course and made favorable comparisons to the original 6-hour version: "The content was more simplistic, and easier, than the 6-hour course;" "I'd recommend it particularly for those who haven't taken Phase 1 in a long time." Overall, the results indicate that all participant in this high-performing group were effective in finding ways to self-motivate for learning no matter the variations of design and delivery in the learning system.

Learning Outcomes (RQ-6)

After confirming statistical equivalence between the baseline pretest scores in all conditions, the mean posttest scores were compared among all three conditions, finding no significant differences. Analysts checked for change between pretest and posttest, finding significant declines in both self-directed learning conditions [Pretest M = 60%; Posttest M = 50% (t (30) -2.57, p = .02)]. Further analysis revealed lack of alignment between pretest and posttest at the level of learning objective, a result of variation in item formats and item difficulty. In effect, individual participants effectively took quite different pretests—with some taking easier pretests than others. The posttest scores alone are not a sufficient indicator of learning since learners in each group could have started with different levels of prior knowledge. Indeed, this was likely since more webcourse users had participated in a DSCA training exercise than had the PERLS users. Therefore, this study's findings related to the measurement of DSCA learning are inconclusive. In the future, learning measurement needs to strictly follow protocols of matched pretests and posttests, and not attempt to use pretest proxies that employ unstable measures.

CONCLUSION

In reviewing the results, we found that PERLS functioned well and received strong, positive endorsements for both microlearning and the specific user experience provided by the app. Despite significant barriers to access, mobile app participants showed a small but significant increase in frequency and overall time spent in self-directed learning over the web course users. Users expressed strong interest in having a mobile self-learning capability built around microcontent, giving the app high ratings for usability and expressing a desire to use it more. The view that "less is more" came through in both focus groups and survey results; learners preferred microcontent to traditional course content, and preferred the 1-hour webcourse to the 6-hour version.

Analyses of mobile app log data showed many participants using the mobile app to "cram" towards the end of the study period in preparation for the phase 2 DSCA course. Thus, future PERLS development should focus on how to foster more frequent usage, which improves retention. To this end, PERLS focus groups suggested relevant future refinements, such as making the capability more accessible in military workplaces, providing more sequenced browsing, and making the full contents of the corpus more visible for browsing and searching.

One limitation of the study was the small sample and the convenience assignment to condition. As a result, there were some biases in the sample that could have affected the results, such as a relatively high percentage of webcourse participants who had taken part in a DSCA exercise during the four weeks prior to the Phase 2 in-residence course. Further, the sample focused on seasoned members of the military, and so has limited generalizability. It would be useful in the future to test the self-directed learning capability with a more different sample of learners.

To close, it is helpful to frame these results against the past half-century of research into adaptive learning technologies. The PERLS approach to supplemental learning relies on learner choice and agency, a core goal of learning technology research (Crooks & Klein, 1996; Salden, Paas, & van Merrienboer, 2006). While this approach allows learners to control cognitive load while improving their sense of agency and motivation, research also has shown that learners do not consistently make optimal choices to ensure learning (Scheiter & Gerjets, 2007). To address this challenge, researchers of adaptive learning technologies have explored the use of data mining techniques to recommend the most effective content (Lee, Lee, & Leu, 2008). In a similar vein, data from this sand other studies should be used to refine PERLS the recommendation system to better align with the user preferences about when and what to learn, and to align with findings on the optimal time to learn for achieving desired learning impacts.

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