# Designing a mobile system for lifelong learning on the move

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**Abstract**        The Life-long Learning Initiative seeks to fulfil a variety of learning needs for Shanghai citizens. Given the popularity of mobile devices in Shanghai, the ability to provide learning in informal settings through mobile devices is a key objective and challenge of the Initiative. In order to learn how to develop usable learning content for lifelong learners on the move, a set of design principles from both pedagogical and usability concerns was identified. Next, a pilot system, based on the design principles, was developed to implement two prototype lessons. Five subjects were recruited to test each prototype lesson using a heuristic walkthrough method and a focus group meeting. Users' feedback showed that both the practical and the micro principles were valued as a method of integrating learning activity into informal settings in their daily lives. Audio was preferred as well. Technical usability concerns which are consistent with previous web experience were also identified. This research builds new knowledge about design principles for lifelong learning on the move and is a milestone in the development of the future learning resource bank for Shanghai citizens.

**Keywords**       design principles, learning content, lifelong learning, mobile learning, user experience.

## Introduction

The rapid advance of wireless, pervasive and ubiquitous computing has potential to enable 'anyone, any time, anywhere learning' as a fourth wave of educational revolution (Sharples 2000; Patten *et al*. 2006). Harnessing the power of ubiquitous computing in support of learning in informal settings is increasingly recognized as an important goal and challenge in bringing the benefits of technology to everyday life (Fischer & Konomi 2007; Sharples 2007; Clough *et al*. 2008).

Similar to trends of other countries throughout the world (Kukulska-Hulme *et al*. 2007; Clough *et al*. 2008), mobile phone ownership has reached 56.3% in

China in 2009; this percentage is much higher in Shanghai at 119.9%, with more than one mobile device per person (MIITC 2009). Given the ready-at-hand availability of mobile devices, it is reasonable to target mobile learning as a key solution for lifelong learning in Shanghai, as well as recognize that lessons learned in developing lifelong learning on the move in Shanghai should have scholarly and practical benefits for other communities and the broad field of mobile and lifelong learning research.

The Life-long Learning Initiative was created by the Shanghai government to build an open, accessible learning network for all Shanghai citizens regardless of lifestyle or status for all kinds of learning purposes, so as to achieve the goal of becoming a learning city for 'anyone, anytime and anywhere' (Wang *et al*. 2009). The goal is for all forms of learning activities mediated by a variety of access technologies to constitute a network for lifelong learning. The unique attributes of

mobile device offer great potential to support lifelong learning outside of formal situations (Ultralab 2003; Fischer & Konomi 2007; Clough *et al*. 2008; MOTILL 2009); therefore, the Initiative sees mobile learning as a solution for fulfilling purposes of lifelong learners who pursue practical learning as needs emerge in their daily lives (Gu *et al*. 2009). For our purposes, mobile devices enable users to access purpose-driven content for intentional learning when and where it is appropriate to meet their needs (Sharples 2000; Clough *et al*. 2008).

In order to make use of mobile technology to support lifelong learning, content needs to be applicable, acceptable and comfortable for mobile delivery. Based on previous studies on mobile learning and especially mobile technologies for lifelong learning, we proposed a set of design principles, characterized as practical, 'micro', and usable, for developing learning content intended for mobile users in an informal setting (Gu & Gu 2008). Following these principles, a framework for developing lifelong learning on the move has been created (Gu *et al*. 2009). In this study we will examine users' experiences with prototypes of learning products, with the goal of verifying and improving the design principles and the mobile system for lifelong learning. The long-term goal is to build generalizable, evidenced-based design principles for lifelong learning on the move and to develop a mobile learning resource bank for the lifelong learning network. This study contributes new knowledge about the value of following a set of design principles to create usable learning materials for learners on the move.

### Design of mobile content for lifelong learning

Lifelong learning has been broadly accepted as a means of improving knowledge, skills and competence in social lives for people throughout the world (Aspin & Chapman 2000; Longworth 2003; Koper & Tattersall 2004). Efforts have been taken to establish distributed lifelong learning network for all (Koper *et al*. 2005), to equip learners with tools for learning as well as tools for living (Sharples 2000; Sharples *et al*. 2002; Fischer & Konomi 2007), so as to provide tools and techniques for learners with which they can learn according to their own needs and styles (Longworth 2003). Because technology enables us to be connected while mobile across place, time, and context (Sharples 2000; Vavoula & Sharples 2009), mobile technologies

have the potential for people to access learning at anytime and anywhere in a rapidly changing world (Waycott *et al*. 2005; Patten *et al*. 2006; De Jong *et al*. 2008).

Sharples (2000) pioneered the design of mobile technologies for lifelong learning, in which users could be equipped with mobile carrying content as tools for lifelong learning. Meanwhile, the past few years have witnessed growing interest for mobile learning and the new opportunities it can create for learning in a variety of contexts (Roschelle *et al*. 2005; Kukulska-Hulme *et al*. 2006; Clough *et al*. 2008; Frohberg *et al*. 2009). Current mobile learning projects offer few lessons and only broad guidelines for designing content for mobile learning (Bradley *et al*. 2005; Churchill & Hedberg 2008), especially for developers of lifelong learning materials about what users 'want to use' given their busy schedules and how the materials should be represented. In identifying principles for designing mobile content for lifelong learning, we started by examining two foundations for learning design from previous studies: pedagogical and usability design.

### Pedagogical design

Lifelong learning is an inseparable part of daily lives for addressing immediate problems, gaining understanding or practicing a skill wherever the needs emerge (Sharples 2000; Fischer & Konomi 2007). Therefore, it is critical to design practical content that can be easily integrated into practice.

Efforts to meet real-time practical needs have been investigated in some studies of informal learning settings with mobile devices (Ultralab 2003; Fischer & Konomi 2007; Tsai *et al*. 2007). In order to engage young adults in 'm-learning' activities to promote their lifelong learning, content was developed which was close to their needs in life, as well as appealing to popular trends (Ultralab 2003). In a Patient-Centered Assessment and Counseling application, mobile devices were used as a successful self-monitoring tool which could meet users' needs whenever the needs occurred in real time (Tsai *et al*. 2007). Fischer and Konomi (2007) reported their study of an information access and contribution system as an instance of lifelong learning supported with mobile technologies, in which the content was extended by end-users' contributions for meeting their everyday needs. Lessons from

these studies are that content must be useful, engaging, and suited to everyday needs for communication, reference, work and learning; these practical learning needs also meet Sharples *et al.*'s (2002) general requirements for lifelong learning.

Meanwhile, it is also critical to design micro content that could be integrated into the busy schedule of lifelong learners as well as compete against distractions while on the move (York 2004; Chisholm 2005; Hug 2005; Leinonen 2007). Prior studies offer some guidance for micro design in terms of information and activity (Hoppe *et al.* 2003; Hsi 2003; Bradley *et al.* 2005; Churchill & Hedberg 2008; Kim 2009). For example, the multimedia alphabet lessons that Kim (2009) designed for mobile learning were less than 2 min in length and gave text first priority over any animation. According to Hoppe *et al.* (2003), restructuring content into small pieces for discussion purposes and providing just-in-time training for specific skills were cited as successful approaches to content delivery with mobile devices. Small, self-contained units or chunks of learning materials also were found more likely to fit into small time slots extending the flexibility of use in Bradley *et al.*'s (2005) study. Another successful approach was the use of pictures with short text blocks which were designed into a portable museum guidebook to enable navigation given limited screen size in Hsi's (2003) field trip mobile application. Because contact with handheld devices is typically only for a short time, Churchill and Hedberg (2008) recommended that design should be task centred and be provided in a single action. Although the characteristics of the end users are different across these studies, the common lesson is to design information and activity in a granular fashion to minimize being overwhelmed by fragmented access to content on a small screen.

## Usability design

Usability is a recurrent theme in mobile learning studies mostly due to the physical limitations of the devices and the fragmented nature of mobile interaction (Wagner 2005; Kukulska-Hulme 2007; Clough *et al.* 2008). Therefore, it is also important to address the challenge of designing usable products for lifelong learning on the move.

Usability is defined as a system's overall acceptability. Usable systems are regarded as being reliable,

compatible, efficient and effective to use as well as enjoyable for users (Nielsen 1994; Kukulska-Hulme 2004). Putting it simply, usability provides a kind of user experience that people not only can use but also 'want to use' (Dix *et al.* 2004).

A review of Kukulska-Hulme (2007) provides an in-depth view of usability requirements for designing mobile learning. While general usability standards might apply, additional considerations are to be taken into account which are (1) compatibility with features of mobile learning 'tasks', such as, time and effort to complete a task; (2) flexibility of use; and (3) users' attitudes. Kukulska-Hulme (2007) further articulated usability requirements by including the following pedagogical usability components: learner control, learner activity, motivation and feedback. Implementing features to address these pedagogical concerns goes beyond merely technical aspects of usability and must be given precedence for the design stage. Additional usability design guidelines that can be found in Churchill and Hedberg (2008) include recommendations for screen presentation, minimizing scrolling and matching the task.

## Design principles

Based upon the pedagogical and usability issues for design described above, we identified a set of design principles for content, activity and usability.

### *Content: practical and micro*

*Practical.* There is a tension between designing learning content that will attract users and content that will fill their in-between moments. Addressing practical needs is the first principle in our design. To fit the nature of lifelong learning, content should be practical so it is easy for users to engage with while still in the flow of their routine daily performance (Sharples 2000; Fischer & Konomi 2007). For example, real-world needs can be addressed by having a how-to-do list as a reference in an emergency situation, or a cluster of words associated with the users context for casual review. In order to meet the requirement of this practical principle, so far we have identified an open framework for developing practical mobile learning content, based on analysis of various groups of users, and their potential use contexts; further, in order to meet users' real-world needs, we introduced current needs that users were seeking by

coding and analysing the frequent needs in the top three popular web sites for Chinese users, including Baidu, Google and Tianya, where users could obtain referential resources, tag on the resources interested to them, or make a new request if what they are seeking is not available there (Gu *et al.* 2009).

*Micro.* Meanwhile, the micro principle recommends having learning content fit into the fragmented time slots which are likely to be the majority of opportunities for everyday folks to access learning. Developing micro content items as small, self-contained and granular learning objects suitable for mobile delivery fits the micro principle (Leene 2006; Sampson 2006). Self-contained learning objects provide a particular referential usage in a particular use context; meanwhile, nearby micro learning objects could also be loosely joined with each other to meet particular usage needs (Leene 2006). Making learning objects micro means dividing objects into as small of chunks as possible; meanwhile, the media format which carries the content needs to also be as simple as possible, where options are provided for users to choose media formats appropriate to their contexts (Gu & Gu 2008).

### *Activity: micro and simple*
Learning activity needs to also be understood as granular, with only one action for one activity (Churchill & Hedberg 2008), such as listening, reading or pushing a button to input feedback. Given the fact that self-directed knowledge acquisition enabled by micro content is the main learning interaction, the learning process is also characterized as a series of 'micro' activities such as 'listen, input' or 'read, select'. With the intention of integrating these kinds of activity seamlessly into daily-life streams (Rieger 2007), simple activity should be designed into the content for meeting the requirements of the potential learning context (Gu & Gu 2008).

### *Usability: consistent and simple*
Along with the pedagogical design principles for content and activity, conventional usability principles mainly relate to interface design, where navigation, control, feedback, error control, consistency and user satisfaction are equally needed in design (Kukulska-Hulme 2007). Consistency in the interface is embodied in navigation, menu, button, colours and feedback in

learning objects. Specifically, usability considerations for mobile learning focus on the needs to keep learners' attention and to keep content fresh in their mind (Nielsen 2001). These considerations will be achieved in our design by highlighting, repetition, and feedback, along with having small content chunks and short media presentation times (Churchill & Hedberg 2008). Additionally, content will be developed to take advantage of the available sense in a mobile situation. Usually mobile users can listen, so audio content is given a high priority. As visual attention may be brief and easily distracted, texts can be simplified and when possible accompanied with pictures (Bradley *et al.* 2005; Kim 2009). Interaction needs to be simplified into button clicks. Multimedia will be used only when sensory richness is required by the learning content and context (Bradley *et al.* 2005). Consistent with the micro principle of content, media presentations will be no longer than 3 min when possible. Given the variety of requirements which must be met to insure usability, previous research (Bradley *et al.* 2005) recommends that design decisions strive to create a balance between simple media and multimedia richness.

## Products description

Guided by design principles for content, activity and usability, our research group has been developing products for learning on the move. This report describes the evaluation of how well the application of the design principles supports the use of two products. These products serve as prototypes for what we expect will be typical of mobile applications for the Life-long Learning Initiative. Specifically, the products were designed for mainstream mobile phones with a resolution of $240 \times 320$ pixels and $320 \times 240$ pixels, and for use across potentially different contexts in Shanghai. The first is a Basic English lesson for the World Expo, and the second is a lesson about how to change a tire in case of a flat.

### *World Expo English*
The learning product of World Expo English was developed with FlashLite 2.*x* and Actionscript 2.0; it could be loaded on any mobile phone with the FlashLite Player, which is common for mainstream systems such as Symbian Series, Windows Mobile and Linux. The objective of the product is for Shanghai citizens to pick up useful English words and dialogues so as to better

Fig 1  Screen of world expo English.

host the World Expo 2010. Pedagogical as well as usability design principles have been incorporated in its design. First of all, World Expo English is currently one of the most practical learning needs in Shanghai as the World Expo 2010 was approaching at the time of its development. Next, content items were divided into self-contained small chunks of word clusters, dialogues and readings. Related words were assembled into a micro learning object; practical dialogue such as the topic about picking up a guest in the airport was also designed as a micro learning object. Next, readings were designed individually as a learning object to keep it micro. As Fig 1 shows, these micro chunks help users to make useful reference in a small time slot and to learn only one word or a cluster of several related words, or only one dialogue, with simple learning activities such as listening and clicking on a button. The size of the learning material is approximately 350 k, with the limited memory of mobile phones being taken into consideration.

Moreover, the icon for the blue World Expo 2010 logo is consistently used for both the selection and menu buttons. Although context-aware design was not articulate in our principles (Bradley *et al*. 2005), context-related pictures are used to make the words and sentences more meaningful. In addition, audio is mainly used along with simplified text, pictures and buttons. In some cases, a piece of text is highlighted and relevant audio is repeated to help users focus on the main information. Users can also request a repeat of particular information with a single button click.



Fig 2  Screen of six-step change tire.

*How-to-do list for tire changing*

The second product is the Six-Step Change Tire, which is anticipated to be one of a series of emergency skill lessons for driving in the country. As a self-contained learning unit, the Six-Step Change Tire illustrates the process of changing a tire with a series of pictures, and it is design to be downloaded into any mainstream mobile phone. Figure 2 shows its screen.

The result of the aforementioned analysis of the top three popular web sites showed that emergency skills when driving in the country are practical for a particular group of users who have limited knowledge or experience about emergency procedures. As one of these skills, how to change a tire is designed into a micro unit, and the content items are divided into small steps for users to follow. In addition, given the context of its usage, pictures with simple text are used to illustrate how to do each step of tire changing. The user simply clicks on the 'previous' or 'next' button to follow the how-to-do series of steps to finish the task.

**Evaluation method**

A heuristic walkthrough method along with a follow-up focus group meeting was used to assess user experience

with the pilot versions of the two products. The data collection framework is a set of questions derived from the design principles for pedagogical and usability objectives. The heuristic walkthrough protocol was developed by combining the advantages of heuristic evaluation, cognitive walkthroughs and usability walkthroughs (Sears 1997). The protocol included a list of heuristics, a list of user tasks and a list of thought-focusing questions in the protocol. Table 1 shows the 18 heuristic questions developed according to the design principles, with 5 questions about content features, 3 questions (overlapping with questions from the other two features) about activity features and 13 questions about usability features. Sixteen evaluation tasks, along with follow-up think-aloud questions, were developed based on the heuristic evaluation method of information systems (Nielsen 1994; Sears 1997). Finally, a question list was designed to guide the focus group meeting as data triangulation, the design of the questions and data assessment were also based on the set of design principles.

The participants were volunteers recruited from university students and employees of the Distance Education Group where this project was conducted. These volunteers represent typical potential end-users of the tested products. According to Nielsen's five users test rule (Nielsen 2000), five evaluators participated for each product evaluation. The evaluation of Expo English was carried out in our usability testing lab by two males and three females, between the age of 20 and 35; three of them are university students, and the other two are office employees, with middle level of English. All of them have been using mobile phones for more than 5 years; one of them has a little experience with mobile learning. The five evaluators individually evaluated Expo English using the heuristic checklist and attended focus group afterwards, guided with a question list.

The Six-Step Change Tire was evaluated by five evaluators outside beside a car, with tools mentioned in the learning product such as a spare tire, a wrench and a jack within the trunk. The five participants including four males and one female; all have a driver's license and have at least 1 year of driving experience. Three of them were between the age of 25 and 35 while the other two were 49 and 50. None of them had a prior successful experience with changing a tire. One of the participants once tried changing a flat tire himself but failed. The five evaluators evaluated the how-to-do list using the

**Table 1.** Heuristics questions.

**1. Content-micro and practical**

| | |
|---|---|
| 1 | Is (are) the length of the content (activities) short enough to be focused and studied on the move? |
| 2 | Are the learning materials self-contained units or chunks, can they be fit into small time slots? |
| 3 | Is it overwhelming to learn in a fragmental way with a small-sized screen? |
| 4 | Is only (all) the information that is essential displayed on the screen? |
| 5 | Do the learning materials serve your (or potential users') practical learning needs? |

**2. Activity – micro and simple**

| | |
|---|---|
| 1 | Is (are) the length of the content (activities) short enough to be focused and studied on the move? |
| 2 | Is it overwhelming to learn in a fragmental way with a small-sized screen? |
| 3 | Is the audio (clear enough to be heard and) easy to select while studying on the move? |

**3. Usability**

| | |
|---|---|
| 1 | Do you feel comfortable with the layout and style of the interface? |
| 2 | Are navigation and important information items consistent from screen to screen? – Consistency of menu items (bottom, right or left). |
| 3 | Are there no more than four to seven colours, and are they far apart along the visible spectrum? (Readable, consistent, and soothing colour, colour combination) |
| 4 | Does each icon stand out from its background? |
| 5 | Is the menu-naming terminology consistent with the user's task domain? (Is the menu language clear?) |
| 6 | Is there visual feedback when an object is selected? (highlight of active menu) |
| 7 | Are you well informed of where you are in the learning materials? |
| 8 | Can you go back to a previous menu or change to an earlier menu choice? |
| 9 | Are there clearly marked exits? |
| 10 | Are text, sound, pictures and animation well integrated? |
| 11 | Are pictures and text clear enough to be displayed on the small screen? |
| 12 | Is the audio clear enough to be heard (and easy to select) while studying on the move? |
| 13 | Does each learning material include necessary media? |

heuristic checklist and attended a focus group afterwards, with a slightly different question list than the Expo English group guiding the discussion.

The mobile phone used in the tests was a Nokia E66 [Nokia Telecommunications Ltd. (NTL), Beijing, China], it has a Symbian 9.2, Series 60 Version 3 operation system with FlashLite Player, a 2.4 inch screen, resolution of $240 \times 320$ pixels (QVGA) and 16.7 million colours. Evaluated products were loaded before the test. Participants only needed to be familiar with direction keys (up, down, left, and right) and functional keys (left, right and OK) before starting.

Evaluators were asked to think aloud during a two-pass walkthrough process with the guidance of the task list, usability heuristics list and thought-focusing questions list. The walkthrough sessions were recorded to capture all details of the performance.

In Pass 1, evaluators explored tasks from the task list and used a think-aloud protocol. Before conducting the task, they could spend several minutes to become familiar with the keypad of the mobile phone used for testing and the function of its buttons if they thought it was necessary. Prior to beginning the session, the evaluators went through each item on the task list and the heuristics checklist to clarify any questions that they might have about the evaluation criteria.

During Pass 2, the evaluators were allowed to explore any aspect of the content they wanted while looking for usability problems guided by the knowledge gained during Pass 1. They could spend as long as they liked identifying problems. Participants were also asked to use a think-aloud protocol during pass 2 and were prompted to consider the thought-focusing questions, such as 'Does this piece of content serve users' knowledge seeking needs?', or 'Once users find the control, will they know how to use it (e.g. press the left/right direction key, OK button, functional keys on the mobile phone)?' Following the task process, evaluators were asked to make a choice of 'Yes', 'No' or 'N/A' in the usability heuristics checklist (see Table 1).

To conclude the evaluation process, a focus group meeting with the evaluators was conducted to discuss user experience with the pedagogical and technical features and probe about the implementation of design principles. Participants in the focus group were asked to speak freely.

## Findings

Data from the heuristic evaluations were analysed along with the data from focus groups and think aloud sessions. The heuristic results showed that Expo English meets 83.3% of the evaluation criteria, while the Six-Step Change Tire meets 93.3% of them. Because of the difference in mobile learning content, three criteria were not applicable for evaluating the Six-Step Change Tire. These non-applicable criteria were not included in the review statistics. Table 2 shows heuristic results for each of the 18 heuristics reviewed. The three questions about activity feature were overlapped with questions from other two features and were not included in the final statistics.

Table 2. Heuristic results.

| Heuristic | Number of criteria | Yes | No | N/A | Percentage of criteria met |
|---|---|---|---|---|---|
| Content | 5 | | | | |
|   Expo English | | 5 | 0 | 0 | 100 |
|   Six-Step Change Tire | | 5 | 0 | 0 | 100 |
| Activity | 3 | | | | |
|   Expo English | | 3 | 0 | 0 | 100 |
|   Six-Step Change Tire | | 2 | 0 | 1 | 100 |
| Usability | 13 | | | | |
|   Expo English | | 10 | 3 | 0 | 76.9 |
|   Six-Step Change Tire | | 9 | 1 | 3 | 90 |
| Total | 18 | | | | |
|   Expo English | | 15 | 3 | 0 | 83.3 |
|   Six-Step Change Tire | | 14 | 1 | 3 | 93.3 |

## Findings for content design

Both of the evaluations of the products reported positive views on the content of the mobile learning units. The length of the content was thought short enough to be focused, and the self-contained units could be fit into small time slots; only essential information was thought to be displayed on the screen. No concerns were expressed about the fit of the units with the fragmented way users expected to have when accessing the content on the small screens. In the think-aloud session, when asked to think about the length of the content, one of the evaluators said 'I like the (reading) paragraph to be short, this length is more suitable when I'm waiting for the metro than that I usually used'. Similarly, another participant expressed her preference for the small dialogue by comparing her own experience: 'I think I can only catch the first two or three sentences when listening on the move'; this micro length seemed more favourable to users like her who sometimes need to pick up learning which will not make them feel overwhelmed. In addition, the walk-through process showed that the content was really micro: the time needed for the self-contained content chunks in Expo English were averaging 101.2, 107.4 and 116.4 s for the participants to finish the chunks of word learning, dialogue learning, and reading. Meanwhile, the evaluation process of the Six-Step Change Tire also showed that the content design is simple and straightforward, with an average 68 s for the participants to walk through the whole process.

The contents of the lessons were judged to be practical by the participants. During the focus group the evaluators of the Six-Step Change Tire reported that it helped them to know how to complete the process if an emergency occurred. During the think-aloud session, when asked if they felt that the content was useful, every participant expressed that they might need this kind of learning resources some day; two of them were eager to keep them for later reference in their own cell phones. One of the males said that it would serve his purpose in case that no one can help him when he was alone on the road with a flat tire, and he would try to do it by himself step by step according to the list. The female participant wanted to keep the tire changing content for her husband. For the evaluators of Expo English, they reported in the focus group session that they found it useful for them to review the words related together with World Expo, even though they already had a middle-level proficiency of English. As one of the evaluators stated, clustering the words related to a certain situation would remind him of their use and help him learn better.

However, evaluators also expressed higher expectations for the practical value of the content found in the products. For the Expo English, evaluators reported that if they needed to find a particular word or a sentence, then this lesson would need to be improved. In focus group meeting, an evaluator expressed disappointment: 'I knew it's not a dictionary, but sometimes we need to look for a particular word'. Similarly, one of the evaluators indicated in the think-aloud session that it would be helpful to include how words are used as well as definitions. For the Six-Step Change Tire the evaluator who had the failure experience of changing a flat tire suggested that additional skills of changing a tire should also be included in the how-to-do list to make it more practical and make tire changing a simpler task. Although participants in the tire change evaluation reported that from the lesson they felt they learned how to change a tire if an emergency occurred, some of them mentioned that it was still hard to tell if they would actually be able to change a tire.

## Findings for activity design

Participants had positive views of how the micro and simple design could be integrated into their activities. Along with the result from heuristic evaluations that there was no overwhelming concern for fitting the units into their active lives, participants also reported support for the way the designs could fit into their activities during the focus group. Specifically, with only one button click needed during any of the learning chunks, participants reported that they were likely to use this kind of learning product while waiting or even on the move. The same participant who preferred the small dialogue mentioned earlier said in both the think-aloud and focus group sessions, 'most of my friends and I like to do something when waiting', and she thought the small content with occasional one button click was exactly what they would like. Similarly, other participants were also confident that the simple way the Expo English activities are represented, along with the small amount of content in each unit, could keep pace with being on the move and only having short amounts of time for these types of informal learning activities in

their daily lives. Likewise, the granular design of activities and the use of simple button clicks in the Six-Step Change Tire unit were viewed as straightforward and a good fit for activity needs.

### Findings for usability design

Both positive and negative points were found regarding technical usability. A main challenge of usability noted by participants related to the challenge of consistency.

The walk-through process showed that all the evaluators felt comfortable with the interface of Expo English; the heuristic evaluation result of 67% showed that evaluators were satisfied with most parts of the interface and its consistent design, including the layout, style, colour, navigation, and control. It was reported that the repeat button was easy to operate and helpful when the dialogue and words need to be reinforced. Highlighting received positive reports in attracting attention, especially in the context of knowing their attention would be fragmented. Except for the three non-applicable criteria, all of the interface design questions in the Six-Step Change Tire received positive points. Evaluators felt satisfied with the consistent designs of layout, colour, navigation and control. Highlighted spots in the pictures helped them to focus on the key part and attracted their attention as well.

On the other hand, there were negative points about the lack of consistency in the design drawn both from the heuristic evaluation and the focus group session for Expo English. For example, consistency of button use needed to be improved. It was found that even a seemingly imperceptible deviation of position would lead to a usability problem on the small screens. One of the evaluators murmured in the think-aloud session that a button was moved, and suggested in the focus group that button placement distracted attention during the task, and it would be even more of a distraction when used on the move. The highlight feature was also reported as needing to be more salient to make clicking easier. Another weakness was reported for the words cluster chunks. Users expected to know how many words were in a cluster and how many were in the previous cluster as well as how many are left to be viewed, even though there were only five or fewer words in total. No consistency problems were reported for the Six-Step Change Tire.

The appealing nature of the media presentation was mentioned as a positive feature of the Expo English during the heuristic and focus group sessions. All of the evaluators thought audio was a good fit for language learning, especially a good fit for mobile learning on the move. For the parts that required reading, there was some impatience expressed in the walk-through session by two of the evaluators, even though the text had already been simplified. It was verified during the focus group meeting that audio of the reading text was also the preferred media presentation. Pictures accompanied with dialogues were thought to be helpful for providing the context for usage. Evaluators felt they did not expect multimedia to be used in presenting the word cluster or dialogue but felt it would be better if the unit of reading was presented with multimedia, with simplified text, and contextual pictures or videos, as well as audio reading.

Towards the principle of simple and appealing media design, two of the four criteria received positive points with the exceptions being the non-applicable items for the Six-Step Change Tire. In the focus group, evaluators expressed that the picture series was enough for them to learn how to execute the process of tire changing, although one of them thought it would be more helpful if the process was accompanied with a video. It was reported from the think-aloud session that text in some steps could be more simplified to save space for pictures; adding another page enlarging the highlighted part in the pictures was suggested in the focus group by most of the evaluators.

### Other suggestions

User suggestions from the think-aloud session and focus group showed that participants highly valued the practical nature of the learning content, and claimed that if the content could really meet their practical learning needs, they were more likely to pick it up in their time slots. As the female evaluator mentioned in the focus group, while the Six-Step Change Tire lesson might meet her needs, it would not be needed by people who do not drive; she would also be interested in micro cooking lesson, but that would not be relevant for people who do not cook. Meanwhile, other evaluators also suggested that developing learning products for a particular group of users, such as people who drive, increases the acceptability of the products to their target users. For the technical design, there is an interesting suggestion that the mobile learning experience should be consistent with users' online learning experiences,

that is to say, the interface, layout and control should meet the expectation of users, who most likely have prior experience with web-based information and learning sites.

In addition, although we did not intend to evaluate the usability of the mobile device itself, evaluators mentioned several limitations of the physical device. The major problem was the small screen and the tiny keys; four evaluators incorrectly pressed the button next to the correct one several times during their operation. Moreover, users expressed their worry about the download price and speed. If learning products are available through WAP, download could be expensive and slow. Another worry was that the processors of their mobile phones were slow, and memory was limited.

## Discussion

Mobile devices are enabling lifelong learners to access learning anytime and anywhere, but the learning products delivered by mobile devices must meet their learning needs to solve problems or satisfy curiosities. In this study, in order to advance our understanding of how to design for lifelong learning on the move, we proposed a set of design principles and then conducted a user experience study with two prototype lessons. The lessons were developed with the guidance of the principles, and the following represent conclusions and provide discussion of our findings.

First of all, we found that the learning products developed following these design principles received positive user evaluations for the content, activity and usability design. Accordingly, we conclude that the set of design principles have value for developing the learning resource bank of the Life-long Learning Initiative for Shanghai citizens. Additionally, this finding supports Kukulska-Hulme (2007), who claimed that mobile learning products which users 'want to use' should go beyond merely technical aspects of usability and include pedagogical concerns. At the same time, we also learned that there is room for improvement both for the design principles and for the way the principles are implemented in the products themselves. The findings suggest additional ways to think about the design principles and new design concerns that must be integrated with the original set of principles.

Concerning the design principles, the findings support the principles that usable learning products intended for informal settings must be practical, micro, and simple both for content and activity. Our findings offer support for guidelines for the design of content dedicated to lifelong learning for which Churchill and Hedberg (2008) have noted that there are limited guidelines for how to develop effective learning content for mobile devices. From the findings of the current study, we can affirm that learning products are more acceptable as a kind of a casual 'snack' (Rieger 2007); they are more easily integrated into the users' possible time slots when the products' design is founded upon both pedagogical and technical dimensions.

Second, the results show that effective implementation of practical and micro principles is highly valued because urgent needs arise while on the move and making good use of their waiting time in real-life situations are of high priority for users. This 'using time productively while waiting' echoes the concerns of pedagogical usability of mobile learning (Bradley et al. 2005; Kukulska-Hulme 2007), while it meets our original goal of designing mobile learning for lifelong purposes. The requirement of developing mobile learning content into small, self-contained chunks is also supported for the design of usable mobile learning content, so as to fit into the time slots available in the flow of daily performance (Sharples 2000). Moreover, the degree to which the small chunk is practical for a particular situation will make it more likely they will 'want to use' it.

Finally, we conclude that usage mechanisms of learning products must be consistent with conventional usability standards, and all be provided with attractive yet appropriate media design. The findings concerning interface designs such as repetition, highlighting, as well as small chunks align with Nielsen's (2001) mobile usability standards. Technical usability concerns such as consistency with previous web experience should not only be considered but must also meet the high requirements called for by evaluators in this study. Also from the results we see that aspects of designs that attract attention to key features and content are highly valued. Similarly audio is preferred, especially for language learning. Additionally, the importance of using simplified text with meaningful pictures echoes previous findings from previous studies (Churchill & Hedberg 2008; Kim 2009). Yet different from Bradley et al. (2005), our findings show that multimedia is not necessarily desired for small pieces of content.

As a step in the process to develop a mobile learning resource bank for the Life-long Learning Initiative, we find that this study shows the value and potential of using a set of design principles for creating mobile learning content. While the heuristic evaluation techniques and the specific nature of the lessons limit the generalizability of our findings, taken as a case report of the application of design principles and in the context of the literature reviewed for the development of design principles, we believe that researchers and designers can cautiously apply the findings. The organization of a variety of findings on mobile learning into design principles for content, activity and usability, the demonstration of a method for examining how well these principles were applied, and the case report about the implementation contribute to research and development by others seeking to harness the potential of mobile devices to support lifelong learning needs emerging in daily routines. However, additional research is needed to refine the design principles and better understand how to apply them for particular sets of users. Our findings show that users have high expectations for the learning content to be 'practical' and that 'practical' may have different meanings to different groups of users. Further investigation is required to determine whether the designed content, such as tire changing, meets practical needs when implemented in a live mobile system. Additionally, further research is needed to build models about the practices appropriate and of high priority for specific groups of users throughout Shanghai.

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