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# Learning Chinese characters via mobile technology in a primary school classroom

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This paper describes a project, including the design, development, and use of a mobile application (referred to as application hereafter) for learning Chinese as a second language in a bilingual primary school. The application was designed for iPod Touch Apple technology with the purpose to facilitate learning of a fundamental set of 200 Chinese characters. The project was a coordinated effort of experts, including an instructional designer, a software engineer, a Chinese language expert, and classroom teachers to develop an experimental Chinese character learning application for the primary school classroom. This paper reports how the project team explored experiences of teachers and learners in a particular context, developed understanding of teaching and learning needs for Chinese language learning, and how these inform design of the educational application. The final outcomes of the project include a Chinese character learning application and recommendations for design and use of educational applications in Chinese language teaching and other similar contexts.

**Keywords:** mobile application; Chinese language learning as second language; mobile learning

## Background

The growth and wide adoption of mobile technology, such as smart phones and tablet PCs, creates promising opportunities for learning anywhere and anytime. Use of such technology in education is referred to in literature as mobile learning (e.g. Kukulska-Hulme & Traxler, 2007; Motiwalla, 2007). Contemporary mobile technology is powerful in terms of its mobility and connectivity, large screen sizes, easy-to-use multimedia production and sharing tools, and tangible user interfaces (UIs) (Churchill, Fox, & King, 2012). The potential of mobile technology has been driving many educators to explore it in teaching and learning. Along with the spread of mobile technology, an increasing number of mobile applications (referred to as application hereafter) are emerging in markets. Although many of them have been designed to support learning English, little work has been done for Chinese language education. It is also noteworthy that many educational applications are designed by software engineers without proper consultations with instructional design experts, and thus the usability of these applications in education do not always meet expectation.

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The Chinese language evokes interest from non-native speakers around the world due to the economical, cultural and political rise of China, but some seemingly difficult differences between Chinese and western languages have posed barriers to many foreign learners. In this context, a Chinese character learning application was developed by our team in 2010 for university foreign exchange students to learn some fundamental set of Chinese characters via Pocket PC technology. This application has been titled Mobilese (see Figure 1). The core content of this application is a set of character templates and animated characters, following which students can practice writing stroke by stroke, hear pronunciations in Cantonese or Putonghua, and explore similar characters and examples of related words. The application is able to detect whether the stroke order and formation are correctly executed, and to generate instant feedback based on writing performance so that learners can correct their mistakes. This set of Chinese characters was chosen by a Chinese language expert, in reference to guidelines in teaching Chinese as a second language published by the Chinese National Language Committee and years of experience in teaching Chinese as a foreign language, as a fundamental base to equip beginning learners with essential understandings for further learning.

Since 2010, a number of schools in Hong Kong have begun to deploy one-to-one mobile device programs where each student is equipped with a mobile device (e.g. iPod Touch) to assist learning. Among these schools, one showed interest in the application and thus funded our project to further develop it for beginning primary school children's use via iPod Touch technology. The sponsoring school admits children from diverse cultural backgrounds, including both Chinese and non-Chinese children. Dual-language programmes in English and Chinese are offered. This diversity of students has challenged teachers. In terms of Chinese language learning, for example, children from non-native speaking families have to spend more efforts and a longer time studying the fundamental concepts. Differentiated instruction had been implemented to tackle this issue. Administrators of the school expected that by bringing the application into the classroom, learning engagement could be enhanced, and students with various learning abilities could effectively acquire knowledge essential for learning Chinese characters and the language in general.
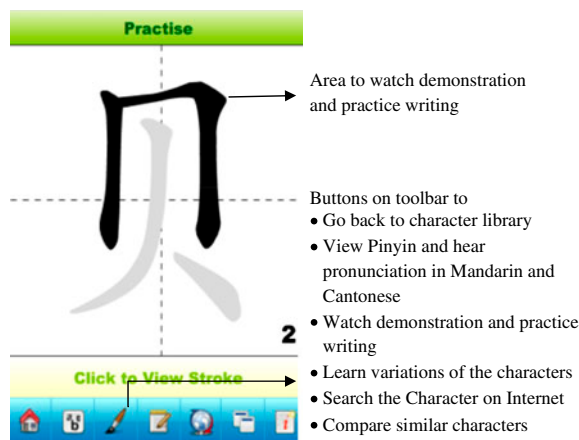


Figure 1.   Screenshot of Mobilese.

This paper reports how the project team gained understanding of pedagogical requirements of teachers and students in the context of a bilingual primary school, and how such understanding informed further development of the initial version of the application. The usefulness of the application for learning Chinese characters was evaluated in the classroom for a short period. It is expected that this paper could inspire software designers to develop applications useful and effective for Chinese character learning. Teachers may also find this paper helpful for applying similar mobile applications to support teaching and learning.

## About the project

This project sought to further develop a mobile application into a version suitable for early primary school students to learn Chinese characters via their iPod technology. It was expected that the mobile application was built on the basis of existing knowledge in Chinese language learning and also accurate understanding of target learners as well as their specific pedagogical context. To achieve this goal, an integration of product and tool research (PTR) in education and user-centerd design (UCD) was considered as a good solution because such an approach could help us develop technical and educational usability of the application in parallel.

UCD is a design strategy that has been employed for the design of mobile applications. The aim of user-centered design is to enhance the usability of software products with which specified users could achieve specified tasks effectively, efficiently, and satisfactorily in a specified context of use (British Standards Institute, 1998). The fundamental principle of UCD practices is the involvement of users in all essential stages of the design and development of software (Gulliksen et al., 2003). User experiences can be promoted when users' characteristics, problems, environments, and habits are sufficiently taken into consideration.

PTR is the study and practice of "the design and development of an instructional or non-instructional product and program" grounded on teaching and learning theories and research (Richey, Klein, & Nelson, 2004). According to this research approach, four typical steps exist for achieving research goals: (a) literature review to identify research problems and frame the study, (b) design to determine system specification, functionality, and interfaces; (c) development to transform design into the product/tool, and (d) evaluation to assess the effectiveness of the development (Wang & Hannafin, 2005).

UCD is believed to be an effective means to capture user requirements in the real context of use. Employing UCD, researchers are enabled to communicate design solutions with learners at early stages, and therefore increase the practicality of PDR outcome. Meanwhile, techniques and skills from PDR research can be made use of to deal with the validity of UCD practices. By outlining and mapping detailed steps in PTR and UCD, we created the design and development plan. Four main stages were undertaken for the redesign purpose, as shown in Table 1.

Designing educational software should build upon multidisciplinary expertise (Abras, Maloney-Krichmar, & Preece, 2004). In light of this, the project team recruited an instructional designer, a software engineer, a Chinese language expert and four classroom teachers. The trans-disciplinary professional background of the instructional designer enabled her to smoothly communicate between teachers and students and technical staff, ensuring that everyone was working toward the same

Table 1.  Phases of the application development and evaluation.

| Phase | Activities in sequential order |
| --- | --- |
| Requirement analysis | (1) Reviewing and analyzing literature on learning of Chinese characters |
| | (2) Gaining understanding of school context through classroom observations, teacher interviews, and students' show-and-tell |
| | (3) Analyzing pedagogical requirements of teachers and learning needs of students |
| Design | (4) Interpreting results of the requirement analysis to determine system specification |
| | (5) Reviewing and analyzing literature to assist decision-making in functional design |
| | (6) Designing functions and UI |
| | (7) Evaluating prototype with teachers and revising system with collected feedback for improvement |
| Development | (8) Translating design into the application product |
| Evaluation | (9) Evaluating usefulness of the application through classroom observations, interviews with teachers and students, and the analysis of learning artefacts |

goal. The role of Chinese language expert was to suggest the learning content of the application and effective teaching strategies to be incorporated into the design.

## Application design and development

### *Requirement analysis*

The review of literature on Chinese language learning suggests three common challenges of studying Chinese characters. The first challenge is developing the structural awareness of characters. A stroke is the basic unit of Chinese writing. Chinese characters are composed from a combination of eight basic strokes and their variations. Strokes are arranged in relation to one another and form simple components which can be further arranged to form more complex structures. The awareness of the character's internal structure significantly affects children's recognition as well as reading of the characters (Tan et al., 2005). If students are instructed on how a character is constructed step by step, they likely memorize it in an organized way (Shen, 2004). The second is executing correct stroke order while practicing the writing of the character. The execution of the correct stroke sequence has traditionally been suggested as the key in accurate production and recognition of Chinese characters (Giovanni, 1994). However, primary school students often meet difficulties and make errors in stroke sequencing, even after being repeatedly taught stroke order rules (Law, Ki, Chung, Ko, & Lam, 1998). The third is related to challenge with pronunciation (So & Siegel, 1997). Chinese characters, very often, do not indicate pronunciation to beginners of the language. While the stroke components of a character may indicate certain meanings, they do not necessarily equate a syllable with a particular tone. Unlike English, the Chinese language is tonal and the tones of a given syllable is directly associated with its meaning. What makes it more complicated is that a considerable portion of Chinese characters corresponds to more than one pronunciation. Additional mental effort has to be made to associate the pronunciation of each character with its written form. Pinyin is suggested as an effective tool to facilitate pronunciation for beginner learners (Wang & Leland, 2011).

With these three suggestions in mind, the team generated a list of questions that should be addressed in subsequent teacher interviews and classroom observations. Some of guiding questions were:

(1) What are challenges and difficulties of mastering characters faced by your students?
(2) How can students be assisted to overcome these challenges and difficulties?
(3) How do you think the application could be designed to support your teaching design?
(4) How do you think the application should be designed to facilitate the learning of Chinese characters?

Four Year-1 Chinese language teachers shared their insights regarding pedagogical needs that the application should address in their classrooms. From their point of view, the potential role of the application was to support the implementation of differentiated instruction so that all students could learn effectively, regardless of their learning abilities, needs, and preferences. The application should be aimed to enable students to learn and practice Chinese characters at their own pace. The teachers confirmed the three suggested challenges identified in the literature. Furthermore, they emphasized that the problem of executing correct stroke order for their non-native speaker children was the most prominent. To address this, the application should be designed to offer learners adequate scaffolding during the writing process. Enhancing children's learning interests by using game-based features was suggested by the teachers as well because children were often distracted during class and teachers' demonstrations or explanations due to their short attention spans.

The instructional designer attended a total of eight lessons over one month. The classroom observations focused mainly on recording classroom dynamics and activities. The analysis of data was guided by a selected pedagogical model-RASE. It was believed that incorporating an effective pedagogical model into the design process would significantly enhance the usefulness of the application to facilitate learning activities. According to the RASE model, there are four key components of a student-centered learning unit, namely, Resources, Activity, Support, and Evaluation (Churchill, King, Webster, & Fox, 2013). If the designed application was deemed as Resource in this model, then the project team should examine how the capability of the application should be developed to create new learning opportunities beyond current situations encompassing the other three elements. The observation data were compiled and iteratively framed into RASE:

- Resources: Resources are tools, informational resources, and materials that students use in the completion of the task. It was found that teachers, textbooks, workbooks, pencils, and dictionaries were major resources that students used in learning activities. The multimedia capability of iPod Touch could empower the application to be a medium to present learning content in the form of audios, animations, and pictures as supplement to traditional paper-based resources. More importantly, it could provide a set of tools with which students were engaged in the creation of digital artifacts through writing and speaking exercises.
- Activity: Activities are learning tasks students are engaged in. Teachers grouped students according to their levels of Chinese language abilities, and

activities of appropriate difficulty levels were assigned to different groups, such as practicing writing on workbook for lower level ability students and storytelling for higher level ability ones. Students learned in a more self-directed and independent way. The observation revealed that the traditional way of learning Chinese characters was a tedious process. Much time was spent on repeatedly exercising writing with pens and workbooks. To facilitate meaning making and knowledge application, students were required to write down their own sentences incorporating new characters, and share the sentences by speaking out loudly in front of class. Sentence construction seemed to be rather difficult for those whose vocabulary was limited. Game-based exercise was recommended by the teachers to increase learning interests. The application could play a role in these activities as a tool to encourage input/output of the Chinese language.

- Support: Support is assistance students receive to accomplish learning tasks. The observation showed that teachers and teaching assistants acted as the major sources of support for students in learning activities. They frequently instructed how to write certain characters to the individuals with low-level Chinese ability. As a personal learning tool, the application could allow students to control their own learning paces; instant feedback or hints could be offered to scaffold the individual learning process.
- Evaluation: Evaluation should allow students to constantly improve their learning. It was observed that evaluation of completed exercises in workbooks was the major way of monitoring student's learning progress. Teachers could not test the pronunciations or stroke order executions of all the students due to time limitations. The application could therefore be designed to archive learning artifacts created during learning activities, such as audio-recorded pronunciations, so that teachers were offered with an alternative to evaluate learning performance of students.

Table 2 presents a brief summary of pedagogical requirements and associated sources of information. Results of user requirements were a set of coordinated perspectives from related work documented in related literature, practicing teachers, and instructional designer. Priority was given to ones identified from at least two of information sources in order to ensure validity of design.

The design of the educational application should take the target learner's technical competency and attitude toward the use of technology into consideration. In this project, 17 Year-1 students, 10 boys and seven girls, aged between five and six, were invited to participate in a short show-and-tell session. These students were recommended by teachers (1) ranging from low to high levels of Chinese language abilities and (2) native and non-native Chinese speakers. Each of the participating children was asked to answer a few simple questions while showing the researcher how they manipulated an iPod Touch. Formal consents were obtained from their teachers, parents, and school principal. Two general questions guided the students' show-and-tell: "Do you like the iPod Touch? Why?" and "What can you do with the iPod Touch?" The results revealed that all of the students were capable of operating an iPod Touch for media capturing and playing tasks, such as listening to stories, capturing photos, and taking videos. They could operate the mobile application using simple gestures, such as swiping and tapping. All of them enjoyed playing games with the iPod Touch. For children aged between five and six years, growing

Table 2.    Pedagogical requirements framed by RASE.

| Requirements for the application framed by RASE | Source of information | | |
|---|---|---|---|
| | Related literature | Teacher interview | Instructional designer's observations |
| *Resources* | | | |
| (1) Learning content presentation | | ✔ | ✔ |
| *Activities* | | | |
| (2) Supporting self-paced individual learning | | ✔ | ✔ |
| (3) Enhancing the existing learning process of writing, reading, and meaning of characters in the classroom | ✔ | ✔ | ✔ |
| (4) Enabling game-based learning activities | | ✔ | ✔ |
| *Support* | | | |
| (5) Demonstrating pronunciation and writing in effective manners | ✔ | | ✔ |
| (6) Reinforcing character pronunciation | ✔ | ✔ | |
| (7) Scaffolding students to write characters in correct stroke order | ✔ | ✔ | ✔ |
| *Evaluation* | | | |
| (8) Archiving students' reflection in learning and teachers' assessment of learning results | | ✔ | ✔ |

up with various advanced digital devices, they had mastered the basic technical proficiency to learn with mobile devices.

In summary, through requirement analysis, the project team built understanding of the pedagogical context in which the application would be used. These understandings then informed the application design in the next phase.

### Design and development of the application

The project team analyzed the user requirements and other related work, including existing Chinese learning applications and literature on Chinese language learning. Agreements were reached on the application's system functionality (see Table 3).
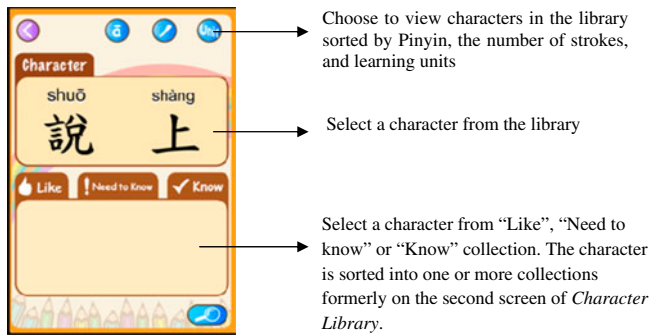
During the design process, prototypes with limited functions were shown to four teachers for suggestions on UIs and functions. These suggestions were then taken back to design plan. The application was finally designed to consist of four main functional modules: *Character Library, Learning Games, My Collection,* and *My Handbook.*

### Character library *module*

*Character Library* consists of six units of Chinese characters suggested by teachers. This is the main venue where learners may learn and practice writing, listening, speaking, and reading characters. The combination of animation, audio, and pictures creates a multimedia-learning environment for learners. Figure 2 is the first screen of the module. As illustrated in Figure 1, characters in the library are categorized by (a) pinyin, (b) the number of strokes, and (c) learning units defined by teachers. By scrolling the "Character" pane in the upper side of the interface, learners select one of the characters from a collection that is sorted based on the aforementioned three

Table 3.  Functional design of the application.

| Pedagogical requirements | Functional design to address specific pedagogical needs identified |
|---|---|
| (1)  Present learning content | Show pinyin along with the character (1)(4) (5) |
| (2)  Enable games to make learning a fun and enjoyable process | Add audio pronunciations (1)(4)(5)(7) |
| (3)  Support self-paced individual learning | Illustrate the entire process of writing a character stroke by stroke (1)(3)(4) |
| (4)  Demonstrate pronunciation and writing in an effective manner | Allow students to directly write on screens of their iPod Touch following animated hints. (3)(6) |
| (5)  Enhance the existing learning process of writing, speaking, and meaning of characters in classroom | Provide instant feedback when students properly finish writing a character or make mistakes (3)(6) |
| (6)  Scaffold students to write characters in correct stroke order | Audio record students' speaking and enable playback (3)(4)(5) (7)(8) |
| (7)  Reinforce learning of character pronunciation | Exercise associating pinyin with correct characters in the form of games (2)(3) (4)(5)(7) |
| (8)  Archive students' learning artifacts for student reflection and teacher assessment | Show words composed of the character (1)(3) (4)(5) |
| | Allow students to take photos of real-world objects related to the meaning of the character (5) |
| | Archive students' learning artifacts (8) |
| | Record information related to the application's learning activities (8) |



Choose to view characters in the library sorted by Pinyin, the number of strokes, and learning units

Select a character from the library

Select a character from "Like", "Need to know" or "Know" collection. The character is sorted into one or more collections formerly on the second screen of *Character Library*.

Figure 2.  The first screen of *Character library*.

categorizations. In addition, the application enables students to tag and categorize characters according to their preferences (Like) or/and learning progress ("Need to Know" and "Know"). Such a learner-centerd feature helps create opportunities for children to manage and monitor their own learning process. Learners may also select a character from their own defined collections from the pane in the lower side of the interface. Personalized categorization of learning content can help individuals to more effectively manage and retrieve their learning materials and resources, and promote self-directed learning (Estellés, González, & del Moral, 2010).

After selecting a character, learners are navigated to the second screen to learn and practice it, as shown in Figure 3. Learners are enabled to freely choose to (a)
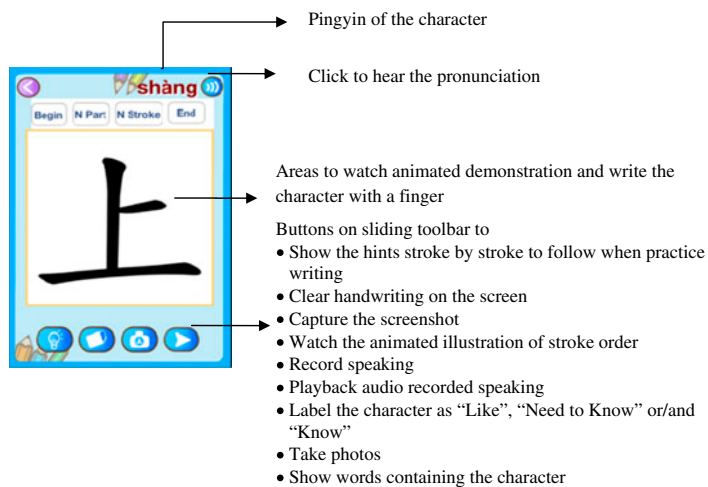
Figure 3.    The second screen of *Character library*.

watch the animated illustration of writing the character stroke by stroke, which indicates the start and the end of each of the strokes, (b) follow the animated hints to practice writing with fingers, (c) take screenshots of their writing, (d) learn related pinyin and hear the audio pronunciation, (e) record their speaking and play it back, (f) browse the related words, and (g) take photos of real-world objects associated with the meaning of a particular character. The design rationales behind feature designs of the *Character Library* module are: (a) multimodality and interactivity of educational courseware assist the understanding of conceptual knowledge (Churchill, 2008), (b) stroke-by-stroke illustration of writing a character through animation can potentially enhance structural understanding of the Chinese character and then improve writing and recognition (Wang, 2005), (c) the functionality that records and plays back utterances stimulates language learners to produce speech and improve their pronunciation (Demenko, Wagner, & Cylwik, 2010), and (d) taking photos in real-life contexts can facilitate meaning making of Chinese words (Wong, Chin, Tan, & Liu, 2010).

### Learning games *module*

*Learning Games* was designed as the strategy to intrinsically motivate students to spend more time learning. The function includes two games: *Pinyin Match* (Figure 4) and *Hear and Match* (Figure 5). To make the games interesting, enjoyable, and challenging, Prensky's (2003) six elements of fun and engaging digital games were identified and implemented, as illustrated in Table 4.

### My Collection *module*

*My Collection* is a learning portfolio system archiving students' digital artifacts created in the application. The learning portfolio developed during the learning process has been widely used to promote reflection on learning content and process (Bhattacharya, 2001; Knight, Hakel, & Gromko, 2008). *My Collection* showcases
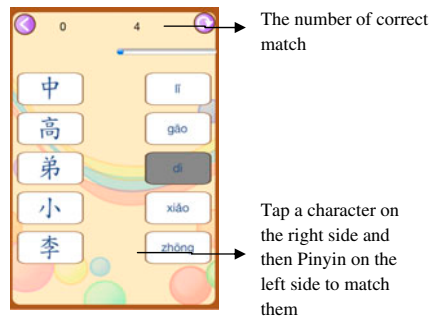
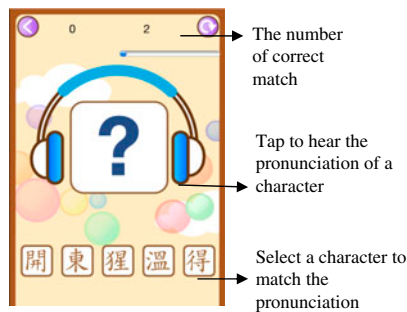Figure 4. The main screen of *Pinyin Match*.



Figure 5. The main screen of *Hear and Match*.

students' learning artifacts created within the application, as illustrated in Figure 6. The latest learning artifacts would replace the ones created previously in *My Collection*. It enables students to reflect on their learning process and share their learning achievements with others, which can intrinsically motivate them to learn more. This function enables teachers to assess students' learning performance and progress.

My Handbook *module*

*My Handbook* is the statistics of students' learning activities within the application (see Figure 7). It summarizes the information related to different types of learning activities students complete within the application. Using this function, teachers and learners can gain a sense of how many activities have been finished.

### *Interface design*

The UI design of the application by and large followed human interface design principles suggested by Apple's developer website (see http://developer.apple.com). Three main changes were made based on the previous version to build friendly UI for children:

Table 4.    Implementation of elements of fun and engaging digital games.

| Elements | Implementation in the application |
|---|---|
| Rules | *Pinyin Match* is a game to engage students in associating characters with correct pinyin. Students should match as many characters as they can with pinyin during one minute *Hear and Match* is a game to reinforce listening skills. In this game, students hear the sound and select the related character in one minute |
| Goal and objectives | Both games calculate the number of correct matches. Students should strive to obtain high scores in the games |
| Outcome and feedback | Prompt feedback is given to students when they make correct matches in both games. In *Pinyin Match*, correctly matched characters and pinyin disappear. In *Hear and Match,* the game does not continue until students choose the correct character. At the end of the games, the systems give scores to players based on their performances |
| Conflict, competition, challenge, and opposition | Students can compete with each other on scores received in the games, or challenge themselves to surpass their previous records |
| Interaction | Competition on game scores can be carried out in group activities |
| The representation or story | *Pinyin Match* and *Hear and Match* were previously two paper-based exercises. The application represents these two exercises in a game-based learning approach with children-friendly interface and exciting elements |
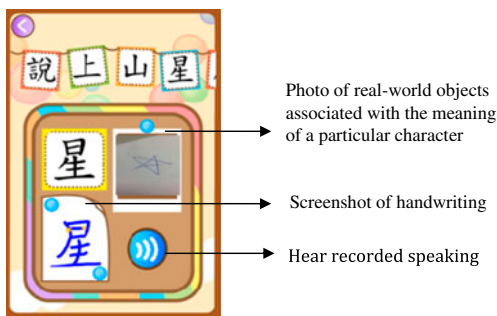


Figure 6.    The main screen of *My Collection*.

(1) The application adopts a soft, bright, and eye-catching color theme. Several versions of interface color theme were shown to students and let them make decisions according to their preferences
(2) The layout of the interface is simple in the sense that a complex UI might confuse children. Take the Home screen as an example. The Home screen was designed with a few options for navigating to the main functional modules. Students were asked to freely navigate within the prototypes. The instructional designer observed their operations on the application and evaluated the ease of navigating within and between functional modules. Suggestions were then offered to the software engineer for improvement.
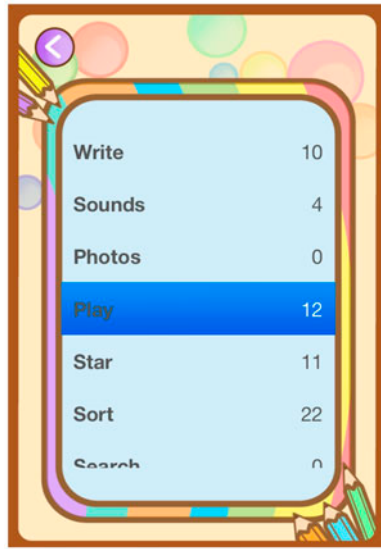
Figure 7.    The main screen of *My Handbook*.

(3)  Simple gestures – swiping and tapping – were enabled for children to manip-
ulate and navigate within the application. For example, students swipe the
sliding toolbar at the bottom of the second screen of *Character Library* to
tap a button (see Figure 2).

### Preliminary evaluation of the application

The application was evaluated by teachers and students in real learning environ-
ments. The purposes of the preliminary evaluation were to assess the ability of the
application to (a) satisfy teachers' pedagogical needs, (b) assist students in learning
Chinese characters, and (c) arouse and sustain students' learning interests. Table 5
presents the methods of data collection to evaluate these three aspects of the ability
of the application. After four participating teachers experimented with the applica-
tion for two months, the instructional designer observed twelve lessons taught in
order to understand how the teachers integrated the application into classroom teach-
ing and how learners used application in their learning activities.

Table 5.    Dimensions of usability evaluation and corresponding methods.

| | Classroom observations | Teacher interviews | Student show-and-tell | Artifact analysis |
|---|---|---|---|---|
| Satisfaction of teacher's pedagogical needs | ✔ | ✔ | ✔ | ✔ |
| Usefulness for students to learn Chinese characters | ✔ | ✔ | ✔ | ✔ |
| Effects on learning interests | ✔ | ✔ | ✔ | |

### Classroom observations

The data from the classroom observations revealed that the teachers were able to successfully integrate the application into their pedagogical design to create a blended learning environment in which students seamlessly switched between physical and digital learning resources for completion of learning tasks. The application as *Resource* was capable of being used for implementing *Activity, Support* and *Evaluation* in student-centerd learning activities. Specifically, the application was used in four general ways:

(1) The application was used in combination with workbooks as a tool for demonstration, practice, and reference. Students used the application to watch demonstrations and practice writing in the correct stroke order first. They then used the workbook to practice handwriting with pencils while writing down a sentence constructed with the character, or recorded their speaking of constructed sentences. They referred to the *Character Library* when encountering unknown characters.

(2) The application was used to independently practice writing and speaking. Students in groups received a sheet listing the characters they needed to review and practice. They took the screenshot of their writing and recorded their speaking of a sentence constructed with the character. In most cases, students played back their recorded speaking immediately. The teaching assistant assessed students' learning performance by checking their learning artifacts saved in *My Collection* in the application.

(3) The application was used to support game-based group learning for reinforcing pinyin pronunciation and listening skills. In addition to playing the games individually, students were grouped to play *Pinyin Match* and *Hear and Match* under the supervision of a teaching assistant. They showed their scores and competed with one another.

(4) The application was used to facilitate characters' meaning making by taking photos of real-world objects. For example, in a class, students initially drew pictures that related to the meaning of the characters on a white paper, and then took photos of their drawings to store it in the application. In another example, students took their iPod Touches home and captured photos of the real-world objects that associate them with characters they were learning (Figure 8).

The data from the observations shows that almost all students could fluently operate the application and were engaged in learning. Students were engaged and responsive.

### Teacher interviews

In interviews, the teachers stated that there were observable improvements in students on all aspects of Chinese language learning and students' engagement in learning characters. According to the interview data, the application was capable of satisfying pedagogical requirements as a tool that enriched group activities, accommodated a variety of learning abilities, and encouraged the input and output of language. All the teachers felt that the application saved much time previously spent on repeated demonstrations; more importantly, it greatly engaged students by increasing

Figure 8.    Four ways of using the application in the classroom.

their learning interests and confidence and removed the barrier of limited vocabulary and allowed students to be more creative in sentence construction through speaking it out rather than writing. The scaffolding offered by the application was perceived particularly helpful for students with lower levels of Chinese language ability to master the correct procedure of writing a character. Inspired by the affordances of the application, the teachers felt they were challenged to explore the new instructional methods and were willing to keep trying it. The following excerpts are typically drawn from the interviews:

> Without the aid from technology, teacher needs to spend more effort on teaching and leading the learning activities etc. Furthermore, the preparation effort of material for interactive learning activities is rather substantial. Teacher can now let the students study independently using the application. The preparation effort of activity materials can be lowered too.

> The application helps the students on the practice of character writing, the compound words. It also serves as a reference tool, say when the student wants to check how to write the word they learned. It supports their independent learning.

> Comparing using technology tool with traditional method, for sure, technology tool can result in higher engagement, motivation and so on. For example in photo taking function of the App, the students were highly engaged in this feature.

> Before the App, the students only used the Chinese Character Writing Workbook to practice handwriting. The most difficult part for non-native students would be the sentence writing part. Usually they would need the dedicated assistance from teacher to complete the work (because their writing word set is too limited). Now with the App, I could suggest the students to create the sentence and record the sentence verbally. They may create sentence by saying it out with being stuck by the handwriting part.

## *Students' show-and-tell*

The results of 17 students' show-and-tell support findings of classroom observation and teacher interviews. A list of simple questions was posed to the same students who participated in show-and-tell previously, regarding enjoyment experiences with the application and its usefulness for Chinese learning (see Table 6). Fifteen of the 17 (88.24%) students stated that they enjoyed learning with the application because it made writing Chinese characters more fun than with pencil and paper. The majority (76.47%) felt that their writing, reading, and speaking improved with the help of the application. Some felt a sense of achievement when they reviewed what they had achieved through *My Collection*. Two students also mentioned that they were fond of sharing their writing and photos stored within the application with their parents and peers. Nevertheless, four students felt neutral for the reason that they had mastered characters prior to using the application. All students indicated that they would like to continue using the application in Year-2.

## *Artifact analysis*

The data from the observations shows that almost all students could fluently operate the application and were engaged in learning. Students were engaged and responsive. The analysis of 17 students' learning artifacts, including 259 screenshots of

Table 6.   Results of students' show-and-tell.

| Questions | Student responses (*n*=17) |
|---|---|
| Do you like the application? | Yes (88.24%); no (5.88%); a little bit (5.88%) |
| Why or why not? | Why (selected typical responses)<br>• It's fun.<br>• I can write the characters.<br>• I like to play the game in application.<br>Why not:<br>• Writing on paper is easier and on iPod you must follow the strokes.<br>• Only a little bit. Because it's so boring just writing. I like English writing more. |
| Does the application help you to learn to read, write, and speak Chinese? | Yes (76.47%) a little bit (23.53%) |
| How do you know this? | Students who agreed the application helped them learn (selected typical responses)<br>• All these games help our Chinese, help my learning.<br>• Because when you write the word and say the word, then you can check it yourself (in *My Collection*).<br>• It shows you how to write the characters (the strokes).<br>• It is helping me how to write and say it. I can record my voice.<br>Those who felt learning a little<br>• Because all the words here, I know already. |
| Would you like to use the application in Year-2? | Yes (100%) |

handwriting, 357 audio files, and 41 photos stored in the iPod Touches, is consistent with the findings of the observation. With the aid of the application, almost all students were capable of writing as well as pronouncing characters correctly. Nearly two-thirds of photos taken by the students are associated with the meanings of characters.

## Summary

In summary, the results of the preliminary evaluation suggest that the functionality of the application is useful for engaging primary school students in learning Chinese characters in an effective and enjoyable manner; it can be used to implement self-directed individual learning, game-based learning, and group learning. For teachers, this application can help them decrease workload, implement differentiated instruction, and increase students' learning interests as well as confidence. The affordances of the application challenge the traditional mindset of teachers and drive them to transform teaching practices.

## Discussion and recommendations

### Use of the application to support Chinese character learning

The application in this project was designed to support learning of Chinese characters via iPod touch technology in the context of a bilingual primary school. The application consists of four main functional modules, providing functionality for studying and practicing writing, listening, and speaking a fundamental set of Chinese characters. Drawing upon findings of previous research and perspective of educational professionals, the design took into account many elements that promote the effectiveness of Chinese character teaching and learning. The results of the evaluation suggest the usefulness of the application for children in the context of Chinese character learning. The advantages of this application over the traditional computer-based multimedia courseware are obvious. The technical features of contemporary mobile technologies – in this project, the iPod Touch – enable students to effortlessly input and output information in a variety of formats to learn the language. Students are not confined by fixed devices and can use a variety of tools supported by mobile technology (e.g. camera features). The mobility of the iPod Touch enables children to learn while walking around in the classroom, on their way home, or any other places whenever they feel like learning. That increases learning time and makes context-based activities possible. However, traditional computer-based multimedia courseware requires certain levels of technical competency to successfully accomplish learning tasks, such as typing with keyboards and handling the mouse, which is challenging for lower grade students (Wong, Chai, & Gao, 2011). Writing with fingers on the tangible UI of the mobile devices is more intuitive, fun, and close to the handwriting experience. There is evidence that interaction with the tangible UI may reduce cognitive load (Kim & Maher, 2008). Compared to other related mobile applications, this application was particularly designed for primary school students and involved practicing Chinese language teachers in all critical stages of the application development.

Drawing upon experiences derived from the project, recommendations are made for teachers to facilitate Chinese learning with this and other similar applications:

- A combination of mobile technology and workbook could take advantage of two media. Writing on workbook is the only way to exercise character presentation which is an essential part of Chinese culture and also prevents students from being over-dependent on technology. On the other hand, use of the application creates a multimedia language environment to enable multiple forms of input and output of language.
- The application can serve as a tool to support differentiated instruction. As a personal learning tool, the application allows students to learn independently at their own pace. Learning game in group is enabled while teachers add conflict, competition, and challenge elements into activities with the help of related features of the application.
- The application-based learning environment is more suitable for children as mobile technology is relatively easy to manipulate compared with computers.
- Teachers can consider use of mobile technology to raise learning interests and create a sense of learning ownership.

## Design of applications for Chinese language learning

Table 7 summarizes a list of features that are proven to be effective in supporting Chinese language learning in this project, and those that can be further developed in

Table 7.    Features supported by evidences to be useful for Chinese language learning.

| Features of the application | Evidences supporting the usefulness of feature design | Features for further development |
| --- | --- | --- |
| <ul><li>Recording speaking and playing it back</li><li>Capturing screenshot of written characters</li><li>Taking photos associated with the meaning of character</li><li>Supporting game-based exercises</li><li>Archiving and organizing learning artifacts in a portfolio</li><li>Demonstrating the process of constructing a character through animations</li><li>Supporting direct writing on tangible interface</li><li>Providing animated hints of correct stroke sequence while writing</li><li>Offering instant feedback when students make errors in writing</li></ul> | <ul><li>Students were engaged with exercises delivered in a game manner</li><li>Teachers were enabled to check students' learning progress</li><li>Student learning interests were enhanced</li><li>Students could correctly associate the meaning of characters with real-world objects</li><li>Students could accomplish independent learning with the application</li><li>Students felt a sense of achievement while reviewing their own learning products stored in the application</li><li>Students were enabled to share their learning products with parents and peers</li><li>Students with limited vocabulary were enabled to record constructed sentences rather than being stuck with unknown characters</li></ul> | <ul><li>Recording writing process to check if the character is constructed in correct order</li><li>Automatically adapting difficulty levels of exercises to students' learning abilities to keep challenging them</li><li>Enabling sharing of learning artifacts through social networking websites</li><li>Adopting the font consistent with that of textbooks</li></ul> |

the future. It is hoped that information in this table could be useful to inform design decisions of applications related to Chinese language learning in the future. One thing worth particular attention is the font of Chinese characters used by Chinese learning applications, as recommended by the Chinese language expert in the project team. Different fonts create different shapes and sometimes they may cause confusion to beginners (e.g. a flat stroke in one font may appear slanted in another, or a hook may be at the bottom of a straight down stroke in one but not in another). Though Hong Kong seems to be less strict, primary school textbooks in both Taiwan and mainland China use Sim Sun, which is the closest to common handwriting. While some scholars do not think fonts matter, differences did cause problems with beginners and teachers. From the learner's point of view, it could be more beneficial to beginning learners if applications are designed in the same fonts as used in textbooks.

## Conclusion

This paper describes how a Chinese language learning mobile application was developed for and used in the context of a bilingual primary school. This project demonstrates the great potentials of mobile technology as a learning tool for Chinese language education. The capabilities of mobile technology can be utilized to design mobile applications that engage learners to learn and practice listening, writing, and speaking independently. This paper should be useful for both Chinese language teachers and software designers. For teachers, recommendations are made in terms of how this mobile application and other similar applications can be useful for supporting Chinese language learning. This mobile application is an effort incorporating perspectives from an instructional designer, a Chinese language expert, and four practicing teachers. Therefore, for software designers, this paper can serve as reference for designing Chinese language learning applications in the future. The main limitation of the project is related to the short period of the evaluation of the application and the small number of students involved. Future work will be done to further evaluate and improve the application.

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