Let's Play Chinese Characters – Mobile Learning Approaches via Culturally Inspired Group Games

Feng Tian[1], Fei Lv[1], Jingtao Wang[2], Hongan Wang[1, 3], Wencan Luo[1], Matthew Kam[4], Vidya Setlur[5], Guozhong Dai[1, 3] and John Canny[2]

[1] Intelligence Engineering Lab, Institute of Software, Chinese Academy of Sciences, Beijing, China
<tf, lf, wha, lwc, dgz@iel.iscas.ac.cn>

[2] Computer Science Division and Berkeley Institute of Design, University of California, Berkeley, CA, U.S.A
<jingtaow, jfc>@cs.berkeley.edu

[3] State Key Lab. of Computer Science, Institute of Software, Chinese Academy of Sciences, Beijing, China

[4] HCI Institute, Carnegie Mellon University, Pittsburg, PA, U.S.A
mattkam@cs.cmu.edu

[5] Nokia Research Palo Alto, Palo Alto, CA, U.S.A
vidya.setlur@nokia.com

ABSTRACT

In many developing countries such as India and China, low educational levels often hinder economic empowerment. In this paper, we argue that mobile learning games can play an important role in the Chinese literacy acquisition process. We report on the unique challenges in the learning Chinese language, especially its logographic writing system. Based on an analysis of 25 traditional Chinese games currently played by children in China, we present the design and implementation of two culturally inspired mobile group learning games, Multimedia Word and Drumming Strokes. These two mobile games are designed to match Chinese children's understanding of everyday games. An informal evaluation reveals that these two games have the potential to enhance the intuitiveness and engagement of traditional games, and children may improve their knowledge of Chinese characters through group learning activities such as controversy, judgments and self-correction during the game play.

Author Keywords

ICT4D, Chinese literacy, Chinese education, developing countries, literacy acquisition, mobile games, traditional games

ACM Classification Keywords

H5.2 [Information interfaces and presentation]: User Interfaces. - User centered design; Graphical user interfaces.

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General Terms

Design, Human Factors.

INTRODUCTION

In developing countries, low literacy is one of the main obstacles that hinder economic empowerment. According to the Education For All Global Monitoring Report 2006, literacy is "crucial for economic, social and political participation and development, especially in today's society [29]." In [14], Kam emphasized the importance of literacy acquisition in India and argued that using mobile learning games for English as a Second Language (ESL) education among children in India is a widely perceived to be a socioeconomic enabler. Literacy is also a big problem in China, one of the biggest yet fast growing developing countries in the world. Despite a higher overall literacy rate in China compared to many other developing countries, e.g., in 2001, the literacy rate was 90.9% in China (vs. 61% in India) [29], the literacy rate varies significantly between different regions in China. Regions suffering from poverty have a much lower literacy rate. According to the United Nations Development Program, illiteracy rates in rural Chinese regions are about five times higher than richer regions in China [28]. Furthermore, the literacy rate in China vary significantly even in the same province. e.g. the literacy rate differs by about 27.53% between different regions in Gansu Province, which indicates that many people in underdeveloped regions in China still face severe literacy problems [17].

Research on improving educational levels and literacy in developing countries using affordable technology is a prevalent topic in the HCI community [10, 13, 23]. As mentioned by Kam et al. [16], the value of English is widely recognized in India. English literacy is important for getting mid-level service jobs, which are the most common steps above menial labor. In contrast, although English is a required second language in middle schools in China, jobs

in China rarely require English literacy. Positions that involve English reading/writing are usually "high-end" jobs that need at least a college degree. Further, these jobs are relatively scarce and can be found only in big cities. On the other hand, Chinese reading and writing skills are required for almost every entry-level job in China. As a result, ESL education is not a key to socioeconomic success in China as it is in many post-colonial developing countries such as India. Rather, we argue that for children facing literacy challenges in China, learning Chinese, especially the writing system, is a more urgent socioeconomic survival skill to acquire.

The Chinese language is the most widely spoken language in the world (over 1 billion Mandarin Chinese speakers vs. 512 million English speakers), and is the only official language in China. Unlike languages with alphabetic writing systems such as English, the reading and writing systems of Chinese present unique challenges to language education. Chinese characters are the basic semantic components in the Chinese language that are completely different from those of English in at least two ways. Firstly, one Chinese character corresponds to only one syllable in pronunciation, such as "中", "国". However, a character in Chinese could be equivalent to a word in English, such as "水" meaning "water", and "山" meaning "mountain". A Chinese word is usually equivalent to a phrase in English, such as "热水" meaning hot water, and "高山" meaning high mountain. Moreover, many characters have one pronunciation, such as "一", "衣", and "医". Secondly, Chinese characters are ideographic rather than phonetic. The characters originated with the Oracle Bone Script, and are continuously evolving in both shape and writing style [27]. Figure 1 shows the evolution of character types.

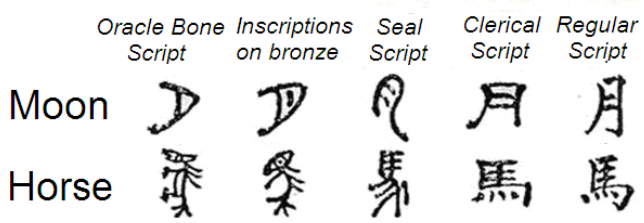


Figure 1. The evolution of the Chinese writing system [27].

Such differences often introduce some unique challenges in learning Chinese characters. Firstly, because the shape (appearance) of a Chinese character provides little clues to its pronunciation (unlike words in English), it is usually difficult to pronounce a Chinese character by just looking at the character. Hence, additional memorization is required to associate a character's shape with its pronunciation. To make things worse, many local dialects in China have different pronunciations for the same character. Secondly, it is hard to correctly recognize and transcribe the character when hearing the corresponding pronunciation. Given that there are only 416 unique pronunciations (syllables) in spoken Chinese vs. around 6000 common characters, to resolve this one-to-many syllable to characters mapping problem, phrase level and sentence level contexts must be leveraged in the transcription procedure. Lastly, it is challenging to write a character with the correct stroke order. Even for people who have received higher education in China, it is becoming increasingly difficult for them to write Chinese characters correctly without the help of a computer and a Chinese input method. As a recognition action rather than a recall action, long-term usage of phonetic Chinese input methods such as "Pinyin" via a QWERTY keyboard could weaken the users' Chinese character writing skills.

Mobile e-learning games have been shown to be a promising direction for improving ESL literacy in India [15, 16]. We hypothesize that educational games on mobile phones could be similarly beneficial for learning Chinese characters in China as many of the advantages of mobile learning in India are likely to hold in China. As shown by Kam *et al.* [15], learning games designed for rural children could be more intuitive and familiar by drawing on the games they already play. From [14], we could easily see found that many games played by rural children in India are group games. However, leveraging culturally inspired group games to help children learn characters are seldom explored.

This paper presents the first step towards constructing effective mobile learning games using culturally inspired traditional Chinese group games. In this study, we first investigated the current challenges in Chinese character learning in two primary schools. We then studied 25 traditional Chinese games played by children in elementary schools in China. Focusing on the key learning problems we have identified, two learning games, i.e. Multimedia Word and Drumming Stroke were designed and implemented to help children overcome the challenges they faced in learning Chinese characters. Finally we report on an informal preliminary evaluation of these two games with children in Xin'an, an underdeveloped region in Henan province, China.

RELATED WORK

There exists several related work pertaining to taking advantage of the digital game paradigm to promote education. Findlater, Balakrishna and Toyama conducted two studies that explore how semiliterate users with very little education might benefit from a combination of text and audio as compared to illiterate and literate users [10]. Aguilera [1] argued for the advantages of using video games for educational purposes. Aranda [3] introduced ELLAD, for using video games in non-formal educational contexts to improve education. Banerjee [4] evaluated mathematics learning games on desktop computers. Mischief [20] is a system for classroom interaction that allows multiple children to use individual mice and cursors to interact with a single large display. It could be well applied in disadvantaged schools where access to

computers is limited due to resource constraints [23]. Moraveji *et al.*'s results demonstrate that children can perform tasks comprising of target selections on a shared large display in large group sizes with minimal impact on performance as long as the targets are not too small [21]. Moed [19] proposed the use of a design for small-group learning on shared computers based on enforced turn-taking in a split-screen, multiple-mouse environment.

Several bodies of research work focus on using mobile devices to facilitate in education. Horowitz [11] examined the mobile device for promoting literacy. Chen [5] developed a mobile learning system on the wireless mobile ad-hoc network. Kam *et al.* [15, 16] is the most similar study we know to date that informed the design of e-learning games for rural children in India. However, due to the differences between Chinese and English, the problems and features in traditional games and the game design, are totally different.

As for research on traditional Chinese games, Huang [12] classified more than 100 Chinese rural village games. Ai [1] compiled 215 classic Chinese child games and their game play. Zhang [35] summarized and analyzed the characteristics of folk games played by children of the Yi nationality in China. However, none of them associates traditional Chinese games to computer game design or to teaching assistants.

Educators in China are exploring game-based teaching approaches: Xiao [33] for junior chemistry teaching, Zhao [36] for network-based English teaching, Feng [6] for science, and Wang [30] uses e-game teaching. In literacy learning, [31, 34, 37] put fun games into the classroom, and Liu [18] tried this method for children with poor sight. However, how to leverage traditional Chinese group games in learning Chinese language is still an unexplored question.

PROBLEM ANALYSIS

To get a better understanding of major challenges and common problems currently existing in Chinese language education for children in China, we first formulated a questionnaire for Chinese teachers in primary schools with the following questions:

- *What are the key skills students need to master learning the Chinese characters?*
- *Can you describe the primary teaching methods you used to help students improve their language skills?*
- *What are the difficult concepts for students learning Chinese characters?*
- *Can you describe some primary teaching methods you used to help students resolve the difficult concepts?*
- *Are there any tools in teaching to help children learn Chinese characters? If so, what are they and how to use them?*
- *What are the advantages and disadvantages of current textbooks and related materials?*
- *What are your comments and suggestions on the current syllabus/methodology of Chinese language teaching?*
- *What are the main methods used in testing and examinations?*
- *How many Chinese characters are required in primary school language education?*
- *What is the difference in education methodology between students in lower grades and higher grades?*
- *Are there any tools and materials used by students in learning Chinese characters after class?*

Based on the questionnaire, we interviewed two teachers in two primary schools in China. The first school is located in Beijing, a relatively developed region. The second school is located in Xin'an, a rural region in the north-west part of Henan province. These two schools are located in regions with obviously different living standards. We collected the results by having on-site face-to-face interviews with the teachers. From the interviews, we got detailed information of the current status in learning Chinese characters, and also some important results which could help us to identify the problems that we should focus on.

For students, there are at least three major requirements in the process of learning a Chinese character, namely, mastering the pronunciation, the shape (including the stroke order), and the usage context of the character. Chinese characters exposed to students in primary schools can be roughly divided into two groups. For each character in group 1, students are required to master the pronunciation, the shape (including the stroke order), and the usage context of the character; for each character in group 2, students need to master the pronunciation, and writing with the correct stroke order. There are about 1500 characters in each of the two groups for primary school students.

There are two main difficulties for students to learn Chinese characters. Firstly, if the number of characters to be remembered is large, children tend to forget previously learned characters. Therefore, it is a big challenge to improve the recall of characters. Secondly, while learning to write Chinese characters, the stroke order is a very important part. The correct order may bring benefits in both memorizing the shape and crafting a better-looking handwriting. However, the stroke order is hard to remember, especially for characters with many strokes. According to the teachers we consulted, many students suffered from mastering the correct stroke orders.

Currently, teachers have applied some methods, especially focusing on the first difficulty. In order to improve the recall of shapes, students were taught songs composed of Chinese characters learned, and cards which include shape and pronunciation of Chinese characters were used in classrooms. Meanwhile, students are encouraged to read more materials after class.

Although such methods could help to improve remembering the shape and pronunciation, these two difficulties are still not completely addressed. According to

the teachers we consulted, *the biggest problem in Chinese education might be motivating the students' interest*. Our research is an attempt to address this issue through group games. We hope to make learning activities more intuitive and engaging by leveraging the patterns of traditional Chinese games into learning activities.

EXPLORATION OF 25 TRADITIONAL CHINESE GROUP GAMES

We also interviewed 12 children in the above mentioned two primary schools to summarize the everyday group games that they love to play on a regular basis. We recorded a total of 25 games, which includes 3 indoor games, and 22 outdoor games. Table 1 shows the main features of the 25 games we investigated. The detailed rules and other information are not described due to the space limitation. We also analyzed these games understand what elements are important in traditional Chinese games. These features may guide us to design better, more engaging mobile learning games.

(a) **(b)**

Figure 2. Two traditional Chinese group games. (a) String game. (b) Beating a drum to spread a flower.

Game Name	Player	Team	Relations between teams (or relations between players if only 1 team)	Roles	Songs	Tools	Predefined boundaries	Technique level
Jumping the rubber band	4-6	2 teams in the same num of the player	Competition and Cooperation	Active Player and aider	Yes	Rubber band	Yes	High
Kicking shuttlecock	>=2	1	Cooperation	Active Player and sleeper	Yes	Shuttlecock	No	High
String game	2	1	Competition and Cooperation	Active Player and aider	No	Red string	No	High
Beating a drum to spread a flower	>=4	1	Competition	Active Player and sleeper	Yes	A drum and a flower	No	Low
Hawk catching the young chicks	4-10	2	Competition	Offensive and defensive	No	No	No	Low
Jumping the squares	>=2	2 teams if the num of the player is larger than 4, else 1 team	Competition	Active Player and sleeper	No	Rubber band	Yes	High
Jumping the rope	>=4	2	Competition	Active Player and aider	No	Rope	No	High
Juming over	>=3	2	Competition and Cooperation	Active Player and aider	No	No	No	High
Throwing the handkerchief	>=5	1	Competition	Active Player and sleeper	Yes	Handkerchief	No	Low
Clapping hands	2	1	Competition and Cooperation	Active Player and aider	Yes	No	No	High
Strider	2 or 4	2	Competition	Active Player and sleeper	No	No	Yes	Low
Throwing the bean bag	>=3	2	Competition	Offensive and defensive	No	Bean bag	Yes	High
Polices and thieves	>=3	2	Competition	Offensive and defensive	No	No	No	Low
Blindman's buff	>=3	1	Competition	Offensive and defensive	No	No	No	Low
"One two three", stick	>=3	1	Competition	Active Player and sleeper	No	No	No	Low
Throwing mud coins	>=4	2 teams if the num of the player is larger than 4, else 1 team	Competition	Active Player and sleeper	No	Mud coins	No	High
Playing billiards	>=2	1	Competition	Active Player and sleeper	No	Billiards	No	High
Flicking cards	>=2	1	Competition	Active Player and sleeper	No	Cards	No	High
Setting foot-point	>=2	1	Competition	Active Player and sleeper	No	No	Yes	Low
Playing house	>=3	1	Cooperation	Active Player and aider	No	Puppets	No	Low
Cock fighting	>=2	2	Competition	Offensive and defensive	No	No	No	High
Cat-and-rat	>=5	1	Competition	Offensive and defensive	No	No	No	Low
Diver train	>=5	1	Cooperation	Active Player and aider	No	No	No	Low
Guessing who am I	>=3	1	Competition	Active Player and sleeper	No	No	No	Low
Catching the match card	>=2	1	Competition	Active Player and sleeper	No	Match cards	No	High

Table 1: 25 traditional games investigated and the main features found in each game.

Cooperation between teams or players

According to our analysis, cooperation is one of the most important game characteristics as it is rooted in a large number of traditional Chinese games (See Table 1). Among the 25 games, 7 games involved in cooperation between teams or players, e.g. in the jumping rubber band game, players on one team were responsible to hold the band stable at a certain height when the other team was playing.

Songs in games

The functions of songs in Chinese games may help improve the games' intuitiveness and engagement. There are 5 out of 25 games using songs. The effects of songs could be summarized into two main categories. Firstly, songs may help player perform actions better by following the rhythms in songs. Among the 5 games that use songs, 3 (e.g. jumping rubber band, kicking cocktail, and clapping hands) demand challenging motor-skills, Songs may play an important role in these games. Secondly, songs may help define the process of games and current states. Among the three games that demand challenging motor-skills, a player's actions have to be consistent with the song. If a song stops, the game is over. In the other games like beating a drum to spread a flower, throwing handkerchief, if the rhythm stops, the game proceeds to the next round.

Resources

Handmade game objects are frequently used in Chinese games. Typical handmade game objects include beanbags, shuttlecocks, red string, and long rubber bands. Among the 25 games we investigated, handmade objects are used in 10 of them. Another interesting finding is that trees and plants are seldom used in Chinese games. This may due to the geographical position of China, especially in the north where trees are not available everywhere. Only one game (jumping rubber band) uses trees as a replaceable resource.

Another important feature in resources is that traditional Chinese games often have predefined game/arena boundaries. Lines, triangles, squares, pentagrams, and composed boundaries are usually drawn by chalks or stones in different color. 5 out of the 25 games use predefined boundaries. Boundaries are not only used to limit the action of players, but also used as additional conditions to design challenging rules, i.e. to throw beanbags in specific shapes without touching the boundaries, or to jump in to specific shapes one by one using one leg, without touching the boundary.

GAMES DESIGN AND IMPLEMENTATION

We designed two mobile learning games based on the above research. Our overall goal is to make it more intuitive and engaging for children to learn Chinese characters. We adopt a cooperation pattern in both games, so all tasks need to be accomplished by multiple players. We use sound and voice in both games. In the first game, the first player can use pronunciation to give a clue for the character. In the second game, a drumming sound is used to control the state of the game, and to bring the feeling of a real traditional game to students. In addition, we leverage rich visuals provided by the mobile phone interface like sketches, photos, to bridge the gap between children and the Chinese characters shown on the mobile interfaces. In the design, we help children transfer the subject matter from the digital game back to their everyday games rather than merely putting the games in the mobile devices. In this way, the digital game could potentially transform everyday, non-digital play into educational experiences. We introduce the two games in detail in the following sections.

Multimedia Word

In this game, children are required to recognize and write a correct Chinese character based on hints provided for pronunciation, a sketch, a photo or other multi-media context. The game design is primarily inspired by two popular traditional Chinese games, namely, the String game [25] and the Pictionary game [24]. The game could be played either as a pair-wise competition or a team based competition. In a typical game setting, children are separated into two teams. Normally, one child in each team will act as the leader and will take charge of the mobile phone while his/her team takes the turn.

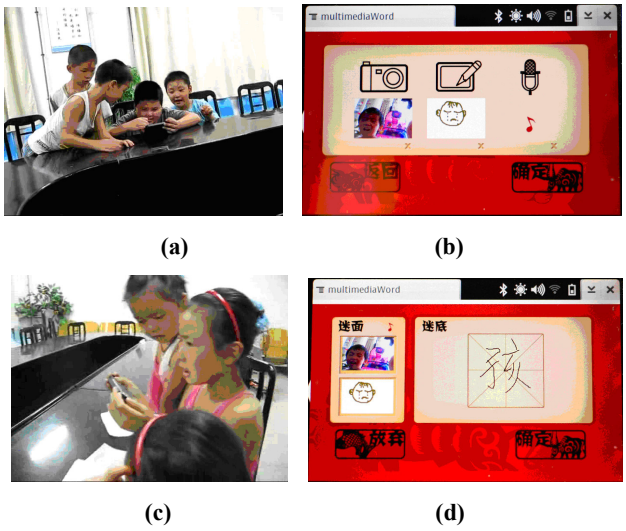
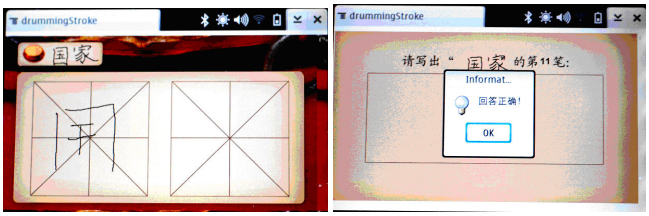


Figure 3. Multimedia Word. (a) Children in the first team are setting clues for the character. (b) UI for the first team. (c) Children in the second team are guessing the character based on the clues. (d) UI for the second team.

When one leader in the first team presses start, one or more Chinese characters will show up on the screen. Then children in the first team will speak out the character, he can also select up to two additional channels to augment the meaning of the word (e.g. sketching a picture or taking a photo). After that, the leader in the first team will pass the mobile device to the second team. Then children in the second team will try to write the correct answer using the clue for the pronunciation, sketch and the photo provided. When this riddle-solving task finishes, the roles reverse.

Drumming Stroke

In this game, children practice the Chinese characters writing ability (writing a character correctly with the correct stroke order). This game pattern is from one famous traditional game: Beating a drum to spread a flower (passing the flower on the rhythm of drum which is played by the mobile devices, when the beat stops, the one who is holding flower is the person chosen). All children join together to play the game.



(a) (b)

(c)

Figure 4. Drumming Stroke. (a) UI for writing characters (b) UI for the penalty session (c) Children are sitting in a circle playing the game

All the participants sit together in a circle. Rather than passing a flower, the participants pass the mobile phone one by one on the rhythm of drum sound played by the mobile phone. Instead of passing the phone directly to the next player as in the original game, each player is required to write one stroke of the given Chinese character by following the exact stroke order. When one finishes with his/her stroke, he/she passes the phone on to the next child. If someone writes a wrong stroke, the drum sound stops, and he/she is asked to correct the stroke and accept the penalty. During the penalty session, the player is asked to write another stroke in specific order of current characters, as shown in Figure 4(b). The penalty session would not be closed until he/she writes the correct answer. In order to help the player when he/she has difficulty in writing the right stroke, the system provides a highlighted clue of the stroke. After his/her penalty session is completed, the drum sound restarts and the game continues.

Note that despite the number of players in each game, we only use one mobile device. We made this design decision for three major reasons. Firstly, as investigated, it is not financially feasible to let each child own one mobile device. Secondly, the principle, “multiple children sharing one resource” conforms to patterns we identified in many traditional Chinese games (in-game resources are limited, e.g. there is only one flower in the traditional game “drumming to spread flower”). Thirdly, it can encourage teamwork among children.

Implementation

Environment and software

The two games are implemented on the Nokia N800 Internet Tablet Platform [22]. The Nokia N800 is a smart phone with a high resolution display (800 by 480 pixels touch screen). It uses an OMAP2420 microprocessor at the speed of 400MHz, 128MB RAM and 256MB flash memory. The N800 runs an embedded Linux based operation system called Maemo. We chose a Nokia N800 primarily because of the importance of pen input for a language with a logographic writing system, and its availability in our current research group. We do not leverage any device unique feature in N800 and the games we created can be ported to other mobile phones as long as they have a touch screen and their built-in camera and voice recording/play back functions are accessible via some publicly available APIs.

The two games were written in C. GTK/GNOME [9] was used to create the graphical user interface and the Gstreamer [7] library was used for multimedia functions such as accessing the built-in camera and recording/playing sound.

Stroke order recognition

As we identified earlier, the stroke order plays an important role in writing Chinese characters correctly and proportionally. Therefore, in order to help the students learn the correct stroke order, our games should detect a stroke order made by students. We designed a stroke order recognition algorithm based on the $1 recognizer [32].

Our algorithm first loads composing strokes of a Chinese character and the corresponding correct stroke order from a template library. Stroke composition information and stroke order information of a given Chinese character can be found from [26].

After a student completes a stroke for a character, the stroke traces collected are matched with the corresponding correct stroke by our recognizer. The $1 recognizer is used in this step to measure the distance between the collected stroke traces and the correct template stroke. Due to the fact that there might be multiple correct stroke orders for a single character, rather than matching input strokes with the strokes loaded from the template strictly, we set a threshold to tolerate a few minor mistakes. If the number of wrong strokes in a character is below the threshold, we accept the input as a correct character. Experiments show this technique improves the robustness of the two games, especially for the Multimedia Word. In addition, in a typical $1 recognizer, shorter strokes are inclined to be

more sensitive than longer strokes: short strokes are difficult to match each other. To address this situation, the threshold is weighted by the length of a stroke.

Finally, if a stroke is accepted, a student can continue to the next one, or else he/she has to rewrite it.

PRELIMINARY USER STUDY

We conducted a preliminary user study to explore how children in an underdeveloped region in China understood and played the above two games. The goal of the study was not so much to validate the games at this stage, as to qualitatively understand how the games we designed are used in practice, especially in the actual context of our target audience.

Materials

We selected 36 single-component characters and 23 composed-component characters as the test material based on feedback from primary school teachers. A single-component character only has one component, such as "与"(and), "九"(nine), "火"(fire), "区"(district), etc. A composed-component character is composed of multiple components, like "燕"(swallow), "拳"(fist), "溪"(creek), "鼻"(nose), etc. Those characters are selected because according to the teachers we consulted, they are either hard to write and remember, or hard to write in the correct stroke order. The 36 single-component characters are "与"(and), "甘"(sweet), "成"(succeed), "北"(north), "母"(mother), "身"(body), "九"(nine), "刀"(knife), "再"(more), "事"(thing), "火"(fire), "水"(water), "为"(for), "王"(king), "玉"(jade), "万"(ten thousand), "年"(year), "世"(world), "山"(mountain), "出"(out), "女"(female), "片"(slice), "去"(go), "里"(in), "齿"(tooth), "由"(reason), "曲"(bent), "皮"(skin), "垂"(droop), "凶"(fierce), "丑"(ugly), "巨"(huge), "良"(good), "过"(cross), "困"(stranded), "区"(district).

The 23 composed-component characters are "笔"(pen), "孩"(infant), "哭"(cry), "扇"(fan), "树"(tree), "睡"(sleep), "蛙"(frog), "芽"(sprout), "圆"(circle), "燕"(swallow), "剪"(scissors), "柴"(firewood), "拳"(fist), "弓"(bow), "熊"(bear), "脖"(neck), "齿"(tooth), "鼻"(nose), "梨"(pear), "鸡"(chicken), "纸"(paper), "旗"(flag), "溪"(creek).

Based on the teachers' input, we used single-component characters in the Drumming Stroke game in order to let the children focus more on the shapes and stroke order instead of the meanings. We used composed-component characters in Multimedia Word to encourage the children to focus on the meanings of the characters, in addition to their shapes and stroke order.

Participants

Nine students (five boys and four girls) from 1st grade to 3rd grade in Xin'an participated in the study. They are aged between 6 and 10 years (mean = 7.9 years). Xin'an is located in the north-west part of Henan province in China and is around 46km by 36km in area [8]. Due to difficulties in transportation, weather and geography (70% of the land are hills and 20% of the land are mountains), Xin'an is considered an underdeveloped region and suffers from poverty according to a recent Chinese government report [8]. All participants live at the edge of an old district in Xin'an, which has poor living condition.

The study took place over two days. Six children we initially recruited and participated in the pre-test session. On the first day, one more child was attracted to the study and joined in the first game (Drumming Stroke). Afterwards, two more children joined the second game (Multimedia Word). In the middle of playing the second game, one child was picked up by his parents because they needed to take him to visit his grandparents. As all of the above 3 newcomers had missed the pre-test, and one child withdrew from the study mid-way, only five children took the post-test. However, we were able to interview all nine children on their gameplay experiences, including those who did not take the post-test.

Methodology

Pre-test

Six participants took a dictation test with the 36 single-component characters and 23 composed-component characters prior to gameplay. Participants needed to write down the corresponding Chinese characters correctly when they hear the teacher pronounce the words. In particular, the children were asked to write and indicate the corresponding stroke order for the 36 single-component characters, while they were asked to write out the other 23 composed-component characters correctly. After the dictation, the answer sheets were collected and graded. The score of each child was the number of characters he or she could correctly write down in the test (one point per character, up to 59 points in total). None of the children were aware of their scores or the errors they made on their tests.

Game-test

After a brief instruction, participants played the two games for three hours. We observed the participants' behavior during gameplay and videotaped the sessions. Seven students played Drumming Stroke while eight played Multimedia Word. Children played each game for about 80 minutes with a 20 minute break between the two games.

Post-test

On the second day, five out of the nine participants took the dictation test again (one boy and three girls did not take the exam). The same teacher graded the pre-test and post-test.

Interview

After the post-test, the children gathered together, played the games freely and answered several open-ended questions about their school life, their difficulties in literacy and other studies, and the "ideal" language learning method

in their opinion. They also provided us with their feedback on our games, and their evaluation of how they and their partners performed in the games.

Observations

Although the time for gameplay was relatively brief, we observed promising results from children who played our games. All the children improved their performance on character recall and stroke order recall in the post-test. Due to the lack of a control group, other factors could have contributed to the improvements we observed, so we do not claim that the above two mobile learning games are chiefly responsible for this short-term performance improvement. Meanwhile, it is worth noting that the children were unaware of their performance on the pre-test and their errors on the pre-test when they took the post-test, so the two games we designed are indeed promising. Follow-up studies are needed to investigate the impacts of mobile Chinese learning games in depth.

Intuitiveness and Creativity

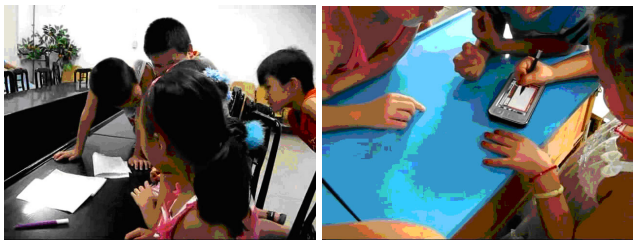
When playing the Multimedia Word game, children showed their enthusiasm for sketching, photo taking and voice recording. Children seldom get exposed to such interaction styles in their daily lives. The children were intrigued by the interactions and continued to engage with the games until they obtained satisfactory results. In Drumming Stroke game, the drumming music in the background appeared to play a very important role in encouraging participants to try their best to write strokes as fast and as accurately as possible. As the music's rhythm got faster, children felt the tension mounting, such that they tried to pass the mobile phone as soon as possible before the drum beat stopped. Some children even attempted to find out their next strokes before it was their turn to draw.

We also noticed that multimedia could effectively inspire children's creativity. For example, during the voice recording stage of the Multimedia Word game, children did not follow our instructions to pronounce the character that needed to be written. They felt that it would make the game too easy and hence less challenging. They instead tried to use other voices to describe the intended character, such as imitating the voice of a crying infant to provide a clue about the character "孩" (infant). Similarly, during the sketching stage of the Multimedia Word, a girl drew a bed and a child in the bed to as the clue for the character "睡" (sleep). The girl also added the moon outside the window and the ceiling lamp to emphasize the night scene..

Roles and Rules

While playing the above digital games, children spontaneously adjusted to modified roles and rules. Firstly, in the Drumming Stroke game, the mobile device can play and stop the drumming while someone is writing an incorrect stroke. In both the Multimedia Word and the Drumming Stroke game, the mobile judge whether the current writing is correct, and the device can also provide clues to guide children to correct their writing. Therefore, all children joining in the game can be more engaged.

Secondly, cooperation among the children was encouraged in both games. In the Multimedia Word game, children spontaneously organized themselves in two teams, and arranged the sequence of playing in the team. In the Drumming Stroke game, when one child had difficulty drawing his/her stroke, other children would spontaneously help the child to fulfill his/her task. While the traditional game was based on the competition pattern, in the mobile digital version, Drumming Stroke was played cooperatively by the children.



(a) **(b)**

Figure 5. Cooperation among different teams and competitors. (a) In Multimedia Word, children in the team of giving clues were supplying more clues when the team of guessing the result was in difficulty giving the right answer. (b) In Drumming Stroke, other competitors were giving suggestions to the current player who is in difficulty writing the correct stroke.

Thirdly, we also found there was a desire to monopolize the phone while playing both games. This might be due to the fact that mobile devices are more expensive than tools in traditional games like a beanbag, or a shuttlecock, and are thus novel to children in underdeveloped regions. Such a relatively expensive asset is always possessed by the more assertive children, especially when the game pattern is team competition. The reader should note that in our group games, we encouraged all children to engage in the activities like controversy, judgments and self-correction, but we do not expect all children to write characters simultaneously on the same shared device. Like resources in traditional games, mobile devices are used as holdable resources to make group games more interesting and engaging, and to support game play in non-classroom environments.

Learning

The scores of the six participants are listed in table 2.

During the interview, we learned that six out of the nine students' families had computers in their parents' workplaces. All of the nine families had mobile phones, but none of the children had their own phones. Only one family had a computer in their home. The data is consistent with the 10% computer penetration rate suggested by a local primary school teacher.

No.	Pre-test:SC	Pre-test:CC	Post-test:SC	Post-test:CC
1	33	20	34	21
2	17	11	18	12
3	21	17	N/A	N/A
4	27	14	31	15
5	18	14	21	16
6	18	11	21	12

Table 2. Scores of six participants in both pre- and post-tests. (SC: single-component character, CC: composed-component character. The pre-test data of Participant # 3 was not used in the analysis due to the lack of post-test data.)

Although there was a high error rate in the actual stroke order test, only three participants felt they had difficulties in mastering stroke order, while the others did not consider it to be a serious problem. Almost all of the children believed it was difficult to write a new character correctly.

Five of the students thought they performed reasonably in the two games, while three of them believed that they could do better. Students showed great enthusiasm for the two games, especially Multimedia Word. For example, after the interview, three girls continued to play Multimedia Word for almost an hour.

During the game play, children can continuously improve their knowledge in characters through personal judgment and self-correction. As all children were engaged in the discussion, everyone could benefit and pay attention to his/her drawing and the result. We also observed that when none of answers provided by the children were correct, only would they would pay more attention to the clues supplied by the mobile device. The children would also reflect on their mistakes. This positive outcome is not always easy to achieve in traditional classroom settings. In addition, children were more willing to be active learners and take the initiative to verify their answers, rather than receiving the information from the device passively.

CONCLUSIONS AND FUTURE WORK

In this paper, we analyzed unique problems in learning Chinese characters. Then we investigated important features in 25 traditional Chinese group games. Based on our analysis, we designed and implemented two group-learning games on mobile phones. Our results suggest that both the Multimedia Word game and the Drumming Stroke game can help children learn essential Chinese language skills via game playing in groups. We performed informal evaluations to understand the game play dynamics qualitatively. Results show that digital games have the potential to enhance the intuitiveness and engagement of traditional games, and it is encouraging to see that children can continuously improve their knowledge in characters through group activities such as controversy, judgment and self-correction.

To our knowledge, this paper is the first to leverage culturally inspired group learning games to help children learn Chinese characters on mobile devices. There are two major directions for our current research:

Firstly, the current experiments were preliminary studies. The results do not yet validate our approach quantitatively. We will continue the evaluation with more participants for a longer duration in rural areas.

Secondly, although we identified some important elements in traditional Chinese games, not all the elements were leveraged during the design process of the two mobile learning games, e.g. handmade game objects and predefined game/arena boundaries could be leveraged to further improve the intuitiveness and engagement of mobile games.

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REFERENCES

1. Aguilera M., Mendiz A., Video games and education: (education in the face of a "parallel school"). *Computers in Entertainment,* 2003, 1(1), pp. 1–14
2. Ai Y. *Guidelines of 215 traditional games for players*. Dolphin Press, Beijing, China, 2007.
3. Aranda D., Sánchez N. J. Understanding the use of video games in non-formal education in Barcelona. In *Proc. ACE 2008*, ACM Press (2008), 385-388.
4. Banerjee, A., Cole, S., Duflo, E., and Lindon, L., *Remedying education: Evidence from two randomized experiments in India.* Mimeograph, MIT, 2004.
5. Chen, Y., S., Kao, T., and Sheu J. A mobile learning system for scaffolding bird watching learning. In *Proc. IEEE WMTE 2002*, IEEE Press (2002), 15-22.
6. Feng J., Use of Games in Science Class, *Education Research Monthly,* 2008(7), 88-90.
7. Government Report - The Current Progress of Poverty Alleviation in Xin'an County, May 31st, 2009, http://www.xinan.gov.cn/xafpb/gzdt/webinfo/1242696764245706.htm
8. Gstreamer, http://gstreamer.freedesktop.org
9. GTK, http://www.gtk.org
10. Findlater L., Balakrishnan R., Toyama K. Comparing semiliterate and illiterate users' ability to transition from audio+text to text-only interaction. In *Proc. CHI 2009,* ACM Press (2009), 1751-1760.
11. Horowitz, J. E., Sosenko, L. D., J. Hoffman, L. S., Ziobrowski, J., Tafoya, A., Haagenson, A. and Hahn., S. Evaluation of the PBS Ready to Learn cell phone study:

Learning letters with Elmo. *Reported prepared by WestEd*, Sep. 2006.

12. Huang J. *Games in villages*. Nanfang Daily Press, Guangzhou, China, 2006.
13. Kam, M., Ramachandran, D., Devanathan, V., Tewari, A., and Canny, J. Localized iterative design for language learning in underdeveloped regions: The PACE framework. In *Proc. CHI 2007*, ACM Press (2007), 1097-1106.
14. Kam M. *MILLEE: Mobile and Immersive Learning for Literacy in Emerging Economies*, 2008, Ph.D. Thesis, UC. Berkeley
15. Kam, M., Mathur, A., Kumar, A., and Canny, J. Designing Digital Games for Rural Children: A Study of Traditional Village Games in India. In *Proc. CHI 2009*, ACM Press (2009), 31-40.
16. Kam M., Kumar A., Jain S., Mathur A., and Canny J. Improving Literacy in Rural India: Cellphone Games in an After-School Program. In *Proc. ICTD 2009*, April 17-19, 2009.
17. Literacy rate in different regions, http://www.china.com.cn/zhuanti2005/txt/2003-03/07/content_5289097.htm
18. Liu Q. Making children in low vision easily learning Chinese characters, *Journal of Modern Special Education*, 2004 (11), 32-32.
19. Moed A., Otto O., Pal J., Singh U., P., Kam M., and Toyama K. Reducing Dominance in Multiple-Mouse Learning Activities. In *Proc. CSCL* 2009, 360-364.
20. Moraveji, N., Kim, T., Ge, J., Pawar, U.S., Mulcahy, K., & Inkpen, K. Mischief: Supporting Remote Teaching in Developing Regions. In *Proc. CHI 2008*, ACM Press (2008), 353-362
21. Moraveji N., Inkpen K., Cutrell E., Balakrishnan R. A mischief of mice: Examining children's performance in single display groupware systems with 1 to 32 mice. In *Proc. CHI 2009*, ACM Press (2009), 2157-2166.
22. Nokia N800, http://www.nokiausa.com/find-products/phones/nokia-n800-r5
23. Pawar, U.S., Pal, J., Gupta, R. and Toyama, K.. Multiple mice for retention tasks in disadvantaged schools. In *Proc. CHI 2007*, ACM Press (2007), 1581-1590.
24. Pictionary, http://en.wikipedia.org/wiki/Pictionary
25. String game, http://en.wikipedia.org/wiki/String_figure
26. Stroke order, http://www.shuifeng.net/pinyin.asp
27. The evolution of the Chinese writing system, http://www.xmuoec.com/gb/teacher/hanzi/02/02_02_1.htm
28. United Nations Development Programme, China, http://ch.undp.org.cn/modules.php?op=modload&name=News&file=article&catid=13&topic=8&sid=447&mode=thread&order=0&thold=0
29. UNESCO, EFA Global Monitoring Report 2006, http://unesdoc.unesco.org/images/0014/001416/141639e.pdf, 2006
30. Wang F. Research about the education in literacy. *Qinghai Education*, 2008 (7), 54-54.
31. Wang Q. Constructing the Model of E-game Teaching, *Modern Educational Technology*, 2007, 17(11), 42-46.
32. Wobbrock, J. O., A. D. Wilson, and Y. Li. Gestures without Libraries, Toolkits or Training: A $1 Recognizer for User Interface Prototypes. *In Proc. UIST* 2007, ACM Press (2007), 159-168.
33. Xiao Z., Li Y., Xu Q., The education in game for Chemistry education in middle school. *Chinese Journal of Chemical Education*, 2008, 29(6), 30-34.
34. Zhang A. The joy method in low level Chinese education, *Journal of Dali University*, 2007, 6(1), 340-348.
35. Zhang X. *A research on the folk play of Yi Nation's children from the perspective of educational anthropology.* 2006, Ph.D. Thesis, Guangxi Normal University, China. .
36. Zhao L. The literacy education in primary school. *Data of Culture and Education*, 2006 (10), 94-94.
37. Zhao R. The Introduction of Digital Game-based Learning for the Resolution of the Obstacles in the Shift from the Computer-assisted Teaching Model to the Computer Autonomous Model. *Computer-assisted Foreign Language Education in China*, 2009 (1), 69-74.