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Authors	Wong Lung-Hsiang, Ivica Boticki, Sun Jizhen and Looi Chee-Kit
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Improving the mCSCL Approach of a Mobile Chinese Character Forming Game via a Design-based Research Cycle

Lung-Hsiang Wong, Learning Sciences Lab., National Institute of Education, 1, Nanyang Walk, Singapore 637616, lunghsiang.wong@nie.edu.sg
Ivica Boticki, Faculty of Electrical Engineering and Computing, University of Zagreb, Unska 3, Zagreb, Croatia, ivica.boticki@fer.hr
Jizhen Sun, Chinese Culture University, 231 Section 2, Jian-Guo S. Road, Taipei, Taiwan, ccsun@sce.pccu.edu.tw
Chee-Kit Looi, Learning Sciences Lab., National Institute of Education, 1, Nanyang Walk, Singapore 637616, cheekit.looi@nie.edu.sg

Abstract: We describe one cycle of design-based research (DBR) in which we explore mCSCL through an iterative process of (re)designing and testing the learning approach with students. The mCSCL application assigns each student a component of a Chinese character and requires them to spontaneously form groups that can assemble a Chinese character. We observe the enactment of the learning design in two modes (with and without the ICT), and found the students favor the card mode over the phone mode due to their emergent trial-and-error strategy. That triggered us to examine the scaffolding strategies by exploring domain-oriented theories to inform us in deciding how we should accommodate their use of the strategy. This cycle of DBR has reshaped our learning design. This paper brings to the fore the value of the interplay of theories, implementations and reflections as advocated by DBR.

Introduction

The proliferation of networked computers supplemented with software applications has provided us with a new network-based medium to design educational services. A variety of studies in the field of mCSCL (mobile Computer Supported Collaborative Learning) has explored opportunities for designing learning applications through mobile technologies (Looi, Wong, & Song, in-press; Zurita & Nussbaum, 2004). While such innovations coupled with learning design look promising, we need to deal with the challenge of adoptability in real classrooms. We adopted a design-based research (DBR) perspective to provide a cyclic process of designing, testing and redesigning the learning design and applications, and to integrate design principles with technological affordances to render plausible solutions. Our goal is to conduct reflective inquiry to test and refine innovative learning environments as well as to refine new learning design principles.

Building on prior studies, we propose the design of a model for a mobile synchronous collaborative learning game with the unique characteristic of spontaneous small group formations. In the game, students follow or adapt the collaboration rules or scaffolds imposed both by the teacher and by the computer system. To complete the learning tasks, they must draw upon their social relationships with other students to negotiate acceptable solutions. Previously, we developed a fraction addition game system and did trials with primary school students. This work yielded positive findings in students' emergent collaborative strategies (Boticki, Looi, & Wong, 2010; Boticki, Wong, & Looi, 2010). We then reused the generic software architecture and game model to implement "Chinese-PP", a game-based learning approach on collaborative Chinese character formation. PP refers to 拼一拼 or "Pin yi Pin" in Chinese, which roughly means "trial assembling". Our DBR methodology allowed us to collect and analyze data to many factors simultaneously and to use the rich data to iteratively improve a design more rapidly than might be accomplished through systematic experimentation on each individual factor (Design-Based Research Collective, 2003). Echoing Roschelle et al.'s (2010) call for transforming handheld collaborative tools to classroom modules, our ultimate goal is to elevate our game model to a pedagogically-oriented learning environment that can facilitate the students' learning growth over the time, rather than drilling them through repetitive game playing. We envisage a series of learning activities to be conducted on a regular basis with varied scaffolds and rules undergirded with a theoretical framework.

Now that we have the mCSCL tool, our discovery of the students' collaborative patterns in the fractions game and a theoretical framework for pedagogical design, we would like to adapt the model and the tool to a different domain – the forming of a Chinese character from components. The students involved in Chinese-PP game may demonstrate different collaborative patterns and encounter different challenges in achieving their game tasks as compared with the previous fractions game. Therefore, it was necessary for us to conduct experiments with students using Chinese-PP as part of the DBR process of building the learning environment.

This paper focuses on such a pilot trial of Chinese-PP, which was conducted in two modes, namely, one using digital technology - the "phone mode" and the other without the digital technology - the "card mode". The trial enabled us to examine the domain-independent and –dependent collaborative patterns and attitudes of

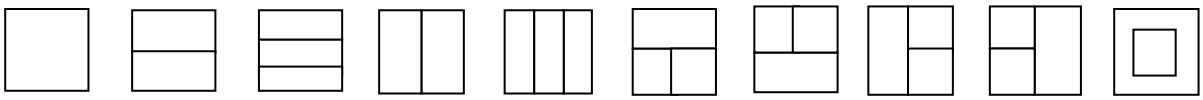
the students in each mode. With that, we gained a better understanding in the affordances of mobile technologies in facilitating such a game. The findings will inform us in the subsequent revision of both the game model and the mobile application, as well as assist us in fine-tuning of our pedagogical framework.

Background Literature

Chinese Character Learning

The Chinese script has always been the biggest challenge for learners of Chinese (Wong, Chai, & Gao, 2010; Y. Zhu & Hong, 2005). Fan, Tong and Song (1987) claim that the logographic nature of the Chinese script constitutes the primary hurdle. Shen (2002) attributes the challenge to the retention of the combination of sound, shape and meaning of a character in learners' long-term memory. This makes it even more difficult for a learner whose first language is based on an alphabetic writing system to master Chinese (Ho, Ng, & Ng, 2003).

The Chinese scripts are a principled and rule-based system – each Chinese character comprises of one or more components, spatially arranged with certain principles (Liang, 2004). Most of the components have fixed roles to play, as either a semantic component or a phonetic component; only a few of them play both roles. Furthermore, the number of commonly used characters for learners (1,000-3,000) is much larger than the number of component types (< 100). The number of characters' spatial configuration is also limited and rule-based. Zhao and Jiang (2006) propose that there are 10 basic spatial configurations for characters (see Figure 1).



1 (木) 2(安) 3(案) 4(对) 5(树) 6(获) 7(想) 8 (程) 9(新) 10(国)

Figure 1. 10 Basic Spatial Configurations for Chinese Characters (with One Character Example Each).

Studies (e.g., Wang, Perfetti, & Liu, 2003; Z. Zhu, 2004) have indicated that those who have acquired Chinese characters recognize them mainly based on their structural elements such as graphic forms and spatial configuration, treating each character as a salient perceptual unit. Tan and Peng (1991) also argue that analyzing the 3-dimensional characteristics (spatial configuration, semantic element and graphic form) is the necessary route leading to the effective recognition and reading of characters. Informed by language acquisition theories (e.g., Comprehensible Input (Krashen, 1985), Information Processing (Bialystok, 1978), and Connectionism (Gasser, 1990)) and Bloom's Taxonomy, we argue that there are six steps in acquiring Chinese characters, in hierarchical order: comprehension, combination, memorizing, application, analyzing, and creation. The fact that a limited number of semantic components and phonetic components can form a large number of characters leads us to argue that learning characters through rearranging and combining their components in different positions is cognitively effective, as it allows learners to comprehend, remember and apply the principles of character formation. This process also has the potential to nurture the ability of using educated guesses when they encounter unfamiliar characters in reading (e.g., a character with the component 氵 is likely to carry a meaning relevant to liquid, e.g., 河 = river, 湿 = wet).

Mobile-assisted Language Learning and mCSCL

In recent years, we have witnessed the paradigmatic development of the Mobile Assisted Language Learning (MALL) framework in enhancing language learning (Wong, Chin, Tan, & Liu, 2010; Wong & Looi, 2010). The focus of MALL research is shifting from content-based (delivery of relatively static learning content through mobile devices) to design-oriented (design of authentic or social mobile learning activities) studies (Kukulska-Hulme & Shield, 2007). In particular, Zurita and Nussbaum (2004) tapped on Syllable-mCSCL, a 1:1 (one-device-per-student) mobile learning game to facilitate Spanish vocabulary learning for young children. In their game design, the students were given language tasks that they had to solve by working in groups of three. A syllable is assigned by the system to each group member's mobile device (e.g., "si", "la" and "bi") and the three students need to determine sequences of the syllables to form correct Spanish words (e.g., "silabi").

Latest developments in the field of mCSCL extend the idea of mobile learning with the collaborative scaffolding in order to include both social and epistemic collaboration scripts encouraging small group participation (Nussbaum, et al., 2009). The design of collaborative scaffolding should encourage social interactions, facilitate joint problem solving, lead to richer knowledge construction and at the same time take into account different and emerging roles, joint group goals and actions and facilitate verbal explanations. These developments mesh well with our goal of designing a component-based Chinese character learning activity through socio-cognitivist and socio-constructivist means.

Towards a One-to-One mCSCL Solution for Chinese Character Learning

Building on the work of other researchers (Zurita & Nussbaum, 2004), we developed the Form-A-One (FAO) System, a mobile collaborative learning game with flexible, small group sizes. In Nussbaum's work, students are assigned to fixed small groups before the beginning of the activities. We adapted Nussbaum's design so that students would have to find and negotiate with other students to form their own groups spontaneously with no fixed size. The activity is conducted in multiple rounds. In each round, a set of fractions are assigned by the system server via 3G connections to individual students for them to form groups with the sum of the members' fractions of each group equals one (e.g., a group of three with 3/6, 1/4, 2/8). When the game advances to the next round, the existing groups are disbanded and a new set of fractions is assigned to the students. The activity consists of three main scaffolding sources: technological, social and the teacher. Technology provides scaffolding in both generic and context-specific rules and logic (in the form of software affordances), while the teacher acts as facilitator and helps the students in dealing with impasses. Social scaffolding is encouraged in order to increase student interaction and collaboration (Boticki, Looi & Wong, 2010).

We conducted a pilot study in late 2009 that involved 16 Primary 3 students (Boticki, Looi, et al., 2010) in Nan Chiau Primary School, Singapore. One important finding was the students' modification of their initially chosen ad-hoc strategies (e.g., gender or personal preferences, looking for the same fractions, randomly sending out invitations, etc., which inevitably ended with impasses) coming as a consequence of them realizing the importance of achieving the global goals besides their local group goal, therefore learning how to collaborate (e.g., breaking out groups for improved solutions). We then analyzed the process by examining the evidence and what it took, in the form of teacher, technology or social scaffolding, to achieve the four elements/principles of cooperative learning (Johnson & Johnson, 1994): positive interdependence, maximum peer interaction, equal opportunity to participate, and individual accountability.

Similar to the fractions game, the Chinese-PP activity is conducted in multiple rounds. In each round, a set of Chinese components are assigned by the FAO system server to individual students' smart-phones (with the Chinese-PP client application installed – see the screenshots in Figure 2a). Students are required to form groups by choosing appropriate characters out of the assigned components, thereby forming a valid Chinese character. Members of each group then discuss and choose one of the general Chinese character configurations (see Figure 1) to organise their components properly via templates (character configurations) supplied by the Chinese-PP application (arrows < and > in Figure 2a). For example, with the components 覀, 示 and 风, students could decide to choose template no. 9 (Figure 1) and place the components in the correct order to form the character.

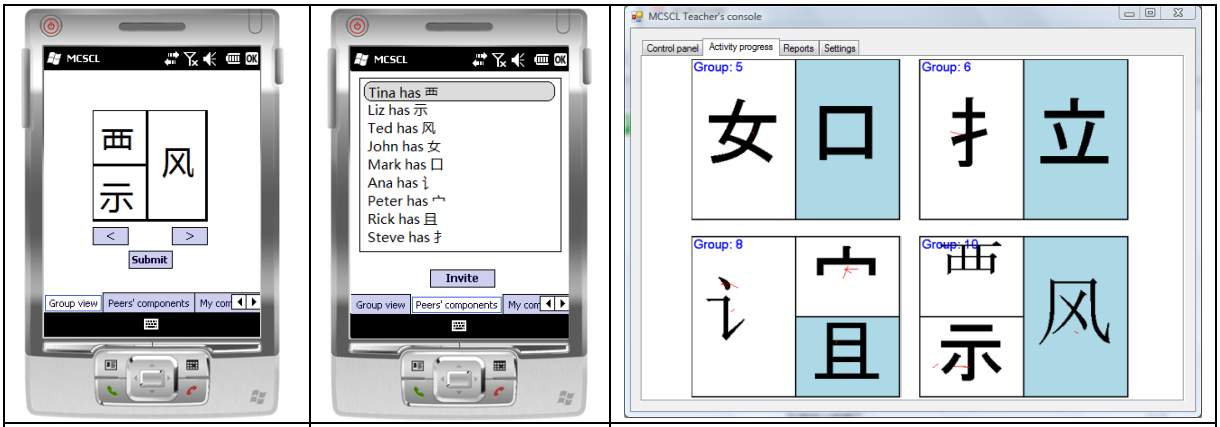


Figure 2a. A student's smart-phone application showing an assembled character out of individual components.

Figure 2b. A student's smart-phone application showing a list of student with components participating in the Chinese learning activity.

Figure 2c. A teacher's view of the Chinese language learning activity (the "Group Status Window"). The screen shows the characters from four groups of students. Each group has an assembled character framed into a template chosen by the students on the device.

In preparing each round of the game, the teacher needs to select a set of components according to the number of participating students and input them to the system. The choice of components should allow the construction of as many eligible characters as possible, and with at least one global solution (i.e., no component/student will be left out) available. For example, for an eight-player game, a possible component set is [木 又 寸 宀 女 禾 口 王], where students could form three groups and construct the characters [树 安 程] or [案 对 程] without any player being left out. However, there exist other combinations such as [宋 对 和], with王 and女being left out (no character with the combination of these components), and a lot more. Although students should be encouraged to socially figure out a combination where all the components are used to form characters,

it is a tall order for our target students to achieve that, given their limited language proficiency (Chinese L2 standard) and cognitive ability (Primary school level). However, we had been keen to introduce game rules to motivate them to form characters with as many components as possible and try to minimize the number of left-out peers. In turn, students who have formed groups should continue to explore other possibilities, perhaps by inviting another peer to join the group and form a new character (e.g., a group with the character 宋may invite their peer with the component女to form案), or even disband an existing group, combine and reshuffle with other components to form two or more new groups!

Micro-cycle of Design, Evaluation and Re-design with Chinese-PP

We ran the first implementation of Chinese-PP in Nan Chiau Primary School, involving 37 Primary 4 (10-year-old) students. These were mixed ability students in Chinese Language and had had one year's experience in using HTC TyTN II smart-phones on a 24x7 basis (and were therefore adept in using the device) for learning science, English and math. Among them, 16 students were also involved in the trial of the FAO fractions game in the previous year. As such a game may also be carried out, for example, using cards with individual character components being printed, we experimented on both the "phone mode" and "card mode" (with four rounds of each game) on two different days. The students were split into two subgroups. Subgroup A with 19 students played one hour of card game followed by one hour of phone game. Subgroup B with 18 students went through both games in reverse order. Table 1 shows the schedule of both subgroups' Chinese-PP experiences.

Table 1: The experimental process of Chinese-PP.

	Day 1		Day 2	
Subgroup A	Card game A-1	Focus group FA-1	Phone game A-2	Focus group FA-2
Subgroup B	Phone game B-1	Focus group FB-1	Card game B-2	Focus group FB-2

The games were played in a special classroom with more open space than usual so that the students could freely move around to negotiate with different peers in group forming. For the phone games, the students could invite potential group members and accept/reject invitations through the phone application. The teacher facilitated all the games by controlling the game pace, hinting the students on-the-fly concerning possible groupings, verifying students' groupings, and determining when to terminate a round.

We video and audio recorded all the games to document and code students' game behaviors and collaborative patterns. The software logs of the students' interactions during the phone games were also used for triangulation. In addition, we conducted focus group interviews as noted in Table 1 (each session involved six students, three of whom had also played the previous fractions game) in order to find out their perceptions in the games and the reasons behind the collaborative behaviors that we observed. Due to the space constraints, we will not show detailed coding and analysis of students' spatial movements and discourses, but will present high-level findings and how they have informed us in our subsequent adaptation of the learning environment.

The reason that we designed the experimental process in this way (Table 1), as opposed to the usual experimental-control group design, is that we wanted to let both subgroups of students to experience the game played in both modes. This approach permitted us to investigate the changes of their perceptions and to see if that might be influenced by the order of experiencing the two modes. Nevertheless, our initial analysis on the focus groups shows that both subgroups of students have expressed fairly consistent perceptions in both modes, and therefore the factor of "which mode was played first" did not have any substantial impact in our analysis.

Findings

Domain-independent Collaborative Patterns

In all the card and phone game sessions, the students exhibited similar discussion patterns as in the previous fractions games. Note that in both types of games, we encouraged the students to form legitimate groups with more peers, and to minimize left-out peers. Typically, in the beginning of a game round, students started exchanging ideas verbally about arranging the components. Most students started with identifying a classmate each to discuss, and then expand from pairs to clusters of 3-4 to discuss alternative possibilities. An initial set of groups was created in the process, with a few left-out students still looking for groupings. However, personal and gender preferences often influenced the formation of these initial groups. If the small amount of left-out students could not form new groups among themselves, they would seek peers' or the teacher's assistance in identifying other solutions. Meanwhile, some students who had already formed groups had considered helping their left-out peers by thinking of the possibilities of adding a group member or even splitting their own group. There came minor changes in the groupings with the effect of personal and gender preferences gradually fading out. Nevertheless, such positive tendencies were not good enough to make the students achieve any global solution (i.e., no peer was left out) in all the Chinese-PP sessions, which we will explicate below.

The gender-shy issue is relatively minor but still shows intriguing influences in the game dynamics – as it might result in sub-optimal solutions at the early stage of each game round which potentially jeopardizes the chance of eventually reaching a global solution. In the card games, as face-to-face (f2f) discussion was the only mode of collaboration, we observed that students almost always started with physical clusters of the same gender to carry out initial explorations. Students who were left out at this stage then proceeded to move around the classroom to seek groupings with members of opposite gender. Conversely, the phone games allow two modes of communication – f2f and phone invitation. We examined both the videos and the software logs and discovered that the same groups of students were less reluctant to invite members of the opposite genders to form groups even in the initial stage. In addition, we compared the final groupings of all the game rounds and found that 65.3% of the groups formed during the card games were comprised of members of the same gender, which was a high contrast with the phone games with only 40.2% of the groups were such. Among the 12 students interviewed during FA-2 and FB-2, 8 of them admitted that they were more gender-shy during the card games but not so during the phone games, while the rest claimed that they were not gender-shy in either mode.

Indeed, with two communication modes being offered by the phone mode, individual students may opt for their most comfortable method in interacting with their peers, which was one of the advantages of the mode. Nevertheless, due to the nature of the domain (Chinese characters) and the software UI design, most of them had surprisingly indicated their preference in the card mode after the study, which we will explicate below.

Domain-specific Collaborative Patterns

During the card games, we observed the students who clustered together often physically manipulated their cards by trial placing them in different spatial configurations. We identify it as a form of social scaffold. Figure 3 illustrates a scenario we observed in one of the card game rounds. Two students who carried the components 女 and 木 respectively tried all four possible configurations to bring them together (i, ii, iii, iv), but none of them formed a legitimate character. Third student who carried 宀 joined them, and tried to match the component with the first two students' components individually (v, vi), and legitimate characters were formed in both cases (宋, 安). They then faced a dilemma of "which friend to 'sacrifice'", thus deciding to try forming a three-component character instead. They formed 桉 (vii) but thought that it was not a character (this is a legitimate but rarely used one that they had not learned before). They eventually figured out vertical placing of the three components and formed the character 案 (viii).

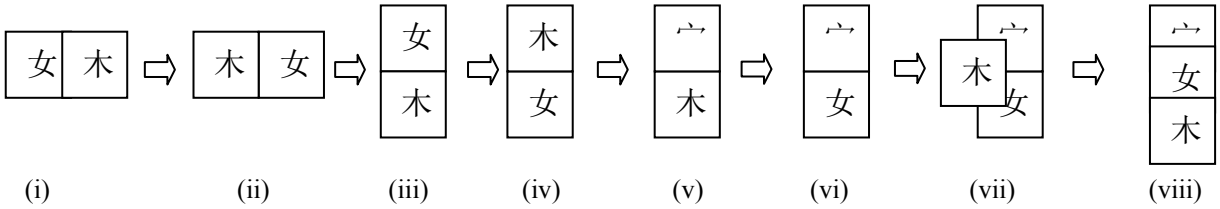


Figure 3. A Scenario of Three Students Manipulating Their Cards in a Card Game.

This is a strategy that we loosely call "trial and error" in this paper. We did not teach them this strategy but they figured it out by themselves. We observed that all students applied this strategy almost all of the time in the card games. The card mode offers the convenience of doing so while the phone mode does not. During the phone games, the students had to study the "peers' components" screen, and mentally construct and picture characters before deciding whom to invite. When playing the phone games, some students still approached each other physically to discuss, albeit not being able to physically "trial construct" characters from their components. In one instance during A-2, two students carried their phones close enough and manipulated their placements to imitate card manipulations (although they found it cumbersome).

At the end of A-2 and B-2, we asked for a quick show of hands to reflect the students' preference between playing card and phone game. More than 80% of them chose the former. The focus group interviews showed a similar tendency, which could be summarized in two points, (1) After A-1 and A-2, most of students had a good expectation in the phone game regardless of whether they had tried it, perhaps due to their technical-inclined mindset after using their phones for a year; (2) Having tried both modes after B-1 and B-2, most students got used to the trial-and-error strategy and found that only the card mode was conducive to that.

Obviously, the UI design and the invitation mechanism of the smart-phone application, both of which were inherited from the fractions game, had been too complicated as well as imposing an additional cognitive burden to them. We asked the students who had played the fractions game before to compare their experiences to the Chinese-PP game. Most of them did not mind playing the fractions game in phone mode as they were capable of the required mental calculations, while spatial configurations were not applicable to fraction additions. This suggests that the application UI was not an issue for this group of students who had been using the phones 24/7 for a year. Instead, it was the domain-specific factor that posed the challenge to them.

Towards the Pursuance of Global Solutions in Game Playing

Regardless of the game modes, the unique game design of Chinese-PP (as well as the fractions game), apart from spontaneous group formation with flexible sizes, is the reinforcement of global solutions (i.e., no student to be left out). In order to work toward this goal, students ought to set aside personal preferences and the pursuance of local (individual) goals to help their peers. While some groups might have formed their characters, the others might have reached a dead-end situation. Students are then required to put their global goal in front of the individual or group goals and start thinking about other possible solutions or group configurations – that is, they need to draw and integrate their thinking and collaborative skills and their linguistic knowledge to achieve this.

In order to encourage the students to work toward the goal, we projected the grouping status window which was originally designed for and only accessible by the teacher, to the students during the phone game. The display offers the up-to-date student groupings where students could study and consider if they could reshuffle or break existing groups to form better solutions. This is a potentially powerful affordance that the card mode cannot offer. However, according to our analysis of the two phone game sessions, the students often took a glance at the display, merely out of curiosity. When we explained to the students during the Focus Group FA-2 and FB-2 on how they could take advantage of the display, they all agreed (including those who did not favor the phone game) that they could benefit from it if they were given another chance to try the phone game.

In addition, after A-1 and B-1, we developed a scoring scheme and applied it in A-2 and B-2. Students accumulated scores by forming legitimate groups – 10 points for a 2-component character (same score to be awarded to each group member), 30 points for a 3-component character, 50 points for a 4-component character, and so on. This was to encourage the students to form bigger groups to fulfil "local" goals. However, in order to motivate them to assist their left-out peers (part of the "global" goal – to reduce the number of left-out students), each student who has formed group and earned points was penalized by 5 points times number of peers left out by the end of a game round. Due to a certain resource and time constraint, we did not automate this functionality in the phone game system. Thus, for both A-2 and B-2, we recorded the scores manually and wrote them on the whiteboard, which was logistically cumbersome and time consuming. However, some students reported to us that the new scoring system did stimulate them to pay more attention in balancing the "local" and "global" goals.

Subsequent Reflections and Further Work

ICT or non-ICT?

The trial seemed to leave us with more uncertainties. Shall we give up the phone mode and settle with the card mode for Chinese-PP due to the nature of the domain? Conversely, what are the potential technological affordances of the phone mode that may justify the mCSCL solution? If the answer is the latter, how can we deal with the perceived "incompatibility" between the phone game and the students' favorite trial-and-error strategy?

We further analyzed the designed and enacted game processes, and concluded that the critical success factor of this game is the intertwining of the local and global goals for the student players that would stimulate their active Chinese character retrievals, thinking of alternatives, applications of component rules, and making educated guesses when encountering unfamiliar characters. It may also further reinforce individual accountability, equal opportunity to participate, positive interdependence, and maximize peer interactions. We believe that the transparency of the global game view (the grouping status window) and the scoring scheme are two potentially powerful scaffold forms which should be retained. Both scaffolds, however, are logistically cumbersome if executed manually. In addition, a minor advantage of the phone mode is that the gender-shy issue could be eliminated at the beginning of each game round, instead of gradually fading out towards the end of a card game. In this regard, we believe that the retention of the technological form of Chinese-PP is justified.

Is "Trial and Error" a Suitable Learning Strategy or a "Bad Learning Habit"?

With that, we decided to provide a theoretical treatment on the emergent trial-and-error method to see if this is a justifiable strategy for Chinese character learning that we should support, or a "bad learning habit" to be rectified – and if that is the case, how can we design scaffolds to help students shake off the habit? We conducted another round of literature review on the relevant issues, which is summarized below.

The acquisition of any subsystems of a language involves how learners establish the connections between forms and their meanings. Most learners attend meaning before form in an attempt to communicate with others (Krashen, 1982). Ellis (1994) argues that the processes for the acquisition of semantic and the formal components of words are distinct. The form-meaning connection is initially made when learners register a form, a meaning and the fact that the form encodes that meaning in some way, or the meaning could be encoded by that form (VanPatten, 2004). Such a process is applicable to Chinese character acquisition as well.

Given the complexity of a form or a meaning that learners should acquire in order to establish the proper relationship between them, it is likely that learners would go through more than one attempt to make the form-meaning connections. Such a view is consistent with Piaget's theory of cognitive developmental stages

that include the sensory-motor period, preoperational period, concrete operational period and formal operational period. Piaget suggests that children first learn by actively doing in a random way and, as a result of experience and reconstruction, gradually move to think logically and more objectively during the concrete operational period that spans from 7 to 11 years old (Inhelder & Piaget, 1958). In our experiment, the students' learning strategies reflect the characteristics of the concrete operational period in which they assimilate in a collaborative learning mode using both trial-and-error and logical thinking as the main strategies to reach the next stage.

One of the strengths of mCSCL is its capability for multiple branching and for allowing learners making multiple attempts at problem solving, or in this case, at form-meaning connections. Therefore, we conclude that we should exploit suitable technological affordances to support such a strategy that students find it natural and even fun to apply.

Redesigning the Technological Support

Informed by our reflections, we revamped the technological support for Chinese-PP. A major redesign of the smart-phone application UI will take place. The two key improvements that we envisage are (1) to make the UI more intuitive and convenient for the students to perform their personal and social learning tasks; and (2) to allow multiple learning pathways catering to individual students' preferences (Looi, et al., 2009). We are designing a brand new UI where students will be given a working space on the screen, with their own and other peers' components all displayed at the edges in the form of "virtual cards". The students could easily drag and drop their chosen virtual cards onto and around the working space. The students will not have to construct the characters mentally but can perform a quick personal, virtual "trial and error" before inviting and negotiating with their peers. Furthermore, the invite-accept-reject mechanism will be simplified; an inviter's trial-composed characters will be automatically sent to all their invitees to support the latter's decision making.

Apart from the smart-phone application, the game status window will also be enhanced to support students' global goal pursuance. Other than the formed characters of the committed groups, the window will also display left-out components. Putting all such information in the same display will further stimulate the students to consider alternative groupings that may improve the overall solutions. Score tracking will be automated; and the students' scores and rankings will be updated dynamically in the same window. We hope that the combined use of the personal UI on the phone and the shared display will further reinforce the balancing between the students' pursuance of local and global goals. However, additional teacher scaffolds need to be in place to ensure students making good use of the resources. We will investigate such scaffolds, experiment with them in the subsequent studies, and incorporate them as either technological or social scaffolds.

Transforming Chinese-PP into an Effective Classroom Module

As stated before, we envisage elevating Chinese-PP beyond a one-off or repetitive mCSCL game design to become an ongoing pedagogical practice that facilitates students' language learning growth. We will co-design 8 one-hour learning session with teachers, with varied teacher/social/technological scaffolds and game rules (e.g., a new game rule "allow cloning of components in the same character" such as composing 淋 with two instances of 木, or alerting them on the relevant linguistic rules through the teacher or technological means) across different sessions. We will vary these elements not just for injecting new excitement to sustain the students' interest. We will strive for mapping a theory-informed (language acquisition theories and Bloom's Taxonomy) Chinese character learning process into the variations of the game elements. We intend to conduct a full-fledged study by implementing the new pedagogical model, with the revamped mCSCL infrastructure in place.

Conclusion

We have narrated our journey of conceptualization, prototyping, trial implementation, reflection, and refining of Chinese-PP which is our mCSCL solution for Chinese character learning. We adopted a DBR approach to embark on an iterative process of (re)designing and testing the learning approach by examining the effects of the technological and social scaffolding. In each iteration, we anticipated how the proposed learning design might be realized in a classroom, and how the students might collaborate, interact and learn as they participate in the activities. From the enactment of the learning design in two modes, we analyzed the actual process of student collaboration and learning in each of these two modes. On the basis of this analysis, we drew conclusions and made recommendations for the next learning design which will combine the best of the two modes.

Thus we found versatility and flexibility via the DBR methodology guiding our quest towards a refined solution to address the challenges that we encountered when students used the current design. In prior mCSCL (or learning technology in general) studies, the grounding of domain-specific learning theories tend to be accorded a lower priority. In the early stage of our study, we observed how domain-specific factors undermined the learning model. That is, the students performed well in, and positively perceived the previous phone-based fractions games. However, in the Chinese-PP games, they preferred the card mode due to their emergent trial-and-error strategy. That caused us to further examine the scaffolding strategies by conducting another round of literature review. We let the domain-specific theories guide us in deciding whether we should accommodate or

rectify the students' use of their emergent strategy. Our early exploratory study of the project has effectively reshaped our overall learning model design, bringing to the fore the value of the interplay and iterations of theories, implementations and reflections, as advocated by DBR.

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