Designing Technology for Content-Independent Collaborative Mobile Learning

Ivica Boticki, Lung Hsiang Wong, and Chee-Kit Looi

Abstract—This paper describes the design of a technology platform for supporting content-independent collaborative mobile learning. The technical architecture provides mechanisms for supporting and monitoring face-to-face collaborative activities between individual students at the class level. We present the theoretical underpinnings of our approach, the designed software and the cycles of a design based (DBR) approach to examining the outcomes of a series of preliminary trials. The experience from the trials has been used to propose a new cycle of the system and user interface re-design. They also provide demonstrations of the platform to support two content-specific learning applications, namely in mathematics and Chinese language learning activities in a primary school setting. Our experimental trials show the enactment of collaborative scaffolding comprising social, technological and teacher scaffolding in supporting the students’ collaboration and learning.

Index Terms—mobile learning, computer supported collaborative learning, mobile language learning, mobile mathematics learning, software architectures, design based research (DBR)

1 INTRODUCTION

The advent of mobile technology brings a new facet to the theory of computer-supported collaborative learning (CSCL) [1] by making collaborative learning activities more dynamic, personal and flexible. Although mobile devices provide a platform for communication, collaborative problem and project-based learning, some studies have reported one drawback of mobile device use [2], namely, teachers face the challenge of tapping this technological enabler in their classrooms to design lesson activities that genuinely integrate mobile devices into curriculum and lesson plans [3] [4-5].

In our attempt to better integrate mobile devices into everyday classroom practices, we present a design for collaborative mobile learning which spans across two dimensions: technological and social, and has the following characteristics: (a) the software system enforces collaborative rules in the technological dimensions therefore supporting face-to-face activities in the social dimension; (b) the technological dimension allows for the use of diverse content types (in other words it is content-independent) and (c) the teacher is able to utilize the technological dimension in order to provide scaffolding to participating students.

Two content areas have been implemented and used in trials with primary school children in Singapore: Chinese language and mathematics learning. The mobile collaborative technology, students’ existing personal relationships and the teacher’s facilitation together provide collaborative scaffolding to the students. This paper focuses on a synoptic description on the technical innovation of the proposed system, which is complemented by the presentation...
of some findings from a series of empirical trials using the Design Based Research (DBR) methodological approach.

2 THEORETICAL BACKGROUND

A variety of studies in the field of mCSCL (mobile Computer Supported Collaborative Learning) have explored opportunities for designing learning applications through networked mobile technologies [e.g., 1, 6-7]. In our approach, we propose a framework for delivering collaborative in-class (and potentially out of class) activities. It is intended to be a generic solution able for supporting learning in diverse content areas. This is achieved by a clear separation of the learning content and the generic collaboration rules and actions which can then be used with different kinds of content. In this paper, we provide an elucidation of the usage in two types of content areas: mathematics and Chinese language content, both delivered to students through the framework in a collaborative manner.

2.1. Enhancing Educational Practices through Collaboration and Mobile Devices

One of the biggest misconceptions regarding computer supported collaborative learning is that “the social interaction happens automatically” [8-9]. It is now known that for collaboration to happen, it is not enough to assign students to groups and merely provide them with computer-based tasks assignments [10]. Some team members might experience difficulties in communication, coordination and interaction with other team members [11], mostly because of the lack of visual contact and body language. Therefore, the real strength of computer supported collaborative learning does not lie in the collaboration around computers. It happens through computers and computer-supported social networks which enable peers to benefit from their interactions [12-13].

A key research in that area covers the use of mobile devices in the education of children six to seven years old [1]. Children were given assignments that had to be completed through collaboration with the certain level of interaction and communication exhibited in the process. Authors reported that the use of wireless networks opened up new educational opportunities and that mobile communication devices enhanced certain components of collaborative learning [8]: learning resource organization, social space for negotiation, communication between team members via wireless networks coordinated with the face-to-face network, coordination between states of activity, possibilities for interaction and the mobility of team members. The advantages of mobile versus classical computer-supported collaborative learning were seen through the enhanced possibilities for communication (conversations didn’t stop during team work), negotiation (computer supported and face-to-face) and mobility (combining computers and personal contact while learning) [1].

2.2. Design Based Research (DBR)

In our attempt to contribute to the existing body of research in mobile computer supported collaborative learn-
ing (mCSCL), we adopted the Design-based research methodology (DBR), also known as design research or design experiments. Collins, Joseph, and Bielaczyc [14] related such a methodology to the term ‘Design Sciences’ coined by Simon [15], as opposed to ‘Analytic Sciences’ which is associated with typical experimental-versus-control group (i.e., experimental design) studies. DBR seeks eventual adoption in school practices and therefore must be situated in real-life learning environments where there is no attempt to hold variables constant [16]. Instead, design-based researchers try to optimize as much of the design as possible and to observe how the different variables and elements are working out [17]. Under such a methodology, the learning design-enactment-reflection-refinement (or, invention-revision) cycles are iteratively conducted; thus as conjectures are generated and perhaps refuted, new conjectures are developed in the next cycle and again subjected to further testing.

2.3. Initial Research Efforts: Examining Collaborative Scaffolding in Learning Fractions

This research project has so far included two major phases. In the first phase, we applied the DBR methodology to collaborative learning of fractions in primary school classroom. Prior to our study, researchers have investigated the relationship between linking a symbol or written procedure with a related understanding, with implications that mathematics takes on meaning only when and where these connections are made [18]. [19] reports learning fractions as a gradual process in which children traverse from their already developed conceptions of rational numbers towards the “conventional world of fractions” stressing out the need for the exploration and consideration of different representational contexts and tools. Other research shows the students who appear to have formed understanding of fractions on a participatory level might be unable to meaningfully participate in further learning without being continually prompted by the teachers. Therefore, according to the well known Vygotsky’s notion of Zone of Proximal Development (ZPD), other more knowledgable persons are able to lead students into higher levels of performance [20].

We sought to leverage on the affordances of mobile technology in providing appropriate fraction representations for social learning. With every student holding a 1:1 mobile handheld, the designed collaborative activity starts with every student receiving a fraction assigned to them and displayed in their handheld. The goal of the activity is for each student to form groups with each other in which the sum of their fractions add up to one. Students can invite others to join their groups via invitations and acceptances through messages sent on the handhleds. Students also move spatially about in the classroom to chat with other students while performing this task.

In designing the collaborative activity for learning fractions, we identified several sources of collaborative scaffolding: technological, teacher and social scaffolding. All the three components are sources for collaborative rules which structure student participation in the activity to support better social interactions and to achieve task completion [21-22].
Technological scaffolding provides technology-embedded structures or rules for sending and receiving messages through the mobile devices which are handhelds. It relies on a specific rule structure and their interconnections, and is triggered via the user interfaces transmitting the messages. Social scaffolding, on the other hand, builds on top of the collaborative rules predefined by the teacher but draws from the emergent collaborative practices such as peer instruction, sharing through discourse, and mediation. The teacher scaffolding provides contextual assistance supplementing both technological and social scaffolding by building on the existing individual and collective group competence. The teacher scaffolding consists of teachers stepping into the activity at critical points in order to facilitate the activity progression. The teacher typically starts a discussion about the problem or impasse students may have, and tries to guide them to a breakthrough or possible solution. In the process, teachers can combine technological and social scaffolding thereby delegating some work to the technological infrastructure or the students.

In the activity the students rely on their social network of close friends in the class. They are more likely to invite their own friends or their own gender friends to form their own group which provides the social level of support. As the students are mobile, they re-arrange their spatial configuration as they move. It is also likely that they interact with those who are near them spatially.

2.4. Broadening Research Perspectives: Learning Chinese Language Characters

In our attempt to generalize our research findings, we started the second phase of research which moves to a different subject area, namely, Chinese language learning. We did that by building on the findings on collaborative scaffolding in fractions learning from the first phase, but we strived to make our technology content-independent. Therefore we created a platform for learning Chinese characters which is durable and can be used in diverse educational contexts – for intermediate language learners, as well as for beginners.

Each Chinese character comprises of one or more components which are spatially arranged according to certain principles [23]. Most of the components serve a fixed role, as either a semantic component or a phonetic component (e.g., a character with the component \( \hat{i} \) is very likely to carry a meaning relevant to water or liquid, e.g., 河 = river, 湿 = wet); only a few of them play both roles. Zhao and Jiang (2006) proposed that there are 10 basic spatial configurations for characters (see Figure 1).

Studies [e.g., 24, 25] have indicated that those who have learned 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 [26] also argued 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, i.e., the ability to attend the visual-graphic form is crucial in learning characters.
Informed by the language acquisition theories (e.g., Comprehensible Input [27], Information Processing [28], and Connectionism [29]) and Bloom’s Taxonomy, researchers have proposed that there are six steps in acquiring Chinese characters, namely in hierarchical order: comprehension, combination, memorizing, application, analyzing, and creation. The fact that a limited numbers of semantic components and phonetic components can form a large number of characters has led to the realization 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.

3. Designing a Content-Independent Learning System

3.1. Content-Independent Learning Technology Model and Design

In a nutshell, Figure 2 depicts a model of the proposed system for content-independent collaborative mobile learning. Students participate in a teaching activity by collaborating around content-specific learning applications scaffolded by the centralized server-side system. Student collaboration takes part on both technological and social dimensions through the exchange of collaborative system messages and by face-to-face collaboration, respectively.

The collaborative scaffolding from the social and technological framework dimension can be applied to different learning content, such as learning fractions or forming Chinese characters or idioms, by using the same set of
social and technological collaborative rules and technological communication mechanisms. The system considers any mobile learning content as the sequence of content elements that can be combined in a sensible unit, and distributes the elements (either generated automatically or as provided by the teacher) to students. In our software design, activity rules are content-dependent and are enforced both by the designed technology and through collaboration with teachers and peers (Figure 3).

![Figure 3. A two-dimensional matrix positioning the main design components in the socio-technological content-driven landscape](image)

Content dependent activity rules are defined for each mobile learning application. The fractions activity comes with rules which determine how to combine fractions (by summing or some other operations), what makes a whole or a solution, how to generate fractions prior to distributing them in order to have feasible local and global group goals, and how to introduce complexity when generating fractions (such as having larger denominators).

Conversely, in the collaborative activity of forming Chinese characters, the basic content elements are components which are arranged spatially to form legitimate Chinese characters. The rules of this activity define different graphical layouts of Chinese characters. They can be used to check whether a combination of Chinese characters produces a valid character and to check the semantics in case there are more feasible solutions than initially predicted.

### 3.2. Software Architecture for Mobile Collaborative Content-Independent Learning

Following the recent developments in the field of information technology, the physical system architecture is designed to be modular, extensible, object-oriented, and multi-layered. The main parts of the system are libraries called frameworks: the Base Framework, the Device Framework and the Server Framework. The latter two are built upon the Base Framework to provide services to specific parts of the system. The Desktop Framework is used by the
applications for desktop computers (in our specific case teacher’s console application); the Device Framework by the client applications and its applicative modules (in our case fractions and Chinese language mobile learning applications) while the Server Framework provides the base for the Contextual Information Service, Event Service, System and Applicative Services (Figure 4).

![Figure 4. Framework’s physical architecture stack](image)

The Base Framework is composed of sub-modules designed for communication between the server and the clients, structuring and assembling event messages [30]. This library is composed of specially designed controls called widgets which are used to implement contextual features of the system: privacy, spatial, contextual, configuration and communication-identification widgets. All of them are used to exchange contextual information between mobile connected client devices and server components. The Base Framework contains basic building components extended by the Device Framework and Desktop Framework in order to support platform specific activity.

The Server Framework is a component based on the Base Framework which provides services to higher-lever server components. It uses common modules for distributed events from the Base Framework and arranges the server side logic to assemble event messages, send event messages to clients, receive information about the message delivery and retransmit messages if the need occurs. It uses configuration, location and contextual widgets, which process contextual information on the server side before it is handed over to the module for contextual information to be stored in the database or to be further handed over to the module for event sending. In addition to using widgets to deliver contextual system architecture, the Server Framework contains modules for data caching in order to ensure fast data access as well as numerous data and parameters specific to the server side of the system [30] (Figure 5).
The Device Framework extends the Base Framework components with new components that enable information exchange between contextual clients (mobile connected device) and server components (Figure 6.). It contains the elements for the module for message receiving and response (explained in detail in [30]). To represent an event message with appropriate programming entities, a special module called the Event Factory is used.

Since all applicative functionality of mobile connected devices in the system is realized as a set of loosely connected modules which can easily be plugged in and out from the system, the Device Framework contains additional modules used to drive the communication. To provide secured access to services, a mechanism for acquiring service tickets from the server side and storing them in a special component called Ticket Store is provided. Stored service tickets can be (re)used by all client applicative modules.
Applicative services are used by the applications installed on mobile connected devices and are commonly used as interface to the central system data repository. Applicative services are mutually independent and do not influence the operation of server services in any way which makes them easily extendable and replaceable, even during the normal system operation.

4. Making Use of Content-Independence: Two Mobile Learning Applications

4.1. Learning Fractions

In the Learning Fractions activity, each student has a handheld device with the preinstalled framework and the Learning Fractions application. Once the application is launched, students’ handhelds report to the centralized server side component via available network connections (e.g. WiFi or 3G). As soon the teacher starts the fractions learning activity, the fractions are delivered to students’ devices (Figure 7) and students can start collaborating in order to complete the task of assembling circles out of individual fractions.

![Figure 7. A fraction assigned and displayed on a student’s mobile device](image1)

![Figure 8. Student issuing a group invitation to his classmate](image2)

Students begin collaborating both on the social and on the technological dimensions in order to come up with a solution. Socially, they circle around the physical learning environment and communicate with their peers in order to negotiate a common solution. They refer to the mobile application containing the list (Figure 8.) of their peers and, once a potential solution is negotiated, they invite a colleague to form a group. Students collaborate and form groups by adding (merging) fractions until they come up with fill circles (wholes).

Prior to the assignment of fractions to students, the server-side component runs a fractions generation algorithm which ensures that there is a global solution, namely, at least one possible solution in which every student belongs to a group and every group has a full circle. Although the random fraction distribution ensures fraction diversity, the teachers can also control what fractions get distributed.

Local optimum presents a formed whole circle within a group. Although optimal for a group, it might not be
optimal for all groups. Some groups might be blocked in reaching their local optimal solutions because one group reached a certain local optimum (Figure 9). The group then has to be broken and other groups have to be assembled, hopefully leading to optimal solutions for all groups which would mean the completion of the whole activity.

![Figure 9. A group configuration of an impasse preventing students from achieving the global goal](image)

4.2. Learning Chinese Language (Chinese-PP)

The second application is called Chinese-PP, PP referring to 拼一拼 or “Pin yi Pin” in Chinese, which roughly means “trial assembling”. Similar to the fractions game, a set of Chinese components are assigned by the system server via available network to individual students’ handhelds. Students are required to form groups by combining appropriate components to form valid Chinese characters. During the process of character forming, members of each group choose an appropriate Chinese character template (character configuration) which is supplied by the Chinese-PP application. For example, with the components 木, 示 and 风, students could decide to choose template no. 9 (Figure 1) and place the components in the correct order to form a character.

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 a game with eight participants, a possible component set is 木 又 寸 女 禾 口 王, where students could form three groups and construct the characters 桐 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 (there is no character with the combination of these two components), and a lot more.
Figure 10. Chinese-PP application user interface enabling character composition

During the activity, the teacher is presented with an aggregate view of all characters formed by the groups. All assembled groups and template-arranged characters are depicted and ready to be shown to the students if the need for additional scaffolding occurs (Figure 11). For example, students should be enticed to compose more complex characters, help their peers by disbanding existing groups and form new groups etc.

Figure 11. Chinese-PP teacher’s console showing assembled groups and Chinese characters

5. Experience from Using Chinese-PP in Trials

Both applications, Learning Fractions and Chinese-PP, were evaluated in a primary school in Singapore [31]. The study essentially involves re-designing the curriculum and the lesson plans so they can be delivered in a “mobilized” way. This means not only appropriating learning contents so that they fit mobile devices, but also encompasses the redesign of complete learning environment which becomes more collaborative, contextual and inquiry-oriented.

Learning Fractions and Chinese-PP present two specific interventions within the project focusing and promoting in-class collaboration between mobile students. Several trials were conducted for each application in order to gather the data about general user experience, system performance, user interface design and to set off a new cycle of system redesign.

A pilot study on Learning Fractions was conducted in late 2009 that involved 16 Primary 3 students [21]. 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).

5.1. Cycles of the DBR Approach to Evaluating Chinese-PP

To carry out the Chinese-PP studies in our collaborating school, we have planned three DBR cycles that aim to advance from the basic learning design towards an effective mCSCL practice informed by language acquisition theories:

- 1st Cycle – Evaluation of the learning design: Two rounds of trial runs (known as micro-cycle 1.1 and micro-cycle 1.2 respectively hereafter) were conducted with small groups of Primary 3-5 (9-11 year-old) students. They just played the game with the prescribed rules so that we could identify emergent learning patterns, iron out logistic and technological issues, and retrieve students’ and teachers’ perceptions of the new environment. The findings in each round informed our refinement in the rules and the software, which were then tested in the subsequent round.

- 2nd Cycle – Pilot classroom lessons: The design of a pedagogical framework to facilitate a series of learning and game playing sessions that foster students’ learning growth over the time. The Chinese Language teacher in the Primary 3 experimental class took the lead in designing and enacting individual lesson plans while the researchers focused on playing the supporting roles.

- 3rd Cycle (not yet started) – Implemented classroom lessons: The school will take over the agency in scaling up the learning model to all its Primary 3 classes. We will provide support in teachers’ professional development as well as collect data in all the classes to assist us in our on-going analysis and refinement of the design.

5.2. Micro-cycle 1.1 of the DBR Process

In the microcycle 1.1, we engaged 37 Primary 4 students in the trial runs. These were mixed ability students in Chinese Language. As such a game may also be carried out, for example, using cards with individual components being printed, we experimented on both the “phone mode” and “card mode” (with four rounds of each game) on two different days. The card games applied almost the same game rules as the phone games except without any ICT support, and the students would need to cluster together to manipulate their cards in trial composing characters. For the phone games, the students could invite potential group members and accept/reject invitations through the smartphone application. The teacher facilitated all the games by controlling the game pace and by providing hints to
the students on-the-fly concerning possible groupings, verifying students’ groupings, and determining when to terminate a round.

All the games were video- and audio-recorded for analysis of students’ game behaviors and collaborative patterns. The software logs of the students’ interactions during the phone games were also used for triangulation. In addition, the focus group interviews that took place after each pilot run were conducted in order to reveal the students’ perceptions in the games and the reasons behind the game playing and collaborative behaviors that we observed (Table 1).

Table 1: Summary of focus group interviews

<table>
<thead>
<tr>
<th>Perceived advantages of playing the “card mode”</th>
<th>Perceived advantages of playing the “phone mode”</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Very fast to find partners.</td>
<td>• Do not need to move around if one does not want to.</td>
</tr>
<tr>
<td>• Conducive for the “trial and error” strategy.</td>
<td>• “It is fun to use the phone” (but could not explain why)</td>
</tr>
<tr>
<td>• Do not need to invite and wait for replies.</td>
<td>• Can easily see all components available and need not walk around.</td>
</tr>
<tr>
<td>• Can easily manipulate the cards for “trial and error”</td>
<td>• Can easily see all components available (in the card game, some students might be selective in showing their cards to the peers who approached them).</td>
</tr>
<tr>
<td>• Do not need to wait for replies.</td>
<td></td>
</tr>
</tbody>
</table>

5.3. Redesigning the Technological Support

Informed by the DBR methodology, we further reflected on the designed and enacted game processes to decide on whether we should give up the phone mode and proceed to use the cards for our future study. Rather than relying on anecdotal judgments, we let the domain-specific theories inform and guide us in deciding whether we should accommodate or rectify the students’ use of their emergent game strategy. In summary, our decision was to retain and improve the mCSCL solution. For example, the students’ trial-and-error strategy in the card mode has inspired us to re-design the smartphone application UI to show “virtual cards” of individual components that can be dragged and dropped onto the working space to try assembling. The tedious manual scoring tasks have been automated as well; individual students’ scorings and their overall rankings are dynamically updated in the teacher’s console (Table 2).

Table 2: Summary of the Chinese-PP technology redesign decision

<table>
<thead>
<tr>
<th>Improvement area (features lacking in the initial design)</th>
<th>Data Collection</th>
<th>Redesign decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group forming/invitation mechanisms</td>
<td>Focus group interviews; researcher observation; video records; software logs</td>
<td>• UI redesign which does not require explicit individual inviting, accepting or rejecting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Each student chooses one or more acceptable groups to belong to</td>
</tr>
<tr>
<td>Character forming mechanisms</td>
<td>Focus group interviews; researcher observation</td>
<td>• UI redesign showing “virtual cards” of individual characters that can be dragged and dropped onto the working space both using stylus and fingers</td>
</tr>
<tr>
<td>Personal space for “trial and”</td>
<td>Focus group interviews; video</td>
<td>• UI redesign in which each student can try out assem-</td>
</tr>
</tbody>
</table>
The invitation-reply system proved to be a bottleneck in the Chinese-PP activity as well, but not as severe as in the Learning Fractions activity due to its more flexible design (students are able to experiment with character formation even if some of the peers haven’t accepted their invitation to join the group). In analyzing the number of exchanged messages during one of the Chinese-PP trials with N=12 participating students, we observed a surprisingly high number of exchanged event messages NE = 317 during less than 5 minutes of activity duration (Table 3). This certainly does not impact our system’s performance itself, but in case of deadlocks (i.e. one student does not reply) usability issues arise.

Table 3. Number of event messages exchanged during one Chinese-PP activity

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number of messages</th>
<th>Event description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ServerSendGroupConfiguration</td>
<td>160</td>
<td>Server sends members’ components to a student</td>
</tr>
<tr>
<td>GroupSubmitSolution</td>
<td>74</td>
<td>A group has submitted a solution (i.e. a composed Chinese character)</td>
</tr>
<tr>
<td>StudentInvitationGroupRequest</td>
<td>23</td>
<td>A student is invited by another student to join a group</td>
</tr>
<tr>
<td>ServerSendGroupInvitation</td>
<td>16</td>
<td>Server hands over a group invitation from one student to another</td>
</tr>
<tr>
<td>ServerCancelledOperation</td>
<td>15</td>
<td>Server cancels an action</td>
</tr>
<tr>
<td>ServerSendActivityInfo</td>
<td>12</td>
<td>Server sends initial activity information to a participating student</td>
</tr>
<tr>
<td>StudentAcceptedGroupInvitation</td>
<td>9</td>
<td>Students accepts another students’ group invitation</td>
</tr>
<tr>
<td>StudentRejectedGroupInvitation</td>
<td>7</td>
<td>A student rejected a group invitation</td>
</tr>
<tr>
<td>TeacherActivityStart</td>
<td>1</td>
<td>Activity start event</td>
</tr>
</tbody>
</table>

We then proposed a completely new user interface design and changes to the architecture event (communication) messages. In the new design, students now have two Chinese-PP applications screens. On the first application screen (Figure 12), they have an overview of all participating peers and are able to drag and drop peers’ components onto a centrally positioned canvas. After they arrange the components on the first screen, student groups on the second screen are automatically created by the system (Figure 13). Students then choose only the groups (characters) they want to participate in (the ones they think are correct). Each choice is supplemented by a number of points a
group gets after it gets accepted.

![Figure 12. A sample of the new UI design – common area for character assembling](image1)

![Figure 13. List of all potential groups ready to be chosen by the students](image2)

The presented approach reduces the complexity of the technological scaffolding by simplifying initial Chinese-PP UI design. There is no functionality loss due to the reductions applied and students will presumably benefit from a more adequate user experience.

### 5.4. Micro-cycle 1.2 of the DBR Process

We advanced to the micro-cycle 1.2 by inviting two groups of students to try out the redesigned system. The first group comprises 15 out of the 37 students who were involved in the first micro-cycle’s experiments (who had moved up to Primary 5). The second group comprises of 16 Primary 3 students (which was not the experimental class of the 2nd cycle), also with mixed abilities in Chinese. After the experiments, most of the students had indicated that they preferred the phone mode. The Primary 5 group who used to prefer the card mode in the last micro-cycle told us that the new UI had essentially resolved the ‘problem’ of inconvenient character composition process, with the additional advantage of letting them seeing all their peers’ components on one screen.

With the UI redesign, we observed one major difference in the students’ game playing pattern as compared to the first cycle. That is, at the beginning of each round, instead of going straight to peer interactions, they spent quite a while to drag, drop and assemble components into characters individually, as though they were attempting a one-player game.

What raised our concern was that some of the students just took their time to work individually and did not bother to advance to peer negotiations. Another issue that we observed was pertaining to the teacher’s facilitation of the game sessions. With the researchers’ assistance in controlling the teacher’s console and supporting the logistics,
the teacher had been too preoccupied with interacting with the students, answering almost every single question from the students, and often giving away correct solutions too easily. Occasionally, we needed to remind her to return to the teacher’s console to approve or reject students’ submitted groupings.

5.5. 2nd Cycle of the DBR Process

In the 2nd cycle of the study, we engaged in a recursive process of designing, enacting and refining a series of Chinese-PP classroom sessions. The sessions take place roughly once every fortnight unless pre-empted by school exams or holidays. According to our plan, at least six one-hour Chinese-PP sessions would eventually be conducted. Each learning session consists of three segments, namely, warming up (about 15 minutes), game playing (about 30 minutes), and recalling (about 15 minutes). In the warming up segment, the teacher delivers brief instructions with Powerpoint files on specific knowledge of Chinese character structure. The aim is to equip the students with prerequisite knowledge for the subsequent (two to three rounds of) mobile-assisted game playing. After the game, the teacher facilitates a recalling activity where the students are asked to relate the characters that they have composed during the game with the character structure knowledge that they have learned from the teacher.

Sixteen Primary 3 students (not the same group of students involved in the micro-cycle 1.2 study) with mixed ability in Chinese took part in the study. To date, we have conducted six Chinese-PP sessions on these students to facilitate their progressive learning growth. During the game playing segments, we collected data on the students’ mCSCL behaviors through field note taking, video recording (with two camcorders that record the processes from two different angles, voice recording (one neck-hanging voice recorder per student), and system logging of the students’ smartphone-based communication. Such data enabled us to trace and re-compose the students’ actual game playing process. As this paper’s focus is to present a synoptic view of the technical innovation of the proposed system, we will only provide summarized findings from our data analysis in the subsequent paragraphs. For more details on the target students’ mCSCL patterns during the games, please refer to [32].

Essentially, during the earlier Chinese-PP sessions (sessions 1-3), we observed that the students tended to be contented in proposing two-component characters and earning 10 points for each group member. As such, their interactions had been fairly minimal. Characters with three components or more had been rarely composed by the students. As advised by the teacher, we revised the game rule and the system prior to the 2nd cycle pilot study by allowing students to join more than one group and accumulate more scores within the same game round (in order to encourage compositions of alternative characters). Nevertheless, the students usually did not bother to take ad-
vantage of this rule and instead stop playing after composing the first legitimate character.

Nevertheless, we had also observed that a high-achievement (HA; in terms of her academic performance in Chinese class) student Wendy (pseudonym) often took the initiative to advise her peers in their game playing. As for the low-achievement (LA) students, they were not left alone during the game. This was because the more proactive students (who were not necessarily HA students) would search for partners to compose their own groups, and they were likely to incorporate the LA students’ components. Consequently, the Chinese character knowledge of the pro-active students could be transferred to their counterparts.

As time went by, the students were getting more familiar with the game and acquired more Chinese character knowledge from the teacher (through the warming up segments) and their peers (through game playing). From session 4 onwards, the students became more keen to compose more complex characters. While we had envisaged (prior to session 4) that the students would typically start with composing simpler characters and then invite more peers to join them to compose more complex characters (“bottom-up”, e.g., two students compose 音 [“sound”], and then invite the third student with the component 心 [“heart”] to compose 意 [“meaning”]), we had surprisingly observed an opposite emergent strategy from them. That is, with the desire to earn more scores, they started with composing a complex character (since they had been getting better in doing so), and then gradually decomposing it and/or replacing certain components to form more characters (“top-down”). For example, during session 6, five students formed the 5-component character 警 (“warn”) and received 40 points each. They then gradually decomposed the character by removing one component each time, and “transformed” it to 敬 (“salute”, 30 points each), 個 (“thoughtless”, 20 points) and 句 (“sentence”, 10 points each). Based on our compilation of the students’ game playing processes in sessions 5-6, the students had been consistently applying both the “bottom-up” and the “top-down” but the latter seemed to occur more frequently.

The students’ adept game playing skills as demonstrated towards the later Chinese-PP sessions constitute a strong evidence for the potential effectiveness of our novel spontaneous group forming approach for mCSCL activities. Whereas prior CSCL studies have focused much on predetermined and fixed student grouping in F2F collaborative learning activities to ensure proper enactment of specific collaborative scripts or scaffolds, our work shows that the alternative grouping approach may result greater in diversity in students’ collaborative patterns and learning gains. We intend to further analyze the game process data in order to distill various socio-cognitive and socio-constructivist processes of their game playing, and to map the cognitive processes to the relevant theories of second language acquisitions and Chinese character learning. It is hoped that such an effort will lead to the discovery of
more effective pedagogy and learning strategies for younger Chinese L2 students in understanding the structure of Chinese characters.

5.6. Emergent and Challenging Teacher Roles

Our observations during both the 1st and 2nd cycle of the DBR process prompted us to reflect on the teacher’s roles in the game. In the future, when such a learning model is translated into a school-based curriculum, researchers will not be around and individual teachers will be on their own. Our participating teacher’s facilitation style during the 2nd cycle will not work. We extracted all the student questions from the transcription of the games. We then asked the teacher to categorize them and determine suitable strategies to deal with each type of questions, with the following intentions in mind: (1) to promote student thinking and collaborations, rather than spoonfeed them; (2) to reduce her burden in classroom orchestration and be able to smoothly switch between teacher-student interactions and the controlling of the teacher’s console. For example, if a student assembles a character on the phone and asks for the teacher’s verification without even consulting the relevant peers (i.e., the student is still in the “personal trial phase”), the teacher may advice the student to discuss with those potential group members.

6. Conclusions

This paper presents an architecture for content-independent collaborative mobile learning, and describe the preliminary trials leading to a new cycle of both system and research re-design. Drawing from the theories of computer-supported collaborative learning and language learning, the system scaffolds students in collaborative activities around concrete content primitives: either Chinese character components or mathematical fractions. Through collaboration on both technological and social levels, students work out solutions to tasks set up by teachers. Technology provides scaffolding via both content-dependent and content-independent software features or affordances, while the teacher acts as facilitator and helps the students to dealing with impasses. Social scaffolding is encouraged in order to increase student interaction and collaboration.

In examining the effects of our interventions, we designed trials with the two applications for Chinese language learning and mathematics learning. Through the trials in Learning Fractions, we explored the notion of collaborative scaffolding consisting of three components: social, technological and teacher scaffolding. We observed occurrences of negotiation, peer instruction and generally collaboration beyond physical and social boundaries. We continued our effort by designing a Chinese-PP application for learning Chinese characters. Our experiment design was taken to a new level by having included a card group as a control group into our experiment. The card group mimicked our software design and allowed us to closely examine its drawbacks learning to a new cycle of software rede-
The next step will be a new cycle of research, software and intervention design. We plan to embed the approach into regular primary school Chinese language lessons as a full-fledged study and examine its effects on a long-term basis. Our software will be redesigned to fit new technologies and UI design principles. By using it, students will be able to take their own individual paths in learning while being guided by the system.

REFERENCES


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