Designing Content-Independent Mobile Learning Technology: Learning Fractions and Chinese Language

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ABSTRACT

The paper describes a framework for content-independent collaborative mobile learning along with the two content-specific applications built on top of it. The technical architecture provides mechanisms for computer-based collaboration that facilitates face-to-face collaborative mathematics and Chinese language learning activities in a primary school setting. We present the theoretical underpinnings of our approach, the software and research design in both mathematics and language learning, as well as 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, and research design.

Author Keywords

mobile learning, computer supported collaborative learning, mobile language learning, software architectures

INTRODUCTION

The mobile technology is bringing a new facet to the theory of computer-supported collaborative learning (CSCL) (Zurita & Nussbaum, 2004), by making collaborative learning activities more dynamic, personal and flexible. In that sense collaboration happens on the move and is integrated with the personal character of mobile devices providing a platform for communication, collaborative problem and project-based learning. However, some studies report the drawbacks of mobile device use (Sharples, 2003) claiming teachers are challenged to tap this technological enabler in their classrooms and to come up with lesson activities that genuinely integrate mobile devices into curriculum and lesson plans (C. K. Looi, et al., 2009)(Roschelle, Rafanan, Estrella, Nussbaum, & Claro, 2010; Shen, Wang, Gao, Novak, & Tang, 2009).

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); (c) the technological dimension can be reused for different content types (e.g. mathematics, language learning etc.) and (d) 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. For each of the content-specific activities, we have conducted a series of trials informing us on the following: user interface design, system performance and, finally, our research design. The mobile collaborative technology, students' existing personal relationships and the teacher's facilitation together provide collaborative scaffolding to the students. Based on the empirical findings, we can plan more thorough series of trials with a redesigned user interface, enhanced system characteristics and a more adequate research design.

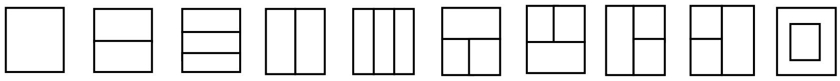
THEORETICAL BACKGROUND: MOBILE COLLABORATIVE LANGUAGE LEARNING

One of the biggest misconceptions regarding computer supported collaborative learning is that "the social interaction happens automatically" (Kreijns, Kirschner, & Jochems, 2002; Stahl, Koschmann, & Suthers, 2006). It is now known that for collaboration to happen, it is not enough to assign students to groups and provide them with computer-based assignments (Johnson & Johnson, 1998). Some team members might experience difficulties in communication, coordination and interaction with other team members (Curtis & Lawson, 1999), 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 benefit from peer experience (Haythornwaite, 1999; Inkpen, Booth, Klawe, & Upitis, 1995).

Independence of time and location together with the potential of supporting interactive team members' communication make mobile computer supported collaborative learning the next logical step in the research and the development of the area of collaborative learning (Cole & Stanton, 2003). By using mobile devices, learning becomes personal since every student has his or her own mobile device. Mobility, flexibility and the fact that mobile devices are always available to students make ad hoc collaborative activities possible. A key research in that area covers the use of mobile devices in the education of children six to seven years old (Zurita & Nussbaum, 2004). 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 (Kreijns, et al., 2002).

Each Chinese character comprises of one or more components which are spatially arranged according to certain principles (Liang, 2004). Most of the components have fixed roles, as either a semantic component or a phonetic component (e.g., a character with the component 氵 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., Wang, Perfetti, & Liu, 2003; Zhu, 2004) 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 (1991) 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.



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

Informed by the language acquisition theories (e.g., Comprehensible Input (Krashen, 1985), Information Processing (Bialystok, 1978), and Connectionism (Gasser, 1990)) and Bloom's Taxonomy, the researchers argue 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 leads the researchers 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.

CONTENT-INDEPENDENT LEARNING TECHNOLOGY MODEL

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., Liu & Kao, 2007; Yin, Ogata, & Yano, 2007; Zurita & Nussbaum, 2004). In our approach we propose a technological solution (a framework) for delivering collaborative in-class (and potentially out of class) activities. This is a generic solution able to support diverse content types therefore being content independent. This is achieved by a clear separation of learning content and the generic collaboration rules and actions which can then be used with different kinds of content. In this paper we present two types of content used in this system: mathematics and Chinese language content, both delivered to students through the framework in collaborative manner (Figure 3).

The collaborative scaffolding from the social and technological framework dimension can be applied to different learning content, such as learning fractions, composing sentences, 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.

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, check whether a combination of Chinese characters produces a valid character and check the semantics in case there are more feasible solutions than initially predicted.

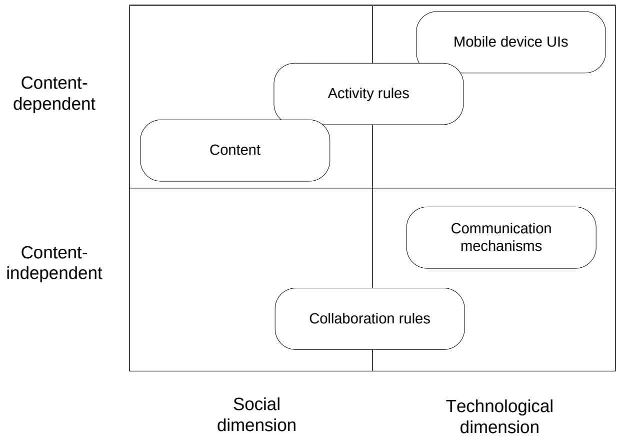


Figure 3. A two-dimensional matrix positioning the main design components in the socio-technological content-driven landscape

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. 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).

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.

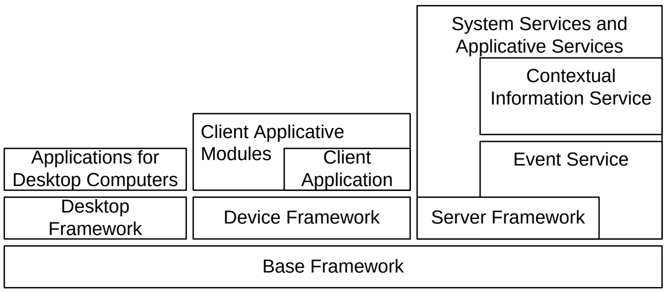


Figure 4. Framework's physical architecture stack

Base Framework is composed of sub-modules designed for communication between the server and the clients, structuring and assembling event messages (Boticki, Mornar, & Hoic-Bozic, 2009). 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. Base Framework contains basic building components extended by the Device Framework and Desktop Framework in order to support platform specific activity.

Server Framework is a component based on the Base Framework which provides services to higher-lever server components. Server Framework assembles and sends event messages, receives client response messages, and manages configuration, location and contextual widgets. These widgets 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. The module for contextual information is used to receive contextual subscription and contextual requests for event message sending (Figure 5) (Boticki, et al., 2009).

MAKING USE OF CONTENT-INDEPENDENCE: TWO MOBILE LEARNING APPLICATIONS

Learning Fractions (FAO)

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

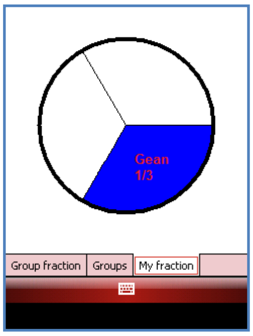


Figure 7. A fraction assigned and displayed on a student's mobile device

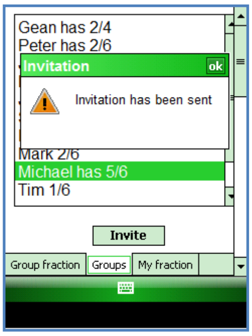


Figure 8. Student issuing a group invitation to his classmate

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 FAO 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 control the type of fractions distributed therefore structuring and fine-tuning the activity.

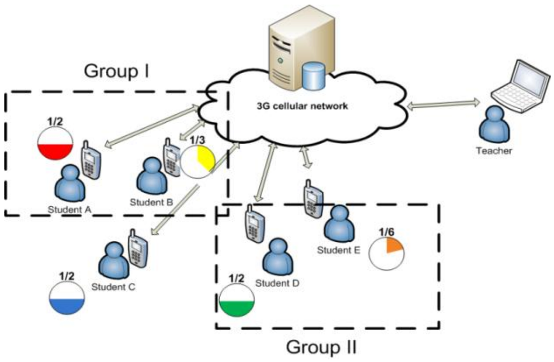


Figure 9. A group configuration of an impasse preventing students from achieving the global goal

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. The group then has to be broken and other groups have to be assembled, hopefully leading to optimal solutions for all groups which in turn lead to the completed activity.

Learning Chinese Language (Chinese-PP)

The second application is called Chinese-PP, PP referring to 拼一拼 or “Pīn yì Pīn” 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 choosing appropriate components forming valid Chinese characters. During the process of character forming, members of each group have to decide on an appropriate Chinese character template (character configuration) supplied by the Chinese-PP application (arrows < and > in Figure 10). 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.

In preparing each round of the game, the facilitator (e.g., 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 (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

Figure 11. Chinese-PP application showing student and their characters ready to be invited to groups

During the activity the teacher is presented with a view of its technological dimension. All assembled groups and template-arranged characters are depicted and ready to be shown to participating students if a need for additional scaffolding occurs (Figure 12). For example, students should be enticed to compose more complex characters, help their peers by disbanding existing groups and forming new groups etc.

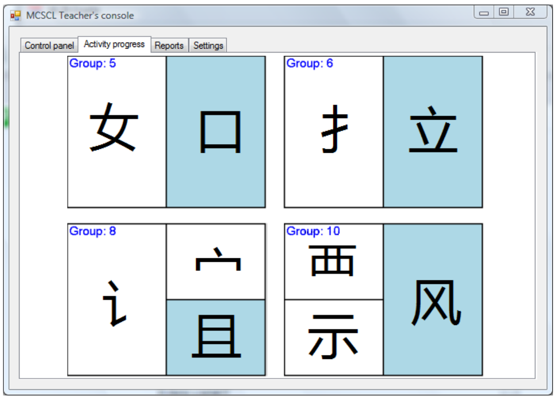


Figure 12. Chinese-PP teacher's console showing assembled groups and Chinese characters

EXPERIENCE FROM USING FAO AND CHINESE-PP IN PRELIMINARY TRIALS

Both applications, FAO and Chinese-PP were evaluated in a primary school under the bigger context of a three-year school-based study "Leveraging Mobile Technology for Sustainable Seamless Learning" (C.-K. Looi, et al., 2010) conducted in Nan Chiau Primary School in Singapore. The study essentially re-designed 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.

Conducted Trials

FAO and Chinese-PP present two specific interventions within the project focusing and promoting in-class collaboration between mobile students. Several trials were conducted per 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 FAO was conducted in late 2009 that involved 16 Primary 3 students (Boticki, Looi, & Wong, 2010). 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).

Based on the same framework Chinese-PP trials with 37 P4 (10-year-old) students with mixed ability were commenced in 2010. In this round of trials students participated in the two main activity modes: card and phone mode. The card group mimicked the Chinese-PP application design and served as the control group in the subsequent comparisons (Table 1). There were two subgroups in total: Subgroup A with 19 students: card game + phone game; and Subgroup B with 18 students: phone game + card game. The activity was followed by the focus group interviews.

	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

Table 1. Experiment design for the Chinese-PP activity trials

A paired-samples t-test was conducted to evaluate the impact of the intervention on 4E students' scores on the Chinese language test. There was a statistically significant increase in scores from Pre-test ($M=8.45$, $SD=2.580$) to post-test ($M=12.95$, $SD=4.544$, $t(31)=-5.721$, $p<0.0005$). The eta squared statistic (0.52) indicated a large effect size.

A New Cycle of System Redesign

Throughout the conducted trials there were some occurrences of degraded system performance. This was especially noted in the first trial attempts with FAO with large groups of students participating in the activity. Students first started using the system cautiously but after they got acquainted with it they gradually applied trial and error strategy by issuing multiple invitations to their peers. This produced a large number of invitations some not being answered by the receiving parties which resulted in long waiting time and eventually resulted in disrupted activity as students' interest shifted to more informal learning scenarios.

The invitation-reply system proved to be a bottleneck in the Chinese-PP activity as well, but not in as significant manner as in FAO due to activity's 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). Analyzing the number of exchanged messages during one of the Chinese-PP trials with N=12 participating students we come up with a surprisingly high number of exchanged event messages NE = 317 during less than 5 minutes of activity duratio. 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.

According to our experience we propose a completely new user interface design which in turn makes the whole request-reply philosophy simpler while utilizing the same unchanged framework just with another set of event (communication) messages. In the new design students now have two Chinese-PP applications screens. On the first application screen (Figure 13) they have an overview of all participating peers and are able to drag and drop peers' components onto a centrally positioned canvas. This in turn automatically creates groups on the second screen (Figure 14) which can then be confirmed after grouped students achieve mutual agreement. Each choice is supplemented by a number of points a group gets after it gets accepted.

Figure 13. A sample of the new UI design – common area for character assembling

Figure 14. List of all potential groups ready to be chosen by the students

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.

CONCLUSIONS

This paper presented architecture for content-independent collaborative mobile learning, software design and implementation and 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 bits: either Chinese latter components or mathematical fractions. Through collaboration on both technological and social levels, students come up with solutions to teacher-set tasks. Technology provides scaffolding in the sense of both content-dependent and content-independent software features or 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

To examine the effects of our interventions we designed trials with the two applications for Chinese language learning and mathematics learning. Through the trials in mobile mathematics learning (FAO) 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 redesign.

As the next step we venture into 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, on the other hand, be guided by an automatic scoring system keeping track of their achievements.

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