

Developing and Implementing a Framework of Participatory Simulation for Mobile Learning Using Scaffolding

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ABSTRACT

This paper proposes a conceptual framework, scaffolding participatory simulation for mobile learning (SPSML), used on mobile devices for helping students learn conceptual knowledge in the classroom. As the pedagogical design, the framework adopts an experiential learning model, which consists of five sequential but cyclic steps: the initial stage, concrete experience, observation and reflection, abstract conceptualization, and testing in new situations. Goal-based and scaffolding approaches to participatory simulations are integrated into the design to enhance students' experiential learning. Using the SPSML framework, students can experience the following: (1) learning in augmented reality by playing different participatory roles in mobile simulations in the micro-world on a mobile device, and (2) interacting with people in the real world to enhance understanding of conceptual knowledge. An example of the SPSML-based system was implemented and evaluated. The experimental results show that the system was conducive to the students' experiential learning and motivation. Moreover, the students who learned with the proposed approach gained significantly higher accuracy rates in performing the more complicated sorting algorithm.

Keywords

Participatory simulation, Scaffolding, Mobile learning, Experiential learning model

Introduction

More and more participatory simulations have been developed on mobile devices for educational use (Klopfer, 2008; Klopfer & Squire, 2008; Squire & Jan, 2007). They have been used in a way that can provide models of real-world settings for students to construct knowledge through active participation in learning activities (Patten, Arnedillo-Sanchez & Tangney, 2006). Some participatory simulations fall into a context-aware category and are more often found in ubiquitous computing (Gay & Hembrooke, 2004; Naismith, Lonsdale, Vavoula, & Sharples, 2004). A system is considered context-aware "if the system uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task" (Dey, 2001, p. 5). Mobile devices are well suited to context-aware applications due to their sensitivity in gathering and responding to real or simulated data unique to a particular location, environment and time (Klopfer & Squire, 2008). Context-aware applications have been the subject of many studies (Hwang, Kuo, Yin, & Chuang, 2010; Chu, Hwang, & Heller, 2010; Chiou, Tseng, Hwang, & Heller, 2010).

Research into context-aware participatory simulations has led to various innovations. However, less studied in this area is the use of scaffolding in a traditional sense to achieve what students want but are unable to achieve in the simulated environments (Luckin, Looi, Puntambekar, & Fraser, 2011). Moreover, few studies in participatory simulations have employed both scaffolding and fading approaches. Roschelle (2003) classified classroom applications into three categories: classroom response systems, participatory simulations, and collaborative data gathering. Chen, Kao, & Sheu (2003) reported a collaborative data gathering mobile learning system for scaffolding students in a bird-watching exercise. However, there is no scaffolding participatory simulation system reported to date. This research therefore developed an innovative framework called scaffolding participatory simulation for mobile learning (SPSML), premised on participatory simulations and experiential learning principles (Kolb, 1984).

This framework is a context-aware participatory simulation for mobile learning using scaffolding and fading approaches whereby students can be scaffolded when needed, and the fading strategies are initiated when the

students have achieved what they want to learn. An instance of the SPSML-based system was trialed and evaluated. The instance is called learning sorting algorithms with mobile devices (LSAMD) and is designed to help students learn abstract concepts presented in face-to-face classrooms.

The next section presents the theoretical background of the SPSML framework, followed by an introduction to the pedagogical design of the SPSML framework. We then describe and evaluate an example of a SPSML-based system. Finally, we draw conclusions.

Theoretical background of the SPSML framework

Participatory simulations

Participatory simulations provide models of real-world settings in which students can construct knowledge through active participation in learning activities (Klopfer & Squire, 2008; Patten, Arnedillo-Sanchez, & Tangney, 2006). Context-aware participatory simulation encourages more active participation and interaction among students because students “do not just watch the simulation, they are the simulation” (Naismith, Lonsdale, Vavoula, & Sharples, 2004, p. 13). This approach enables students to become immersed in an augmented learning environment in which they take an active role in their learning process and enhance their understanding of abstract concepts in complex learning situations.

In contrast, when engaging in participatory simulations in mixed learning environments (virtual and real worlds), students actively interact with the environments, the teacher, peers, and the other people concerned to construct knowledge and solve authentic problems (e.g., Dunleavy, Dede, & Mitchell, 2009; Klopfer, Yoon, & Rivas, 2004; Klopfer & Squire, 2008). According to Dede (2005), participatory simulations (a) support collaboratively sieving and synthesizing experiences rather than individually locating and retrieving information, (b) enhance active learning based on real and simulated experiences that offer opportunities for reflection, and (c) facilitate the co-design of learning experiences personalized to individual needs and preferences. These features have been taken into account in designing the SPSML framework.

Experiential learning

The pedagogical design of the SPSML is premised on Kolb’s experiential learning model, which focuses on experience as the main force driving learning because “learning is the process whereby knowledge is created through the transformation of experience” (Kolb, 1984, p. 38). Thus, learning is a constructive process in context. It happens in a cyclical model (see Fig. 1) consisting of four stages: concrete experience, reflective observation, abstract conceptualization, and testing in new situations (de Freitas & Neumann, 2009; Kolb, 1984; Lai, Yang, Chen, Ho, Liang, & Wai, 2007).

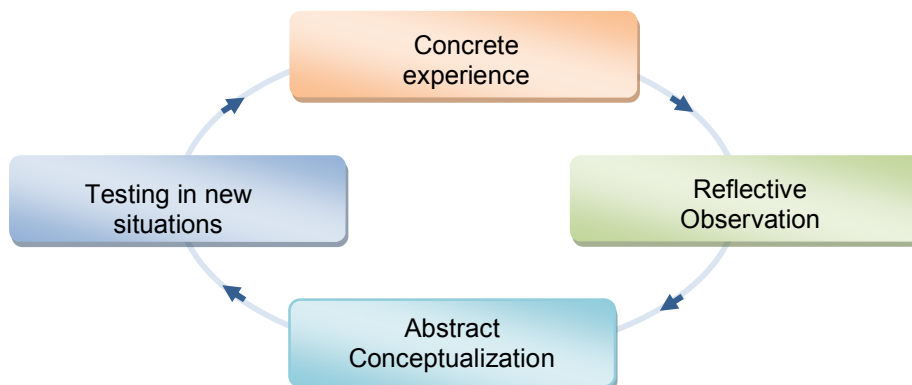


Figure 1. Kolb’s experiential learning model

This model requires that learning scenarios, which may be embedded with a series of different objectives, activities, and outcomes, be integrated into the experiential pedagogical design. One issue to be addressed is to move away from a set of sequencing of learning to more options (Barton & Maharg, 2006). These different routes for learning have the potential to increase students' engagement. Participatory simulations using mobile technologies are well suited to experiential learning in that they provide models of real-world domains for students to gain knowledge through active participation, and provide rich data that "augment" users' experience of reality by connecting data on the mobile devices (Klopfer & Squire, 2008). The following describes the four stages of the experiential learning model:

1. *Concrete experience.* Student experiences can fluctuate between the virtual environment and real life by enabling digital simulations in authentic problem-solving situations in which learners play different roles to interact with other entities that have different skills (Dede, 2009).
2. *Reflective observation.* Reflection may involve revisiting learning activities. Although reflection can occur during any stage of the experiential learning cycle, these explicit virtual tasks ensure that students can engage in reflection (de Freitas & Neumann, 2009).
3. *Abstract conceptualization.* Students gain new knowledge by integrating previous observations, interactions and reflections into logically sound concepts, which provides contexts in which they can consciously create structured understandings of their experience. We need to focus on what kinds of abstractions would be most relevant in student learning contexts, using experiential learning models with a view to the particular learning outcomes.
4. *Testing in new situations.* In the on-going iterative cycle, students are expected to be able to test and practise these concepts by actively experimenting, for example, in a follow-up practice in new situations. Thus, as a component of a course curriculum, the participatory simulation provides a virtual space that complements their learning in real life and within which they can engage experientially to construct conceptual knowledge.

However, experiential learning has its drawbacks. First, it lacks a mechanism for making students focus on the learning objectives in context (Miettinen, 2000). Second, students may lack the skills and pay inadequate attention to abstraction of concepts from experience (Lai, Yang, Chen, Ho, Liang & Wai, 2007). We postulate that there are two ways to overcome these hurdles: (a) by adopting Squire's (2006) and Schank, Fano, Bell and Jona's (1994) goal-based approach to participatory simulations premised on constructivist theory, and (b) by scaffolding. The important aspects of the goal-based approach are to focus on the learning goals that should be intrinsically motivating and the role that the learner plays.

The criteria for the design of learning scenarios are as follows:

- Thematic coherence. The process of achieving the goal is thematically consistent with the goal itself.
- Realism. The design must be authentic to produce varied opportunities for learning the target skills and knowledge.
- Empowerment. The design puts students in control to increase the sense of agency.
- Responsiveness. Prompt feedback is provided to help students acquire skills and knowledge.
- Pedagogical goal support. The proposed design is compatible with and supports the acquisition of skills and knowledge.
- Pedagogical goal resources. Students are provided with appropriate help.

The adoption of role play is to reinforce and explore difficult concepts that can be integrated into face-to-face classrooms or be used in complex learning environments. The participatory simulations provide students with a dynamic interactive role-play activity in an experiential learning process so that students get to experience, observe and reflect, form abstract concepts, and test their solutions in new situations. Scaffolding and fading built into the participatory simulations is another important approach to addressing the problem of students' lack of skills in abstracting concepts from experience, which is elaborated on in the next section.

Scaffolding and fading

A number of studies on the design of context-aware participatory simulations using mobile technologies have reported the usefulness of the systems for enhancing student collaborative learning and problem solving (e.g., Dunleavy, Dede, & Mitchell, 2009; Klopfer & Squire, 2008). However, in many cases, there is a recognition-production gap between what students want to achieve and what they are able to achieve themselves in the simulated

environments. This gap can be bridged via scaffolding (Luckin, 2008). Scaffolding, as provided by human tutors, has been well established as an effective means of supporting learning (Soloway, Norris, Blumenfeld, Fishman, & Marx, 2001).

Luckin, Puntambekar, & Fraser (2011) posit that research exploring the use of mobile technologies to support learning rarely involves scaffolding in the traditional sense. Scaffolding enables learners to realize their potential by providing assistance when needed, and then fading out this assistance as meaningful learning takes place (Collins, Brown, & Newman, 1989). The notion of scaffolding is associated with the work of Vygotsky (1978): a novice learns with a more capable peer, and learning happens within the novice’s zone of proximal development (ZPD). With the development of technology, scaffolding tools are specially designed to help students learn in the complex learning environment. Different learners in the same class may have different ZPDs.

However, in many cases, support for learning provided by the tools “focuses on providing ‘blanket support’ (i.e., the amount and type of support is constant for everyone and is not sensitive to the changing level of understanding in learners)” (Puntambekar & Hübscher, 2005, pp. 7–8). To cater to the different needs of students, in designing scaffolding in tools, it is important to consideration (a) the multiple ZPDs of students, (b) building fading into the system so that the tools themselves may be removed when students do not need them anymore, and (c) teacher’s orchestration and facilitation of the learning process so that students can make good use of the scaffolding tools and resources for learning (Puntambekar & Hübscher, 2005).

Pedagogical design of the SPSML framework

In this study, we propose a context-aware participatory simulation framework called SPSML for designing learning systems on mobile devices using scaffolding and fading strategies. The SPSML is designed to facilitate students’ experiential learning in either complex social contexts or face-to-face classrooms. The scaffolding and fading instructional strategies are used to help students’ experiential learning processes. It provides opportunities for students to be involved in active participation and interaction and increases motivation. The SPSML framework consists of five sequential but cyclic steps that use Squire’s (2006) goal-based approach and scaffolding and fading strategy use (see Figure 2).

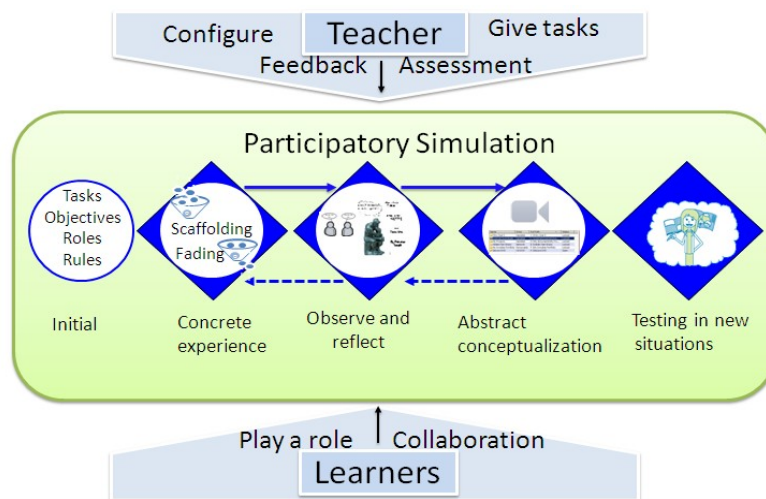


Figure 2. The SPSML framework

Step 1. Initial process

Before implementing the SPSML-based system, the teacher will define: (a) the learning objectives of the activity, (b) the simulation tasks, and (c) the rules and participant roles for playing the simulation (Squire, 2006). The learning

objectives are to help the students to reach their goals, and they need to be identified in order to help the students accomplish the tasks successfully.

To begin the activity, the teacher will set up rules and participant roles to configure the system. The teacher will explain to the students the general ideas of concepts to be learned in face-to-face classrooms and provide examples to guide them. The teacher will also explain to the students the learning objectives of the activity and how to use the system on their mobile devices such as personal digital assistants (PDAs).

Step2. Concrete experience

Concrete experience is composed of scaffolding and fading procedures.

Scaffolding

When students start experiencing and acting during the activity, the teacher will assign different tasks and roles for them to play in the simulation, according to the rules. The system on the mobile device will guide the students in how to do the tasks and play the roles if they need help. This step acts like a bridge used to enable the students to master the conceptual knowledge in face-to-face classrooms. The system assists students by providing information about where the mistakes are and how to correct them so that they are able to achieve the goals of the task. This system is composed of three stages: point out mistakes, help to correct, and discuss (see Figure 3):

1. *Point out mistakes.* The scaffolding system will assist students by providing some instructions about where the mistake is immediately after they make the mistake. It helps the students complete the task effectively.
2. *Help to correct.* When the students cannot solve the problem themselves, the system will facilitate them in this regard. There are three kinds of scaffolds at this stage: hint, illustration and teacher's help, as shown in Figure 3.
 - Hint. The system will offer a hint about a solution to help the student find out ways to perform the tasks and play the roles based on an ongoing diagnosis of student learning (Puntambekar & Hübscher, 2005).
 - Illustration. The system will describe the goals of the tasks or provide key information about how to play the role with a simple example.
 - Teacher's help. If the students want to make an inquiry to a teacher, the system allows the teacher to provide facilitation. The teacher can observe the status of each student's participation and the roles they are playing on the mobile device in order to respond to the inquiry.

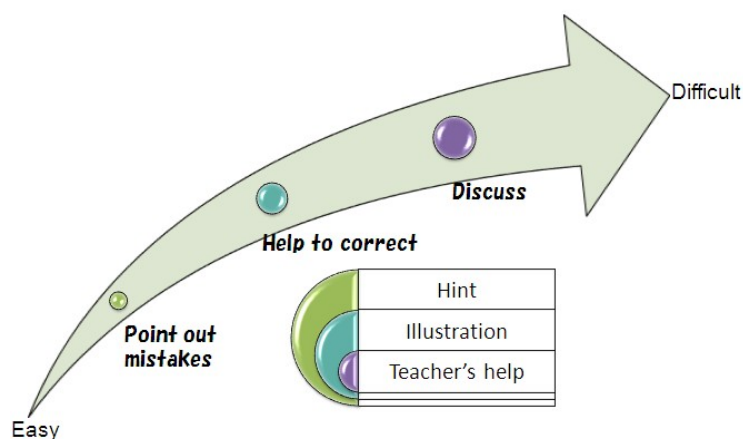


Figure 3. Three stages

3. *Discuss.* The students are allowed to discuss with partners via mobile devices. Discussion is a source of ideas for other students, using evidence in support of claims, getting advice, and providing explanations that others

can understand, as well as a vehicle for some of the reflection necessary to turn one's experiences into well-formed and well-indexed cases in one's memory (Kolodner & Nagel, 1999).

The students will construct the learning goals collaboratively via discussion. They construct initial understandings of the concepts by participating in the discussion after the concrete experience.

Fading

After participatory role play on the mobile device, students will gradually be able to understand the methods and strategies to solve the problems and become more experienced with the conceptual knowledge. At this point, the fading process starts. The students use the fading mode to practise independently. Then, the system reduces the help messages gradually, and more responsibilities are shifted to the students. Finally, they will be able to solve the problems themselves without the scaffolding of the system. In the meantime, the teacher can also help orchestrate the gradual reduction of the system's help function according to the level of understanding of the students.

We have designed the fading mode as three levels depending on the different ZPDs of learners:

- **Level 1.** Point out the mistakes only, but require the students to find out how to correct them. They can discuss with their role-play partners at this level. They can also seek help from the teacher.
- **Level 2.** Do not point out the mistakes, but have the students correct them by themselves. They cannot get help from the teacher, but they can discuss with their partners.
- **Level 3.** Do not provide help and discussion, but have everyone complete the task by him/herself at this level. After all the students pass Level 3, it means that they have mastered the conceptual knowledge.

Step 3. Observation and reflection.

After completing the concrete experience of participatory roles in the simulations, the students carry out discussions and reflections. They reflect on what they have learned, how well they have understood, and what else they want to learn. If they need more experience in participatory simulations, they can restart the simulation from any step such as from the scaffolding or fading step rather than from the initial step because all their prior experience has been saved in the database.

Step 4. Abstract conceptualization

Because the student experience in the participatory simulation is recorded and stored in the database and these records can be converted to a video, the students can review their learning progress by watching the video or looking at the history record. This step helps the students transform their learning experience and construct conceptual knowledge to achieve their learning goals.

Step 5. Testing in new situations

After conceptualizing what they have learned, the students can try out the concepts in their real-life situations to deepen their understanding of the conceptual knowledge.

An instance of implementation of the SPSML-based system

In this section, we describe an instance of the implementation of the SPSML-based learning system LSAMD, which supports the learning of sorting algorithms (abstract concepts). There are four sorting algorithms in the system: bubble sort, insertion sort, selection sort, and quick sort.

Figure 4 shows the LSAMD interface. Using this system, all the students stand in a line with a PDA, and the teacher assigns an array of numbers to the students and asks them to sort these numbers according to a certain algorithm. The

new position of each step is sent to the server. They receive these tasks, collaborate, and exchange physical positions according to the algorithm.

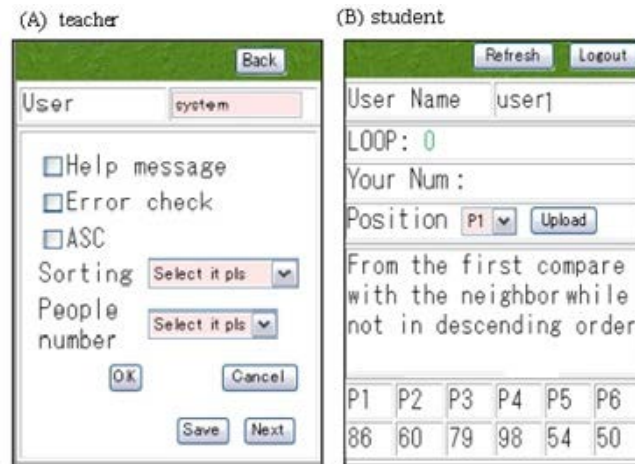


Figure 4. Interface of LSAMD

Simulation description

In LSAMD, the students play the role of data in the simulation of the sorting algorithm to visualize the data flow of the computer in the real world.

Determine learning objectives. The learning objective of the simulation is to help students master the sorting algorithms.

Set up a simulation. The teacher sets up the algorithms to configure the server, then selects a sorting algorithm and sets the number of the students. After the random data are generated, the teacher sends these data to the students. The students will get the data to be arranged from the server according to their ID. The students play the roles of the data in the sorting algorithms. They analyze, compare, discuss, and swap the assigned data. The results will then be sent to the server, and the server will compare the correctness of the results. At the same time, the teacher can view the results, evaluate student understandings of the algorithms, and design new ways to explain the compilation of the data.

Design task. This simulation is provided for students to sort the algorithms together. The students use this system to study the four algorithms in a group.

Set up scenarios for using LSAMD. This is a scenario of the SPSML-based LSAMD system to learn sorting algorithms:

1. The system generates the data randomly and sends them to the students. Following is a sample of the “quick sort” algorithm. In the example, the array list, “78, 35, 22, 67, 56, 38, 15, 11,” is sorted in ascending order. All the students stand in a line with a PDA, which displays their numbers and positions in a table and also displays the pivot.
2. The teacher turns on the option with error checking and help messages, and the students can discuss with each other which is in the scaffolding mode. The system will initialize Left to First and Right to Last. It will also give hints and illustrations to solve the problem. In Loop 1, a help message like this will appear initially: “Define the value in position First to be the Pivot and define Left to be First and Right to be Last.” After discussion and comparison, the students pick 67 as the Pivot, define Left and Right, and upload them to the server. The results are shown in Figure 5.
3. Then, the system will issue a message such as “Move Left to the first value, which is greater than the Pivot; Move Right to the first value, which is less than the Pivot, then exchange these values.” After discussion and comparison, the new position is uploaded to the server. The students will also change their physical standing position in the line.
4. The server will evaluate the change of positions and send an error message if the change is done incorrectly. In the case of making mistakes in the change of positions, the message will then point out the error position and ask the students to correct it.

- “Then move on to Loop 2.” Each student will discuss and compare the result with his neighboring student according to the messages provided by the server in Loop 1, and this process goes on for a few loops depending on the problem until the whole array is sorted.

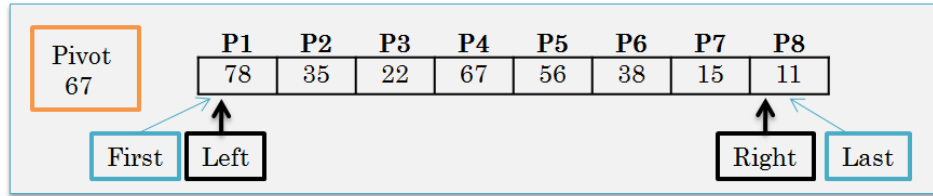


Figure 5. Initialization of the quick sort

When the students master the quick-sorting algorithm at a certain level, the teacher changes the scaffolding mode to fading. For every loop, the student who needs to move first is the leader who takes control of the sorting process in the loop by directing other members to exchange positions. The teacher will turn off the help message option so that the students are situated in level 1 of the fading mode; that is, the system only points out the error position and the learners can discuss with each other to solve the problem. Then, the teacher will turn off both the help message option and error checking option, thus situating the students in level 2 of the fading mode, in which they can discuss with each other to solve the problem. Finally, in level 3, discussion is not allowed; that is, the students are directed by the leader to switch positions to complete the task.

A pilot study

A pilot study was carried out to evaluate the LSAMD system. Twenty-one students participated in the study. They were divided into three groups and were briefed about how to use the system. The procedures of the pilot study are as follows:

Initial stage. The teachers briefed students on the rules of the sorting algorithms and demonstrated how to use the system.

Role-play. The students played the role of data in the simulation of the sorting algorithms. The system guided the students to sort numbers. The system would check the students' sorting and provide feedback if there was a mistake in the positions of the numbers. Then, the students would correct the number positions and send the new positions back to the server. In the meantime, the teacher monitored the students' learning progress and gave comments and feedback. The students could discuss and compare with each other before exchanging positions. When the students mastered the sorting algorithms at a certain level, the system would gradually reduce the help function.

Observe and reflect. Students discussed and reflected on the sorting algorithms together and the teacher acted as a facilitator.

Understand abstract concepts. The students were able to conceptualize the abstract concepts of the sorting algorithms.

Try out new sorting algorithms. The learning history was stored in the server. When they tried a new sorting algorithm, they would review their previous sorting experience to seek better understanding of the new algorithm.

Evaluation

To find out if the SPSML-based system would be helpful for the learning process, we designed an experiment using LSAMD. We set up a control group and an experiment group to compare the accuracy rate of every sort algorithm (every step was recorded).

Participants

A total of 41 master's students with prior algorithm-sorting experience participated in the experiment. The students had learned the sorting algorithms about three years earlier, when they were undergraduate students. However, most of them had not used sorting algorithms for a long time so they had forgotten the rules. The average age of the students was 22 years old. Their past examination on sorting algorithms was used as the pretest. They were divided into two groups according to their average achievement: 21 students were assigned to be the experimental group (average achievement = 72.5), and 20 students formed the control group (average achievement = 73). According to their pretest achievement, it can be inferred that these two groups did not significantly differ prior to the experiment.

Experimental procedure

The students in the control group learned with a sorting algorithm system, which did not provide them with participatory simulations or scaffolding. When using the system, the students first selected a sorting algorithm, and then the system generated numbers in an array. The students performed the sorting operations by exchanging the position of the numbers in the array. If the sorting was wrong, the system only provided an error message such as "There are some mistakes," but did not point out where the mistakes were. These mistakes were stored in the database. The students could also refer to books before using the system.

For the experiment group, the students learned with LSAMD. They stood in a line with a PDA and participated in participatory simulations. They could use the scaffolds "Point out mistakes," "Hint," "Illustration," "Teacher's help," and "Discussion." The mistakes they made as well as the types of scaffolds they used to solve the problem were stored in the database.

Results

Accuracy rate

The accuracy rates of the two groups of students who sorted the data with different algorithms were compared by an independent *t*-test, as shown in Table 1. For the quick sort, the average accuracy rate and standard deviation were 81.86 and 10.12 for the experimental group, and 52.30 and 9.29 for the control group. The average accuracy rate of the experiment group is higher than that of the control group, and the difference between the two groups is statistically very significant ($t = 9.73$, $p < 0.01$), indicating that the LSAMD system is helpful to students in enhancing their conceptual understanding of this sorting algorithm. On the other hand, for the bubble sort, insertion sort, and selection sort, the average accuracy rates of the two groups do not show significant difference. Because the "quick sort" has been recognized as more complicated than the other sorting algorithms, it could be concluded that the SPSML framework was helpful to the students in improving their learning achievement in terms of complicated conceptual understandings.

Table 1. Accuracy rate

	Group	<i>N</i>	MAR (%)	<i>SD</i>	<i>t</i> -value
Bubble	Experiment	21	93.29	5.60	0.95
	Control	20	91.35	7.34	
Insertion	Experiment	21	90.33	7.91	1.25
	Control	20	86.85	9.94	
Selection	Experiment	21	89.35	8.99	1.78
	Control	20	83.10	12.84	
Quick	Experiment	21	81.86	10.12	9.73**
	Control	20	52.30	9.29	

Note. *N*: Number of students; MAR: Mean of Accuracy Rate; *SD*: Standard Deviation; ** $p < 0.01$

We also analyzed the records of the mistakes the students made, which were stored in the database. For the quick sort, more identical mistakes were made in the control group than in the experiment group. This may be due to the

fact that the students could not get just-in-time scaffolding when they made mistakes; hence they did not know the reason why they made these mistakes. In contrast, in the experiment group, the students made the same mistakes fewer times because they solved the problems using the scaffolds (“point out mistakes,” “hint,” “illustration,” “teacher’s help,” and “discussion”), which helped them correct the mistakes in time. The findings also demonstrate that the SPSML framework was helpful to the students in enhancing their learning.

Finally, we worked out the percentage of each type of scaffold used by the students in the experiment group to help them solve their problems (see Figure 6). Figure 6 shows that “discussion” was the most frequently used scaffold (48%). This result is also consistent with the questionnaire results.

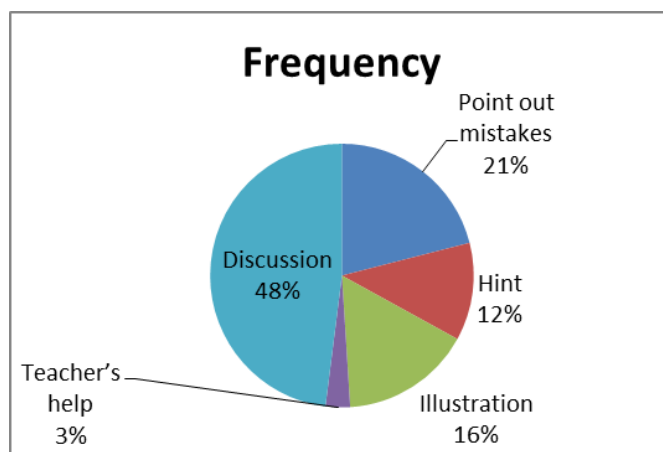


Figure 6. Percentage of each scaffold used by the students

Student attitudes towards scaffolding and fading, and participatory simulations on the SPSML-based system

After the pilot study implementation, a survey was conducted. It consisted of nine closed-ended questions about student attitudes towards the use of the SPSML-based systems (Table 2) on a five-point Likert scale from strongly agree to strongly disagree (5 to 1). All of the students completed the survey.

Table 2. Survey results

Student attitudes towards scaffolds and participatory simulations	SA/A(%)	NN(%)	D/SD(%)	M	SD
Q1 It was helpful to point out mistakes for us.	76.0	24.0	0.0	4.2	0.81
Q2 It was helpful to offer hints.	76.0	24.0	0.0	4.1	0.79
Q3 It was helpful to illustrate the basic outlines of tasks.	62.0	29.0	10.0	3.8	0.98
Q4 The comments from the teacher helped me to improve my understanding.	38.0	38.0	24.0	3.2	0.87
Q5 It was helpful to discuss with partners; the comments from others helped me to improve my understanding.	95.0	5.0	0.0	4.6	0.6
Q6 It was useful to guide us step by step.	52.0	38.0	10.0	3.6	0.92
Q7 It is necessary to reduce the help function when I become more experienced.	86.0	14.0	0.0	4.3	0.73
Q8 I like learning by participatory simulations.	76.0	24.0	0.0	4.2	0.81
Q9 Using these history records and videos, it was helpful to reflect on the learning process.	57.0	24.0	19.0	3.6	1.07

Note. SA/A: strongly agree and agree; NN: neither agree nor disagree; D/SD: disagree and strongly disagree; M: means; SD: standard deviation

Table 2 summarizes the results of the student attitudes towards scaffolding and fading and the participatory simulations designed using the SPSML-based systems. The first five questions are related to scaffolding. The results

show that the mean scores of Q1, Q2 and Q3 are close to 4 (agree), which means that the students were satisfied with these scaffolds (point out mistakes, hint, illustration, teacher's help and discussion). Approximately 70% of the students considered that the scaffolds "point out mistakes" (Q1) and "illustrate the basic outlines of tasks" (Q3) were helpful for their learning, while approximately 80% agreed that the scaffold "hint" (Q2) was helpful. Regarding the scaffold "teacher's help" (Q4) however, student attitudes varied. This might be due to the fact that the number of teachers was limited and the students could not get teachers' help in time. On the other hand, 94% of the students agreed that the scaffold "discussion" (Q5) was most helpful for them to improve their understanding among all the scaffolds. The mean score of Q5 is close to 5 (strongly agree). Figure 7 shows a graph of mean scores for each of the scaffolds.

The result of item Q6 shows that over half of the students considered that using the scaffolds to guide them step by step was useful. By examining student use of the scaffolds recorded on the system, it was noted that the students did not use the scaffolds to learn easy sorting algorithms such as "bubble sort," but, rather, they used the scaffolds to guide them to learn complex sorting algorithms such as "quick sort." The results indicate that the SPSML-based systems are suitable for solving complex problems. The findings are consistent with other studies. For example, Klopfer and Squire (2008) found that the students were basically able to solve simple problems on their own, but required additional teacher support to resolve more complex issues.

The results of item Q7 show that it is necessary to reduce the help function when the students were progressing in their learning. In terms of student attitudes towards the participatory simulations (Q8), approximately 84% of the students indicated that they liked learning in this way. Finally, a majority of the students agreed that it was helpful for them to reflect on their learning progress using learning history records and videos (Q9).

Reliability statistics

Reliability analyses were conducted for two SPSML-based systems using SPSS. The Cronbach's alpha of all the survey items (13 Questions) is 0.832, and the Cronbach's alpha of Part 1 (student attitudes towards scaffolds and participatory simulations) is 0.741; thus, we can conclude that the survey items have relatively high internal consistency.

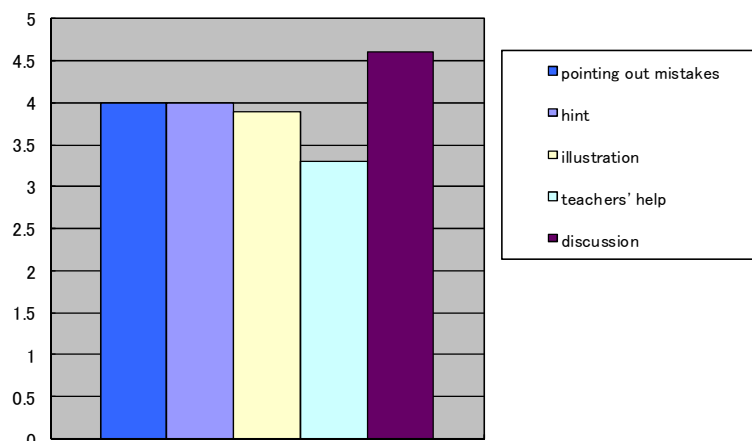


Figure 7. Mean scores for each of the scaffolds

Discussion and conclusions

In this paper, we describe a conceptual framework, SPSML (scaffolding participatory simulation for mobile learning) developed on mobile devices for helping students learn conceptual knowledge in classrooms or in complex social contexts. We adopted an experiential learning model as the pedagogical design of the SPSML framework, which consists of five sequential but cyclic steps: the initial stage, concrete experience, observe and reflect, abstract

conceptualization, and testing in new situations. Scaffolding and fading were designed on the SPSML framework to support experiential learning. Using the SPSML framework, students could play different participatory roles in mobile simulations and understand abstract concepts better.

An instance of the SPSML-based system LSAMD was implemented and evaluated. It was used to engage students in a participatory role-play to learn abstract concepts of sorting algorithms. Student attitudes towards the use of the system were evaluated using both a closed-ended and open-ended survey. The results show that generally the students expressed positive attitudes towards use of the system, and considered that the system helped them deepen their understanding of the abstract concepts more effectively through scaffolding, discussion, and trial and error in the participatory simulations for experiential learning. This indicates that the learning systems under the SPSML framework were conducive to the students' experiential learning, improved their motivation, facilitated collaboration, and advanced their conceptual understanding. Moreover, the experimental results also show that the SPSML framework was helpful to the students in improving their learning achievements in terms of complicated conceptual understandings.

The main contribution of this study is to propose mobile learning with scaffolding approach to improving students' learning performance in the area of computer algorithms. Although mobile learning and scaffolding have been employed in previous studies, the application domains have mainly been natural science, social science or mathematics courses (Chen, Kao, & Sheu, 2003; Chu, Hwang, & Tsai, 2010; Hwang & Chang, 2011). To our knowledge, no mobile learning study with scaffolding has been applied to computer courses, not to mention the learning of computer algorithms, which is fundamental and important for fostering programming skills (Kordaki, Miatidis, & Kapsampelis, 2008). Therefore, the approach of this study is innovative from the perspective of learning computer algorithms.

In comparison with the traditional approach, in which students practise computer algorithms with paper and pencil or a computerized editing system (Lau & Yuen, 2010), the SPSML-based system not only situates the students in a context for experiencing each step of the algorithms, but also provides them with various learning supports (e.g., supplementary materials and feedback). Moreover, those computerized systems developed by previous studies, such as the TRAKLA2 system (Malmi, Karavirta, Korhonen, Nikander, Seppälä, & Silvasti, 2004), an interactive algorithm simulation system with animation, are more like the system used by the control group of this study. That is, in those previously developed systems for teaching computer algorithms, no scaffolding (i.e., fade-in and fade-out of discussion, help, and feedback functions) is provided, not to mention the provision of experiential learning.

To sum up, in this study, the participatory simulations using mobile technologies have situated the students well in experiential learning contexts (Klopfer & Squire, 2008); moreover, the integration of participatory simulations and scaffolding is helpful to the students in significantly gaining a higher accuracy rate in performing complicated sorting algorithms.

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