Patterns of Reflection for Problem-Solving in a Mobile Learning Environment

Jung-Chuan Yen & Ming-Puu Chen

***Abstract*—**This study explored the nature of students' reflections on solving a given problem in a mobile technology enhanced learning environment of a computer networks course. Participants were 143 college freshmen taught by the same instructor. A process and content analysis method were employed to explore learners' reflective patterns during and after problem-solving tasks. The results suggested 4 conclusions: (a) participants' reflection-in-action declined slightly across lab sessions, and reflection-on-action increased slightly across lab sessions, (b) participants generated more reflection-in-action and reflection-on-action during the early stages of problem-solving with the help of mobile technology, (c) providing learners with sufficient training on the use of mobile technology prior to the tasks is critically important to enhancing learning, and (d) learners with high prior-knowledge revealed higher frequency in reflection. Finally, it was suggested to examine the relationships between participants' flections on given problems and learning performance in a explicitly manner.

***Keywords*—**Mobile learning, Reflection pattern, Problem solving, Content analysis

I. Introduction

In recent years, there has been an extensive amount of research done on the effectiveness and evaluation of digital learning in accommodating with mobile technologies [1], [2]. The positive results most often have been reported, such as provided much scope for designing innovative learning experiences that can take place in a variety of outdoor and indoor settings, enhanced learning outcomes, increased learners' motivation, facilitated cognitive skills development, promoted interactive learning, and supported constructivist educational activities by means of collaborative groups[3], [4], [5], [6]. Moreover, the utilization of mobile devices has been confirmed more positive attitudes towards learning, and a higher quality of social interaction [7]. However, there was few efforts been made to exploring the intension of students' problem-solving reflection of learning processes on using mobile instructional tools. In other words, there is still a shortage of empirical validation of the content analysis on what and how student reflective thinking to solve problems in a mobilized digital learning environment.

The goal of the education of college is not only to encourage students to strengthen their knowledge and technical skills but also to become an effective problem-solver and active independent learner. In mobile learning, students are usually required to engage in more intensive self-regulative efforts than in traditional teacher-directed classroom situations. The teacher does not supply or even determine clear, concrete learning tasks and procedures, but provides context and starting points for the students' own explorations; the students are themselves responsible for generating their specific learning agenda and setting up their learning goals. Furthermore, learning tasks of mobile situations are often more open-ended and ill-structure, and thus more complicated to work with than those of conventional learning situations. Therefore, teachers should not rely too much on students' unguided thinking, but should intervene by providing pedagogical scaffolding if students are not able to make progress themselves.

Therefore, the purpose of this study was to investigate students' reflective thinking for problem solving in a mobilized digital learning environment. By content analysis, the frequency and the ratio of learners' intrinsic thought of problem solving such as understanding, planning, execution and evaluation were concluded and the reflection patterns were also discussed.

II. Literature and Related Works

A. Problem solving in science learning

Problem solving is a common approach in science education. It has also been applied in a number of educational programs and learning system, lately, those always innovate and assisted by modern information and communication technology. Digital learning system in science education was always coupled with novel arrangements of instructional embedded objects, providing alternative forms of interactions through familiar actions with unfamiliar effects, and then encouraging learners to reflect and think beyond their present actions to higher levels of abstraction [8], [9]. Problem solving may be regarded as consisting of phases, each of which has its own particular epistemic objective as well as specific challenges for the teacher and requirements concerning her or his guidance. A starting point for the process of problem solving is creating context for a study project to help students understand why the issues in question are important and worthwhile to investigate. During this stage, the teacher creates

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a motivational basis (such as novel tools or materials) for the progressive inquiry process and helps students make cognitive commitments to pursue their personal reflections.

The recent development of problem-solving tends to merge the portability and connectivity features of mobile technologies together to allow broader ways and opportunities for real life authentic learning [10], [11]. According to the trend and previously described, problem solving in science education possesses new challenges for learning. There is a need for more information about how students and teachers are facing the challenges of using new technologies, and more specifically, how the teacher's guidance should be carried out in the learning environment. The goal of the present investigation is to analyze patterns of the students' reflection behaviors across the phases of the reflection-in-action and the reflection-on-action for problem solving in a mobilized learning environment.

B. Mobile technology facilitating reflective thinking

One of the major concerns about e-learning courses is that many of them focus on the traditional knowledge acquisition model of learning rather than on encouraging students in solving complex real world problems [12], [13]. Researchers criticized that students are usually unable to apply knowledge in solving complex problems due to accruing inert-knowledge from partial materials and surfacing thinking in online environments. Therefore, how to facilitate learners' authentic learning of problem solving and raise the concepts of ownership and reflection on learning, become a valuable issue for e-learning.

Reflective thinking refers to the process of analyzing and making judgments about what has happened. Learners are aware of and are able to control their learning by actively performing reflective thinking during learning. Reflective thinking is especially crucial in prompting learning during complex problem-solving situations because it provides learners with an opportunity to step back and think about how a set of problem solving strategies are appropriate or inappropriate for achieving the goal. Therefore, Dewey [14] suggested that reflective thinking is "an active, persistent, and careful consideration of a belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends".

The ubiquitous computing advances have added mobile technologies the potentiality to become a powerful tool for facilitating reflective thinking. For example, reflective dialogues are always used to offer opportunities for reflective thinking by means of questioning and feedback [15]. Despite the fact that it is affirmed that the use of digital augmentation in mobile learning environment offers a promising way for enhancing the learning process, rare efforts had been made to explore what and how influences of reflective thinking affect students' problem-solving [16]. Therefore, there is still shortage of empirical validation of the performance and attitudes toward the utilization of mobile tools in web-based reflective learning environments.

C. Learning behaviors by content analysis

The rapid development of Internet technology has changed the nature of learners' behaviors in online environments. As a result, there is raised concern over how to assess the learners' thinking and their interaction of online environments. Many studies examining this trend have focused on communication patterns of face-to-face or computer mediated group collaborative problem-solving [17], temporal patterns of learning sequencing [18], and teacher's guidance of inquiry learning [19]. Thus, it can be seen that the content analysis on students' learning behaviors has concerned educational researchers for decades. However, previous studies rarely addressed the issues of learners' reflective thinking with or without using novel technology that were perceived as contributing factors to the design of better mobile learning activities.

To take the full benefits of mobile technologies in facilitating learning, researchers claimed that the development and use of mobile technology should suit the individual characteristics in order to facilitate learners' learning in a pedagogically sensible manner. Systemic assessment frameworks were also suggested to analyze online interaction in ways of educational meanings [20]. Therefore, the present study aimed to examine learners' reflection patterns by means of content analysis on their thinking across different mobile learning situations.

III. Methods

A. Participants and Context

This study was conducted in a college-level computer network laboratory. Participants were 143 IT major freshmen who were taking the computer networks course. Participants were familiar with the Internet and computers, but were without previous mobile learning experience.

The course is based upon the establishment of an online discussion forum among the participants and tutors. In the forum, activities were undertaken around four hands-on laboratories over a six-week period. The laboratories were hosted in the web-based learning environment and participants become engaged in collaborative learning and tutoring processes as they support each other and the group as a whole in a range of structured activities.

B. The mobile instructional tools

The course materials and instructional system of this study are similar to the one used in our previous studies [22]. Hands-on problem-solving laboratories have been commonly recognized as an important way to foster learning for novices in learning computing skills. In this study, instructional multimedia on computer networks and reflective learning supports are delivered via a wireless mobile device to scaffold learners' successful learning experiences. The role and functions of mobile technology and web-based technology for the present study are illustrated in Figure 1.

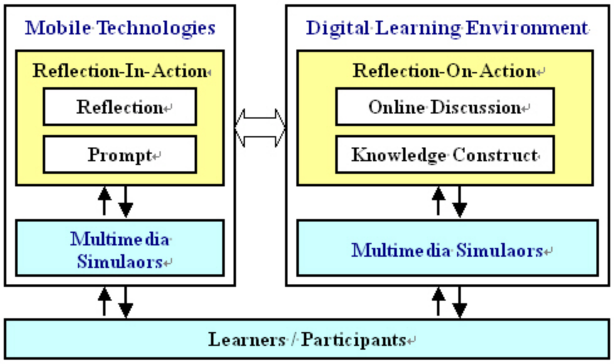

Fig. 1 Research framework of this study

During the IT problem-solving processes, learners could access to instructional multimedia through mobile devices to learn how to solve the encountered problems. As shown in Figure 2, for fostering reflective thinking and problem-solving, reflective prompts were embedded in the instructional multimedia and delivered to the learners through the employed mobile device during the interaction between learners and the instructional multimedia. The laboratory guidelines were also delivered via the mobile device to guide the learners to accomplish the laboratory sessions smoothly. Thus, the employed mobile technology gave the participants opportunities to learn to solve the encountered problems with supports of instructional multimedia and reflective prompts (see Figure 3).

Fig. 2 The instructional multimedia simulator

Fig. 3 The reflective prompts and discussion forum

C. The content analysis

The classification of each problem-solving reflection was based on consensus between two coders. Both coders were experienced teaching expert of the course domain and trained for three hours on the function classification scheme [21] (see Table 1) before coding all of the reflective thinking. The inter-rater reliability between the two coders was .83. Decisions about messages with different codes were re-made in discussions between the coders and the researcher.

Table 1 Classification scheme of problem solving

1	Problem Definition (PD)	
	1a	Problem analysis: Statements that define or state the causes behind a problem
	1b	Problem critique: Statements that evaluate problem analysis statement
2	Orientation (OO)	
	2a	Orientation: Statements that attempt to orient or guide the group's process
	2b	Process reflection: Statements that reflect on or evaluate the group's process or progress
3	Solution Development (SOLD)	
	3a	Solution analysis: Statements that concern criteria for decision-making or general parameters for solutions
	3b	Solution suggestion: Suggestions of alternatives
	3c	Solution elaboration: Statements that provide detail or elaborate on a previously stated alternative.
	3d	Solution evaluation: Statements that evaluate alternative and give reasons, explicit or implicit, for the evaluations.
	3e	Solution confirmation: Statements that state the decision in its final form or ask for final group confirmation of the decision.
4	Nontask (NT): Statements that do not have anything to do with the decision task.	
5	Simple agreement (SA)	
6	Simple disagreement (SD)	

Resource from: Poole & Holmes (1995), p.105.

After the function classification coding of students' reflective thinking, we should make a inference on the coding to the problem-solving behaviors patterns by corresponding with Table 2. And then the total number of patterns in each category was summed by group within each problem that they solved.

Table 2 The corresponding table between coding and problem-solving behaviors

	Problem-Solving Behaviors	Corresponding Lists
U	Understanding	1a, 1b, 2a
P	Planning	3a, 3b
E	Execution	3c, 7*
V	Evaluation	2b, 3d,3e

ps. * Including all the reflective thinking about programming

IV. Findings

In this study, the frequency and the ratio of learners' intrinsic thoughts during the problem solving process of understanding, planning, execution and evaluation were extracted by means of content analysis with experts' crossing check for ensuring the reliability of the analysis.

The frequencies of reflection-in action and reflection-on-action for each lab sessions are shown in Table 3. The higher frequency of reflection-on-action indicated that giving appropriate opportunities, participants could generate more thoughts concerning how to solve a given task when reflecting on it after the task than right in the problem-solving task. Furthermore, the reflections are commonly perceived to be helpful for enhancing the performance of problem-solving.

Table 3 Summary of frequencies and ratios of learners' problem solving in lab sessions

Laboratories \ Reflection Phase	Reflection-In-Action		Reflection-On-Action	
	frequency	*ratio*	*frequency*	*ratio*
Lab 1	90	40.5%	132	59.5%
Lab 2	85	38.6%	135	61.4%
Lab 3	77	35.5%	140	64.5%
Lab 4	78	34.7%	147	65.3%
Sum	330	37.33%	554	62.67%

As the lab sessions go by, participants showed a slightly decline in reflection-in-action while working on problem-solving and also revealed a slightly increase in reflection-on-action after the problem-solving tasks. This implies a trend that participants seem to get familiar with solving problems using mobile technology in the later sessions. In other words, this implies the importance of providing sufficient training in the earlier stages of problem-solving, especially for utilizing technological tools in problem-solving tasks.

To explore the nature of participants' reflections in/on task, the frequency and the ratio of learners' intrinsic thoughts during the problem solving process of understanding, planning, execution and evaluation were further examined. The summary is shown in Table 4 and Figure 4.

Table 4 Summary of frequency and ratio of learners' problem solving in different reflection phase

	Reflection-In-Action									Reflection-On-Action								
	U		P		E		V		SUM	U		P		E		V		SUM
	f	*r*	*f*	*r*	*f*	*r*	*f*	*r*		*f*	*r*	*f*	*r*	*f*	*r*	*f*	*r*	
Lab 1	77	85.6%	12	13.3%	1	1.1%	0	0.0%	90	40	30.3%	63	47.7%	29	22.0%	0	0.0%	132
Lab 2	60	70.6%	22	25.9%	3	3.5%	0	0.0%	85	46	34.1%	69	51.1%	20	14.8%	0	0.0%	135
Lab 3	55	71.4%	20	26.0%	2	2.6%	0	0.0%	77	46	32.9%	68	48.6%	24	17.1%	2	1.4%	140
Lab 4	55	70.5%	19	24.4%	4	5.1%	0	0.0%	78	30	20.4%	58	39.5%	52	35.4%	7	4.8%	147
SUM	247	74.8%	73	22.1%	10	3.0%	0	0.0%	330	162	29.2%	258	46.6%	125	22.6%	9	1.6%	554

The nature of reflection-in-action and reflection-on-action of participants in the stages of problem-solving process is shown in Figure 5. The nature of participants' reflections during problem-solving reveals that participants tended to generate more reflections during the earlier stages of problem-solving both for reflection-in-action and reflection-on-action. This implies that in a problem-solving task, participants need to invest extensive efforts in understanding the problem and planning possible solutions, nor matter during the task or after the task. This also indicated that for facilitating better problem-solving performance, sufficient support should be arranged to smoothen the understanding and planning stages of problem-solving. Therefore, the introduced mobile device provided the potentiality in facilitating the earlier stages of problem-solving both for working on the task and reflecting on the work of problem-solving. In other words, the handy mobile device has contributed to better understanding and planning of a given task. However, solving the problem itself needs the participant to carry out the solution plans in the real place. Therefore, the mobile device did not have much help in facilitating the later stages of execution and evaluation of the problem-solving.

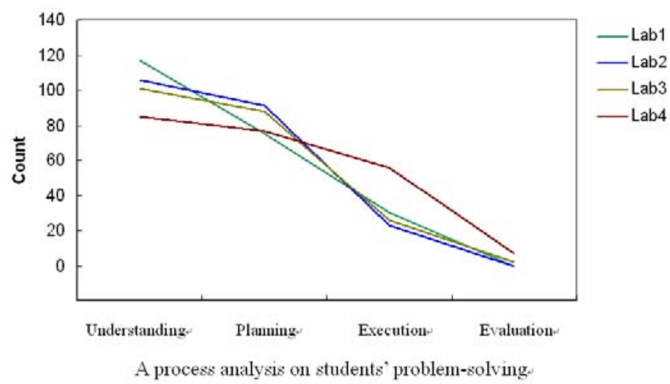

Fig. 4 Summary of learners' problem solving in different Lab session and reflection phase

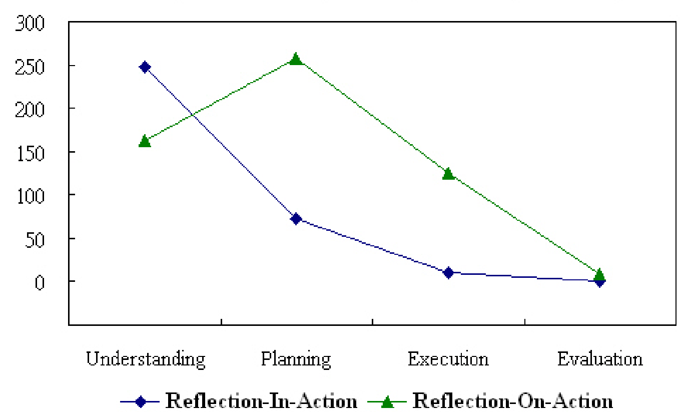

Fig. 5 The nature of participants' reflection-in-action and reflection-on-action in the stages of problem-solving process

Furthermore, the *t*-tests were conducted to examine the effects of independent measures on learners' prior-knowledge and reflection. The result showed that learners with high prior-knowledge or high-reflection revealed higher frequency in reflection and the summary is shown in Table 5.

V. Conclusion

Nowadays, mobile devices have become the most conveniently used and portable learning platform for various educational purposes. The meaningful use of mobile technology in educational settings not just can motivate learners to be more engaging and active in learning activities, but also can facilitate learners to generate better performance. In the present study, the method of content analysis was employed to explore the nature of an introduced mobile technology on participants' thoughts during and after a given problem-solving task.

Table 5 Summary of *t*-test on learners' prior-knowledge and reflection on frequency in reflection

Independent measures \ Problem-solving	Understanding		Planning		Execution		Evaluation	
	f	%	f	%	f	%	f	%
Low prior-knowledge	149	42.3%	154	43.8%	47	13.4%	2	0.6%
High prior-knowledge	202	48.6%	137	32.9%	70	16.8%	7	1.7%
Low-reflection	129	43.1%	119	39.8%	49	16.4%	2	0.7%
High-reflection	215	47.3%	163	35.8%	70	15.4%	7	1.5%

Although the mobile device was limited in the screen size and ways of input, learners showed high degree reflections in the earlier stages of problem-solving both during the task and after the task. In other words, the handy mobile device did contribute to better understanding and planning of a given task in the learners. Furthermore, the results of this study also suggested that the provision of sufficient training in the earlier stages of problem-solving for utilizing technological tools in problem-solving tasks is critically important. Therefore, learners' can truly benefit from the specific characteristics of the technological tools and generate better performance with the help of the technological tools.

Although the relationship between participants' flections on given problems and learning performance was not directly examined in present study, the effects of the employed mobile device on learning was explored through the examination of the nature of participants' reflections during and after the given tasks. Therefore, it is suggested that further study can examine the relationships in an explicit manner. Therefore, the relationships and issues of reflections on problem-solving through the use of mobile technologies can further identified.

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