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Developing Pre-service Mathematics Teachers' Metacognitive Thinking for Learning and Teaching with Mobile Technology

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Abstract: In the present study, we report the preparation of 24 pre-service teachers who were in their third academic year, majoring in teaching mathematics and computer science in the middle school, for using metacognition in their mathematical problem solving. We used different tools to collect data: The pre-service teachers' solutions' texts of carrying out activities on solving authentic real life mathematical problems that emphasize metacognitive processes, the pre-service teachers' texts for the design and preparation of such activities that encourage students' metacognitive processes, interviews with the pre-service teachers, the discussion texts in the social network sites and observations of the implementation of activities. To analyze the data, we used the constant comparison method. The research findings indicated that the participating pre-service teachers developed their metacognitive skills as learners at the beginning and then as teachers. This development as teachers included two aspects: activity design and activity implementation. In addition, we describe a preparation model that included different phases starting from the theoretical phase and ending in a reflection phase, where some parts of these phases are cyclic. We concluded that it is possible to educate pre-service teachers for metacognitive practices, as learners and as teachers. To succeed in this education, the pre-service teachers need to solve activities that emphasize metacognitive skills, to design such activities, to teach them, to discuss their practices, and to reflect on the whole sequence of metacognitive processes. Special attention was given to using mobile technology in solving authentic real life mathematical problems and to collaborative learning.

Keywords: Professional development, Preparation model, Pre-service teachers, Pre-service teachers preparation, Mathematics teachers, Metacognitive thinking

Introduction

Researchers pointed at the contribution of metacognition use on students' learning. For example, students who demonstrate metacognitive knowledge and skills perform better in their learning (Schoenfeld, 1992). In addition, researchers pointed that metacognition knowledge and skills could be developed by education (Schneider & Artelt, 2010). This implies that teachers colleges should prepare pre-service teachers to teach with emphasis on the use of metacognitive skills, if in learning or teaching. The present paper describes an experiment that intended to educate mathematics pre-service teachers for using metacognition in their problem solving, as learners, and in their instruction in the middle school, as teachers. The experiment was held for a full academic year with 24 pre-service teachers who were in their third study year, majoring in teaching mathematics and computer science in the middle school. Two of the authors were the pedagogical supervisors of these pre-

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service teachers in the frame of practical training. The middle school students who were part of the experiment were selected from eighth and ninth grades according to the recommendations of their mathematics teachers who were also mentoring teachers for our pre-service teachers. In this experiment, we requested our pre-service teachers to use metacognitive processes for solving authentic real life mathematical problems in addition to encouraging their middle school students to do so. In the whole experiment, we depended on the work of Davidson and Steinberg (1998) with special emphasis on using mobile technologies in the solution strategies. In addition, special attention was given for collaborative learning among the learners. To encourage the use of metacognition in problem solving among our pre-service teachers and among the middle school students, we requested the pre-service teachers to work in social sites forums – specifically in the Edmodo social network, which was installed on the pre-service teachers' and the middle school students' mobile phones. The participating pre-service teachers utilized the social networking sites to discuss the use of metacognitive processes in problem solving. In addition, they utilized these social networking sites to lead the middle school students in their metacognitive processes through posing questions that would encourage these processes.

Literature Review

Researchers looked at metacognition as cognition about cognition or knowledge about knowledge (Flavell, 1976; Panaoura, Philippou & Christou, 2003). Flavell (1976) was the first to use the term 'metacognition' to refer to the individual's awareness, consideration and control of his or her own cognitive processes and strategies. Since then, a variety of definitions has been given to the term of metacognition. Du Toit and Kotze (2009) argue that the various definitions of metacognitive processes in the literature, including that of Schoenfeld (1992), emphasize the monitoring and regulation of cognitive processes. Moreover, Gavelek and Raphael (1985) argue that metacognition involves promoting effective understanding through adjusting the cognitive processes involved in the activity. Furthermore, Panaoura et al. (2003) say that it coordinates cognition, affecting it and, as a result, affecting students' academic success.

Researchers pointed out that metacognition is comprised of two different components connected to each other. Veenman et al. (2006) argue that the most common distinction in metacognition distinguishes between metacognitive knowledge and metacognitive skills. Flavell (1999) defines metacognitive knowledge as the knowledge or beliefs about the factors that act and interact to affect the course and outcome of cognitive enterprises. These factors include the person, the task and the strategy. The person factor concerns what a person believes about himself/herself and other people as cognitive processors. The task factor concerns the information about the object available to a person during a cognitive enterprise, where different tasks entail different mental operations. The strategy factor involves knowledge about strategies likely to be effective in achieving goals and their cognitive undertakings. On the other hand, metacognitive skills involve planning, monitoring, evaluating and regulating the processes leading to achieving goals.

In addition, researchers suggested ways to encourage students to use metacognitive processes (e.g., Spiller & Ferguson, 2011). Flavell (1979) emphasizes that metacognition improves with practice. Schoenfeld (1992) describes ways that students can practice monitoring and evaluating their performance on math problems. For example, pause frequently during problem solving to ask themselves questions such as “What am I doing right now?” Spiller and Ferguson (2011) say that if we want students to use metacognitive processes, we need to encourage them to consider the nature and sequence of their own thinking processes. Chauhan and Singh (2014) say that as students become more skilled at using metacognitive strategies, they become confident and more independent as learners. Moreover, researchers studied how students' knowledge influences their use of cognitive and metacognitive processes. Awawdeh-Shahbari, Daher and Raslan (2014) investigated the relationship between mathematical knowledge and cognitive and metacognitive processes exhibited by students from Grades 6, 7, and 8 who engaged in a set of model-eliciting activities in groups of 4-5 students each. The results of the study showed that the highest percent of cognitive processes and lowest percent of metacognitive processes occurred amongst the Grade 6 students, while the lowest percent of cognitive processes and highest percent of metacognitive processes occurred amongst the Grade 8 students. The Grade 6 students’ metacognitive processes were more awareness than regulation and evaluation skills. Conversely, the Grade 7 and 8 students employed more regulation and evaluation processes.

In the present research, we wanted to educate mathematics pre-service teachers for using metacognitive processes, as learners and as teachers, through utilizing mobile technologies and collaborative learning.

Mobile Technology in Mathematics Education

Mobile technologies in general have been used in the mathematics classroom for more than a decade now. Advantages of using mobile technologies in education encourage teachers' use of these technologies, where various reasons encourage teachers to use them in their teaching (Daher & Baya'a, 2014; Ng & Nicholas, 2012). Ng and Nicholas (2012) examined the reasons that encourage teachers' use of mobile technologies. They reported that teachers are interested in mobile technologies for their professional development and because these technologies raise students' motivation to learn. In addition, these mobile technologies influence positively students' behavior and emotions. These positive influences of mobile technologies make us encourage our pre-service teachers to use them in their teaching. In the present research, we encouraged them to use the mobile technologies in their metacognitive experiences, especially in solving real life mathematical problems.

Research Rationale and Goals

Schneider and Artelt (2010) point that the importance of educational contexts for the development of metacognitive knowledge was first highlighted in the field of memory development. This was done in studies that focused on the development of children's strategies in learning. These studies indicated that most of the memory and meta-memory development was not so much a product of education and practice rather than of age. It was the aim of the present research to develop educational contexts for the development of pre-service teachers' metacognitive knowledge and skills in solving, designing and implementing authentic mathematical problems with mobile technology when metacognitive skills are emphasized. To develop such context, our previous attempts for developing educational contexts and models for pre-service teachers' professional development in innovative practice (Daher & Baya'a, 2015) were taken into account. We took into consideration that the model should be detailed regarding its phases and the processes of each phase. We expected that such detailed model would help teacher educators plan and carry out professional development courses in the use of metacognition in learning and teaching for pre-service teachers. The description of this model would enrich the literature that lacks such a model.

Research Question

What are the phases of the preparation of mathematics pre-service teachers for integrating metacognition-based authentic mathematical activities that utilize mobile technology in their teaching?

Findings

In this section, we will describe the preparation model and its induced processes.

The preparation processes included several steps which aimed to gradually develop the awareness of the pre-service teachers to metacognitive thinking processes in solving authentic real life mathematical problems, and in designing and implementing activities that emphasize metacognitive processes among students. These steps involved theoretical preparation related to the topic of metacognition; designing activities based on metacognitive skills and the use of mobile devices that utilize proper midlets for solving authentic mathematical problems; implementing these activities by themselves and with middle school students; and, at the end, reflecting on and evaluating of the whole preparation process. We illustrate each step below.

Phase One: Theoretical Preparation for Metacognitive Thinking

In this phase, the pedagogical supervisors emphasized three major aspects of metacognitive thinking: definition of metacognitive thinking, the importance of metacognitive thinking in problem solving, and the assessment of metacognitive skills. This was done through the workshop sessions which accompanied the practical training. Each of the sub-phases is described below.

First sub-phase of phase one: Definition of metacognitive thinking

At this sub-phase, our goal was to engage the pre-service teachers in discussing the various definitions of metacognitive thinking as presented in the literature. For this purpose, a set of definitions were presented and discussed with the pre-service teachers.

Discussing these definitions, the pre-service teachers became aware that studies vary in their definitions of metacognitive thinking, where these definitions are based on psychological or educational approaches. Despite this difference, they are compatible and conform to the characteristics of metacognitive thinking. In line with our objectives, the educational approach of metacognitive thinking was adopted. The pre-service teachers discussed the educationally-approached definitions, where some of the definitions were: “Metacognition refers to one’s knowledge concerning one’s own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact” (Flavell, 1976, p. 232), "Metacognition is individuals’ awareness and control of their cognitive processes in learning" (Swanson and Torhan,1996), "Metacognition is form of executive control involving monitoring and self-regulation" (McLeod, 1997; Schneider & Lockl, 2002) and "Metacognition is thinking of one self-reflection, which allows him control of his thoughts and self-rebuilt, also plays an important role in learning and problem solving" (Guss & Wiley, 2007).

Second sub-phase of phase one: Using metacognitive process in solving authentic real life mathematical problems

At the beginning, the pre-service teachers were engaged in solving the following problem: “A computer engineer from a village in the suburbs was hired to work for a Hi-tech company in the city. We want to help the computer engineer to find the most efficient way to get to work. He must make the decision within a month”.

To encourage the pre-service teachers to use metacognitive skills, we requested them to utilize the theoretical framework developed by Davidson and Steinberg (1998). In addition we encouraged them to utilize mobile tools in their solutions. The main metacognitive skills that we suggested were: Encoding and representation of the givens before the beginning of the solution processes; problem decomposition; planning; selecting and implementing strategies to reach the goal (efficient solution of the problem); monitoring of the plan (through the solution process to reach the goal); evaluating the solutions; searching for other solutions; evaluating the strategies used; and searching for other strategies that could improve and make the solution process more effective. Doing that, we discussed with the pre-service teachers the use of mobile technologies as tools that assist the use of metacognition in solving authentic mathematical problems.

Third sub-phase of phase one: Measurement of metacognition

We introduced the pre-service teachers to several suggested methods for measuring metacognitive thinking, including suggested questionnaires. The participating pre-service teachers came to know that the measurement of metacognitive thinking varies according to the purpose of the measurement. Researchers suggested methods for measuring metacognitive thinking for the knowledge component as well as for the skills component. At the same time, they suggested to measure metacognition at the personal level, as well as at the group level.

To evaluate the metacognitive knowledge we should consider three aspects: Person - where the individual's general abilities to learn and to handle information and self-knowledge about his or her learning process are identified. Task - where the individual's knowledge of the nature of the problem is assessed. Strategy - where the strategies available to the individual to solve the task successfully are identified and used flexibly.

To evaluate the metacognitive skills we should consider the skills: Planning - where actions are defined and arranged, the direction of thinking is determined, strategy is chosen, obstacles and methods to overcome them are identified; monitoring - where the problem solution process is monitored, also the progress towards the goal and errors are detected and addressed; evaluating – where the extent to which the goal or expected outcomes are achieved, performance assessment, and effectiveness of the plan and strategy.

Fourth sub-phase of phase one: Discussion of research in the field of metacognition

The pre-service teachers were requested afterwards to work on research papers in the field of metacognition. They did that in pairs or triples. When the pre-service teachers presented their readings, many of the ideas and terminology in the field of metacognition were discussed. At this stage, several terms and concepts related to metacognition were explored and investigated through various examples. After the presentations, the reports on the articles were uploaded to Moodle, for all the participating pre-service teachers to read.

Phase Two: Designing Activities that Would Encourage Metacognitive Thinking

At the first phase, the pre-service teachers had theoretical background and knowledge of metacognition that we expected would be sufficient for them to prepare authentic real life mathematical problems that encourage the use of metacognitive skills in a mobile environment. Therefore, the pedagogic supervisors requested the pre-service teachers to design such activities. Each pre-service teacher was requested to choose a midlet (a mobile information device applet), learn this midlet, and design an activity for solving an authentic mathematical problem that would raise the need for the use of the midlet; i.e. the middle school student could select the midlet in one solution strategy (a metacognitive process related to the strategy selection metacognitive skill). For example, one pre-service teacher chose a midlet from ‘Science Journal App’ as a tool for carrying out the following activity:

The school neighbors wrote a complaint to the village police claiming that the school bell makes a high noise that disturbs them. The school administration appointed a science teacher and a group of students to examine the neighbors claim, and adjust the school bell speakers so the sound would not exceed the allowed level by law. Help the students accomplish their task.
The pre-service teacher suggested the following metacognitive processes to help the students perform their task:
<u>Encoding of the givens</u>: Searching for the noise law in the internet, which determines the level of noise allowed in the neighbourhoods.
<u>Representation of the givens</u>: Getting the village map and locating the school and the complaining neighbours. Drawing a sketch for these locations with distances.
<u>Decomposition of the problem</u>: Deciding on locations with different distances from the school to measure the bell sound at each one of them.
<u>Planning</u>: (1) Searching for a strategy to measure the sound, then measure the sound at the different locations while the bell is on. (2) Comparing the sound levels with the sound allowed by the law. (3) Adjusting the bell sound so that the closest neighbour would not get a sound exceeding the sound level allowed.
<u>Selecting and implementing strategy</u>: Because of the mobile and real life situated problem, the students would search in their mobile phones for a suitable application. They would find one, such as 'Science Journal App' for measuring sound level.
<u>Monitoring of the plan</u>: The students are advised to repeat their measures several times to make sure that they will get accurate results.
<u>Evaluating the solutions</u>: The students would get to the locations of the complaining neighbours, and measure the bell sound after they adjusted it, to make sure they solved the problem by checking with the neighbours if they are still complaining about the noise.
The pre-service teacher attached to this activity the following teaching materials which she prepared: Description of the mobile application, link to the internet site of the mobile application, and her reflection on the use of this mobile application. These materials were required from each pre-service teacher, and were uploaded to a Google internet site that was constructed by the pre-service teacher.

Phase Three: Implementing Activities that Would Encourage Metacognitive Thinking

First sub-phase of phase three: Discussing the implementation of the activities in Edmodo forums

In the following phase, the pre-service teachers were requested to form groups of 5-6 pre-service teachers each, in order to implement some of the prepared metacognitive activities with the students in the training middle school. To ensure effective implementations, each group of pre-service teachers was advised to open two Edmodo groups to discuss the implementation of the activities. The first Edmodo group included only the group of pre-service teachers working together, while the second group included the group of pre-service teachers together with the group of middle school students with whom the activity will be implemented.

To ensure the effectivity of the Edmodo forums discussions, the pre-service teachers were advised to ask proper questions that would encourage metacognitive thinking. We used Schoenfeld's (in Davidson and Sternberg, 1998) method to teach monitoring and evaluating the performance regarding mathematics problem solving. For example, the pre-service teachers could ask "What are we/you doing right now?", "Could we/you do what you are doing in a more effective way?", "What other strategies are available that could better my work?" The pre-service teachers' Edmodo group also discussed the implementation of the task and obstacles that could be faced with students.

Second sub-phase of phase three: Carrying out the same collaborative activity by each group of pre-service teachers

The pre-service teachers were advised also to carry out a task, suggested by the supervisors, by themselves and upload to the Edmodo group teaching materials and suggestions for improving the interactions with their students. For example, they described various strategies for the performance of the measurements that would be taken in the activity. At the same time, they suggested questions that would encourage students to use metacognitive skills. The pedagogic supervisors of the pre-service teachers were part of the two forums and contributed to them only when necessary to encourage the metacognitive processes by the pre-service teachers and the middle school students.

The task that the pedagogical supervisors suggested to the pre-service teachers was:
Tiling task: A landlord asks you to calculate the costs of tiling the wall that includes the entrance to his house. How can you help him?

At the beginning, the pre-service teachers discussed the task in their Edmodo group, suggesting how metacognitive processes could be utilized in it. Afterwards, the pre-service teachers carried out the task by themselves using two midlets: 'Photo Ruler' and 'Smart Measure'. Throughout the performance of the task by the pre-service teachers, they discussed in the Edmodo forum the obstacles they faced and suggested strategies to overcome them. The Photo Ruler gave relative non-realistic measurements, but the Smart Measure helped in converting the proportional measurements to realistic ones, when performing measurements from a specific location.

Third sub-phase of phase three: Carrying out the same activity with middle school students

The next sub-phase was to implement the same tiling activity by the pre-service teachers with students in the training middle school. Following are examples of the discussions held at this sub-phase between the pre-service teachers and the students in the Edmodo forum.

Examples from the encoding:

PST (Pre-Service Teacher): "Do you need more data to carry out the task? If yes, discuss ways for getting these data."
S (Student): "We need to find the measurements of the tile that the landlord chose to tile with."
S: "My uncle works in tiling and has a shop of tiles. I will ask him to give me tiles' sizes and the cost of doing the tiling."
S: "How do we choose a tile? It is not given in the task."
PST: "You can agree among you on one type and assume the same size for all the tiles."

Examples from the representation of the problem:

PST: "Discuss together a good way to represent the problem."
S: "We could ask the landlord if he has the architectural sketch of the house."
PST: "What if the landlord does not have it?"
S: "We could take a picture of the entrance wall."
PST: "Does this give you measurements of the wall, windows and door?"
S: "We can print the picture, or draw a sketch, and do measurements of the wall by ourselves, and write it on the sketch."

Examples from the strategy selection:

PST: "How would you do the measurements?"
S: "We can use the meter instrument."
PST: "what about measuring the height of the wall?"
S: "We can use a long rope, but we need to go up to the roof."
PST: "Do you think this is possible and realistic. Discuss this strategy with the group. Find alternative strategies and discuss which one could be realistic, feasible and easy to implement."

The last discussion continued until they reached an agreement on using the Photo Ruler and Smart Measure. Afterwards, the pre-service teachers accompanied their students in practicing the midlets. Doing that, the pre-service teachers uploaded user guides for the two midlets to the Edmodo forum in which the students were participants. They posed questions in the forum and directed the students to answer the questions in order to discuss their ideas and thoughts regarding the implementation of the activity. The students were also encouraged to upload their work in the field, such as pictures taken of the house entrance, screenshots of their measurements using the mobile midlets, and any other material related to their solution processes.
Some students worked in two groups and provided two solutions for the same entrance wall, therefore, the pre-service teachers directed them to evaluate their solutions and compare between them. Throughout carrying out the activity, the pre-service teachers kept asking the students to monitor their solutions and make sure that they are advancing towards the goal.

Fourth sub-phase of phase three: Carrying out different collaborative activity by each group of pre-service teachers

By the end of the implementation process of the first task which was the same for all the groups of pre-service teachers, each pre-service teacher had already completed the design of the personal mobile-based and metacognition-based authentic mathematical activity. This design prepared the ground for the second collaborative task to be carried out by the groups of pre-service teachers. Each group was requested to select the best activity among those prepared by the members of the group. This was done through discussion in the pre-service teachers' Edmodo group. The discussion involved the two factors of the activity: its utilization of metacognitive processes and of mobile midlets.

After the selection of the best activity for each group, each group of pre-service teachers implemented the chosen collaborative activity with the students. Throughout and after the implementation, they reflected on it in their forums.

Fifth sub-phase of phase three: Reflecting on the implementation process

The pre-service teachers reflected in their Edmodo forum on the obstacles they faced throughout the implementation of the first task with their students. These reflections were taken into consideration in the planning and carrying out of the second task. They reflected again on the second task, but this time the reflection was done together with their students.

At the end, all the pre-service teachers evaluated the whole preparation process in the general forum - the forum for all the pre-service teachers.

Phase Four: Evaluation of the Whole Preparation Process

When evaluating the preparation process, the pre-service teachers mentioned the following aspects:

Edmodo as a social networking site for collaborative learning

The pre-service teachers were impressed with the way Edmodo allowed them to organize, communicate and upload materials for their use, and the collaborative use of their students.

Following are some statements of the pre-service teachers: "Our experience with Edmodo was fantastic. We were able to discuss, follow up and monitor our preparation of the task and the students' solution process", "The experiment was interesting and distinctive. We have benefited greatly from Edmodo for it enabled interactive collaborative mobile learning".

Development of the thinking processes

The pre-service teachers reported that they started thinking differently. In addition, they pointed out that the experience expanded their horizons.

Following are some statements of the pre-service teachers: “We are now different people. We think about problems in a different way. We are now trying to organize the givens in any problem we face, and we think about the steps and strategies of the solution process”, “We grasped through the experiment many scientific and educational concepts and processes”.

Expose to mobile applications

The pre-service teachers valued that they recognized new mobile applications. Following are some statements of the pre-service teachers: “We have learned about many educational and collaborative mobile applications that can be integrated into math lessons", “The experiment broadened our horizons, and revealed us to many authentic problems that could be solved with mobile applications”.

Obstacles the pre-service teachers faced through the experiment

The pre-service teachers reported some of the obstacles they encountered during the preparation process in general. They described the process in its early stages as relatively difficult. They stated that they needed more practice in metacognitive thinking in order to lead their students in using this thinking, especially in implementing the first collaborative activity. However, they got more ability over time, particularly when addressing the second collaborative activity.

Following are some statements of the pre-service teachers: “In the first collaborative activity, our work was slow and uncertain, but with the beginning of the second collaborative activity, we were much better in metacognition and carried out the activity emphasizing metacognitive skills”.

Obstacles the pre-service teachers faced with the middle school students

The pre-service teachers reported that they faced different obstacles in carrying out the activities with their middle school students. These obstacles were due to the difficulties which the students confronted in Edmodo as a new learning platform. They also confronted difficulties with the mobile applications, and with the authentic activities that the students were not used to.
Following are some statements of the pre-service teachers: “The students were introduced to new technological pedagogical models that they were not used to. So, they had technical difficulties at the beginning of the experiment, especially with the downloading and operating the mobile applications in real life situations”, “After presenting the task to the students, some ambiguity was observed, perhaps because this type of questions, activities and learning in Edmodo was new to them.”

Overcoming the difficulties with successive workshops

The pre-service teachers noted that the successive workshops conducted by the pedagogical supervisors, through which questions, challenges and solutions were raised and discussed, contributed to overcoming the above obstacles. The forum in Edmodo, which included all the pre-service teachers and the pedagogical supervisors, and the collaborative work among the pre-service teachers, contributed to overcoming and absorbing the challenges, motivated them and raised their confidence. This motivation and confidence affected positively the students in the middle school and raised their collaboration and commitment.

Following are some statements of the pre-service teachers: “Parallel to the guidance of the pedagogical supervisors and the collaboration among the pre-service teachers, we began to notice students’ interaction and engagement”, “The students were enthusiastic about the activities and praised the unique experience they had in these unique and authentic activities.”

Opinions and suggestions for improvement

In addition to the previous reports, the pre-service teachers emphasized the importance of allowing more time to the implementation of the activities with the middle school students. They also pointed to the importance of working in small groups (3-4 pre-service teachers). Furthermore, they also suggested exposing the participants in the experiment to more tasks from various fields, and not only mathematics, to get deeper understanding of the metacognitive thinking.

Following are some statements of the pre-service teachers: “There is a need to present more tasks from various fields to strengthen our metacognitive thinking in order to be more competent in this kind of thinking”, “We must allocate sufficient time for each activity with the students to emphasize the various metacognitive processes”, “The groups should be constituted of 3-4 pre-service teachers. When more persons are involved, not all of them will be active.”

Discussion

The present paper describes a model, together with its induced processes, for educating mathematics pre-service teachers in using metacognitive skills in their solving, with the assistance of mobile technologies, of authentic real life mathematical problems, in addition to designing and implementing activities that would encourage students’ metacognitive thinking. This model is part of our other models of preparing mathematics teachers to teach mathematics, with the assistance of technology, and which emphasize specific aspects of mathematical thinking, as high order thinking (Daher & Baya'a, 2015).

Our experience in educating the pre-service teachers in one academic year proved that this education could be successful on condition that it follows a sequence of phases in the actual preparation: Theoretical preparation for metacognitive thinking, designing activities that would encourage metacognitive thinking, and implementing activities that would encourage metacognitive thinking, by the pre-service teachers themselves then with their students. These phases include sub-phases that take care of the various aspects of the phase. The complementary of the theoretical and practical aspects of the preparation plan, as well as the sequence of phases are essential and can help and lead the pre-service teachers to develop professionally in applying metacognitive skills in their teaching. This importance of the sequence of phases in the pre-service teachers' preparation has been emphasized in the literature. For example Daher and Baya’a (2015) suggest a sequence of phases to prepare mathematics pre-service teachers for integrating high order thinking skills in their teaching. The preparation model suggested in this paper is different from the one suggested in the previous study in the extent of the theoretical part. This emphasis may indicate the complexity of the metacognition construct, which makes it necessary to discuss deeply its characteristics depending on the literature.

The success of the preparation is also conditioned by its engagement with the theoretical as well as the practical preparation. This connection of research and practice has been long considered as a way to improve teachers' practices (Lerman, 1990), i.e. to develop professionally, here in utilizing metacognition in the preparation and implementation of mobile-based mathematics activities. We utilized this connection of research and practice in previous preparation models of mathematics pre-service teachers, but here it has a special value because of the complexity of the metacognition construct, which makes it necessary to attempt scaffolding the meanings of metacognition for learners and teachers (e.g. An, & Cao, 2014). The literature helped clarify the meaning of this construct for the pre-service teachers.

Conclusions and Recommendations

Metacognition meanings are not simple to internalize, so preparation is required to ensure that learners and teachers use the metacognitive knowledge and skills appropriately during their learning and teaching. In the present research, we proposed a model, together with its induced processes, for the preparation of pre-service teachers to utilize metacognition in the preparation and implementation of mobile-based mathematics activities. Further research is needed to study the various aspects of pre-service teachers’ preparation to integrate metacognition in their teaching, for example whether there is difference among these pre-service teachers’ due to their content knowledge or pedagogical knowledge. Another issue is the professional development of in-service mathematics teachers in using metacognition in their teaching, and whether the same sequence of phases is also suitable for them. A third issue is mathematics teachers’ beliefs about using metacognition in their teaching, and how these beliefs are affected as a result of their preparation to use metacognition in their teaching.

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