IUMPST: The Journal. Vol 4 (Curriculum), June 2014 [www.k-12prep.math.ttu.edu]
ISSN 2165-7874

Teachers' awareness of creativity in mathematical teaching and their practice

Areti Panaoura
Frederick University
Cyprus
pre.pm@frederick.ac.cy

Georgia Panaoura
Cyprus Pedagogical Institute
Cyprus
sepggp3@ucy.ac.cy

Abstract

The purpose of this study was to investigate pre-service teachers' awareness of creativity in mathematics and mainly their ability to transfer the pedagogical knowledge for mathematical creativity into their suggested lesson plan as an indication of practice. The sample of the study was a group of pre-service teachers who were attending a bachelor degree program and had a special interest in the teaching of mathematics. Results of the qualitative analysis of the data indicated that their initial conceptions about creativity were affected by their previous experiences and the value of creativity in mathematics was underestimated. A course enabled them to propose teaching activities characterized by fluency and flexibility; however they preferred to use routine mathematical activities when they were asked to develop lesson plans due to their lack of strong self-efficacy beliefs to propose original activities and relate their actions with self-reflection. Discussion concentrates on using exploration and investigation of mathematical ideas, in order to fulfill the goals of the creative thinking, and in the development of courses at pedagogical departments which will enable pre-service teachers to get acquainted with new pedagogical ideas and apply them into practice.

Theoretical framework

Contemporary curricula emphasize the development of students' creative thinking (Lamon, 2003) in all aspects of learning. Creativity is an integral part of mathematics (Brunkalla, 2009) and has been proposed as one of the major components to be included in mathematics education, since "the essence of mathematics is thinking creatively" (Mann, 2006, p. 239). A review of the literature about creativity in general and mathematical creativity in particular reveals different definitions (Leikin et al., 2013) and various approaches and interpretations (Shriki, 2010). Treffinger et al. (2002) identified more than 100 contemporary definitions of the concept. Creativity in mathematics may be characterized in several ways such as employing non-algorithmic decision making as well as divergent and flexible thinking which allows one to pursue many different avenues and perspectives in solving a problem (Levenson, 2013). Some researchers refer to creativity using expressions that relate to cognitive abilities such as aptitude, approach, and knowledge (Sternberg & Lubart, 1996), or to conceptual thinking abilities that involve flexibility, fluency, and originality (Leikin & Pitta-Pantazi, 2013). Sriraman (2004) argues that in the context of mathematics, "it is sufficient to define creativity as the ability to produce novel or original work" (p. 20). As Livne and Milgram (2006) claim, creative ability in mathematical thinking is the ability to perceive patterns and relationships using complex and non-algorithmic thinking, and being capable of original thinking in mathematical symbols. It the present work we adopt fluency, flexibility and originality as main components of creativity. Fluency is related to the continuity of ideas, flexibility is associated with changing ideas and producing a variety of solutions, while originality is characterised by the uniqueness (Lev-Zamira & Leikina, 2011).

From a very young age, we are taught to appreciate the beauty of literature, art, music, and poetry, but not the beauty of mathematics. However, studying mathematics is much more than acquiring skills related to algorithms or applying strategies to solve routine word problems. In the mathematics classroom the teacher has to give students the opportunity to realize and appreciate the fact that doing and learning mathematics is a complex process which is fulfilled in different steps such as preparation, incubation, enlightenment, and approval (Erdogan et al., 2009). Even when the teachers acknowledge the importance of their role in fostering creativity, they report several factors that inhibit the manifestation of mathematical creativity, excluding them from accepting any responsibility (Kattou et al., 2009).

Research literature reveals that teachers' conceptions and their practice are related. Therefore, except from raising future teachers' knowledge and skills regarding mathematical creativity, it is also important to invest in their conceptions related to the specific matter. A recent study exploring pre-service primary teachers' conceptions of creativity in mathematics teaching (Bolden et al., 2010) revealed narrow conceptions which were bound up with the idea of 'teaching creatively' rather than 'teaching for creativity'. Teachers are supposed to provide appropriate classroom atmosphere for creativity in mathematics education, since it is well acknowledged that basics of creative thought are developed at the earlier ages of primary education (Leikin & Pitta-Pantazi, 2013). In order to be able to foster their students' mathematical creativity teachers should acquire suitable pedagogical knowledge during their training (Shriki, 2008); however many teachers admit to a lack of prior experience or proper preparation on developing students' creativity (Shriki, 2010). Pre-service programs have to explicitly explore with students what it means to be creative if future teachers will be able to foster their students' mathematical creativity (Levenson, 2013).

As Lev-Zamir and Leikin (2013) note, creativity in mathematics teaching has hardly been studied systematically in relation to teachers' conceptions and their practice. One of the new skills necessary for teaching is being able to choose appropriate tasks in order to meet various educational goals. Several studies have pointed out the importance of having students engage in appropriate tasks that may encourage aspects of mathematical creativity. For example Kown et al. (2006) proposed the use of open-ended problems for developing students' creativity in mathematics. Sheffield (2006) argued that a task which can be extended and thus promotes further questioning can promote mathematical creativity. Undoubtedly the task alone cannot promote mathematical creativity. The teacher in the group environment of a classroom has several roles in the promotion of creativity (Levenson, 2011): choosing appropriate tasks, fostering a safe environment where students can challenge norm without fear of repercussion, and playing the role of expert participant by providing a breakdown of the mathematics behind a process. As Mann (2006) suggests, emphasis of creativity is placed on creating authentic learning situations where students are thinking, feeling, and solving real problems.

One of the major positive beliefs of the last decade is that creativity is of a dynamic nature and consequently it is possible to develop teachers' knowledge and skills with the aim to enhance indirectly students' mathematical creativity. Creativity needs time to develop and thrives on experience (Mann, 2006). For this reason the present work concentrates on Cypriot pre-service teachers' conceptions of creativity in teaching mathematics in relation to their ability to choose tasks for developing their students' creativity, as a goal of the New Curriculum in Mathematics (NCM, 2010).

One emphasis of the new teaching model used in the centralized educational system of Cyprus the last three years, after the development of the NCM (2010), is the use of exploration and investigation of mathematical ideas. The emphasis of many mathematics education reform documents is based on the need to change the environment of mathematics

classroom in order to promote mathematical investigation and exploration (Egodawtte et al., 2011). Within the current reform of the educational system in Cyprus and the implementation of the new school mathematics curriculum teachers are provided with new instructional material for teaching in grade 1 and grade 2. One of the main emphases of the new teaching model which is proposed is the systematic use of "exploration" and "investigation" as two learning processes which help students develop rich understandings of mathematics. Teachers are to actively engage students in open-ended learning experiences in order to foster an environment of inquiry and to promote students' curiosity. The emphasis is to replace algorithmic and rule-based applications with authentic mathematics learning and to enable students to think critically and creatively in mathematics. It is explained to the pre-service and in-service teachers that mathematical exploration is like a journey to the world of mathematics without having a specific destination, without expecting all the students to arrive at the same place, without spending the same time and effort. It is a procedure which highlights the students' inter-individual differences and at the same time it tries to develop the mathematical communication, positive attitudes towards mathematics, and use of different representations, etc.

An example of exploration from the teaching textbook of the first grade is presented at Figure 1. It asks students to classify groups the children and justify their answers. It is obvious that there are many different answers depended on the different criteria and each answer can be characterized by different level of difficulty.

Figure 1

An example of an "exploration" activity

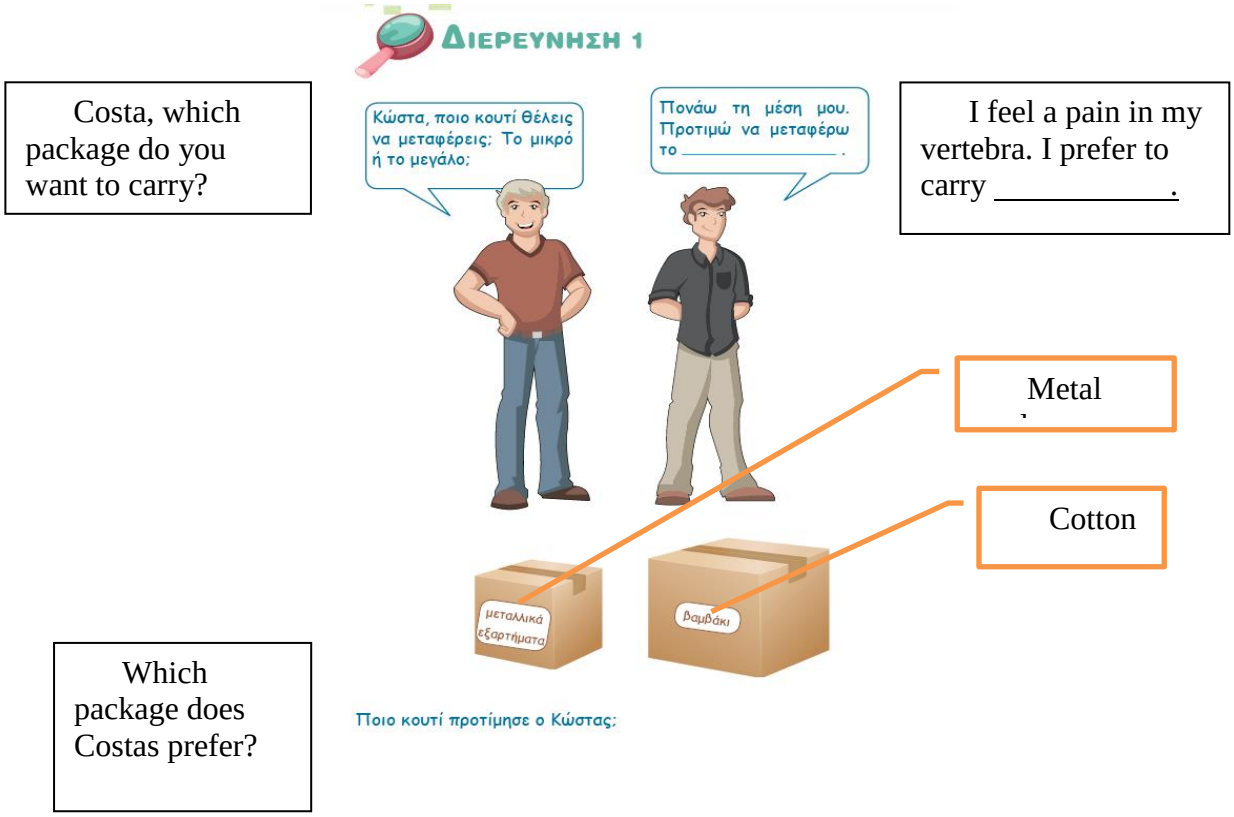
Instructions: Classify into groups using different ways.

In the case of the mathematical investigation, students are expected to pose hypotheses, examine them and draw specific conclusions. In the whole procedure the teacher provides appropriate tools and manipulatives in order to enable the students to examine their hypotheses. The "journey" has a specific destination and the conclusion is common for all the students.

An example of an investigation from the textbook of the second grade is presented at Figure 2. The first man asks the second one which box he prefers to carry. The second one

tries to decide which one is lighter. The smaller box is full of metal, while the bigger box is full of cotton. Students are expected to conduct experiments and justify their conclusions.

Figure 2
An example of an "investigation" activity



Teachers must be fluent in lesson management, flexible in reacting to students' unexpected responses, and original in using surprising teaching ideas. The present study concentrates mainly on the final aspect of creativity and particularly the conceptions and practices of creativity in teaching methods. Particularly the aim of the present study was twofold: a) to investigate pre-service teachers' conceptions of creativity and their awareness of creative thinking in mathematics; and b) to investigate pre-service teachers' ability to transfer into their lesson plans the pedagogical knowledge they acquired about mathematical creativity after the completion of a broader program aiming to discuss new trends in mathematics education, in particular the use of a new teaching model which includes investigation and exploration. We believed that if teachers understand the value of investigation and exploration they will be more positive in realizing the value of creativity in mathematics and capable of suggesting and proposing creative activities for the teaching of mathematics.

Method

The research was carried out during the first semester of the third year of the studies for a four years bachelor degree program in educational studies (at the Department of Education). In the previous year students had attended a course on the basic mathematical concepts and a course on the didactics of mathematics. The specific semester they attended an elective course called "specialization in mathematics education" during which they had the opportunity to discuss the recent trends of the research on mathematics education and get

acquainted with the research in mathematics education. One of the main purposes of this course was to give students the opportunity to become familiar with the current reform of school mathematics in Cyprus and the NCM (2010).

The sample of the study consisted of the ten students who had chosen to attend the elective course "specialization in mathematics education". Every week for a total of 13 weeks they attended a three-hour lecture on a specific subject and worked cooperatively on practical activities on the same domain. Creativity in mathematics was the subject under discussion during the fourth meeting of the group. At the previous meetings the group had discussed the new trends in mathematics teaching and learning with regard to the concepts of exploration and investigation as teaching and learning processes in mathematics.

At the meeting about "creativity in mathematics teaching and learning" the pre-service teachers were first asked to write on a sheet of paper whatever came to their minds as the definition of "creativity". Then they were asked to analyse the relation of creativity with mathematics in respect to their own experiences. After having expressed their initial conceptions and beliefs about creativity and its relation with mathematics, students discussed, with the involvement of the first author, the definitions of creativity proposed in the literature, as well as research findings related to mathematical creativity. Additionally, in order for the future teachers to be able to appreciate the beauty of creativity in mathematics, they solved mathematical problems which, according to the literature, enhanced creativity. At the next meeting they were assigned to study the new mathematics textbooks which are currently used in Cyprus in grade 1 and grade 2 within the school mathematics reform and work in groups for a week in order to: (i) choose one activity which can be used to develop students' creativity and justify their selection by using arguments related to the new emphases on creativity, and (ii) change an existing activity from the textbooks in such a way that it is suitable to be used for fostering students' creative thinking. After the completion of the course, and as part of the course final assignment, they were asked to develop two lesson plans for the teaching of a mathematical concept at grade 1 or at grade 2 of the primary education. The plans were analysed qualitatively in order to investigate the pre-service teachers' ability to transfer their knowledge of mathematical creativity in new situations. The year they will be asked to teach mathematics at primary schools and probably we will be able to judge their ability to transfer the conceptions and ideas into the real teaching and learning environment.

Results

Most pre-service teachers (eight of them) in the sample included in their definitions of creativity the idea of "originality" of the final product, while they also referred to the use of different processes in order to investigate and encounter a new situation. For example, a pre-service teacher defined creativity as "the human ability to follow a unique way of thinking in order to create something different". Another one argued that "it is the ability of *some* people to investigate and explore new things in order to create something original". It seems that "one has to think *outside the box* in order to find out something *uncommon*". This ability can be obvious from human's behaviors or sometimes a person can "create different and original mental scenarios". A student added the concept of "unconscious mental activity" and the conception that "imagination" as important components of creativity. Finally, a pre-service teacher brought up the idea of flexibility and fluency, suggesting that creativity "is the concept which indicates the many and different new approaches in order to solve a situation and as a consequence the many different results and discoveries".

While most of the definitions of creativity referred to the originality of the final product, in their analysis of the relationship between creativity and mathematics the pre-service teachers focused mainly on the procedure and not on the product, presenting conceptions

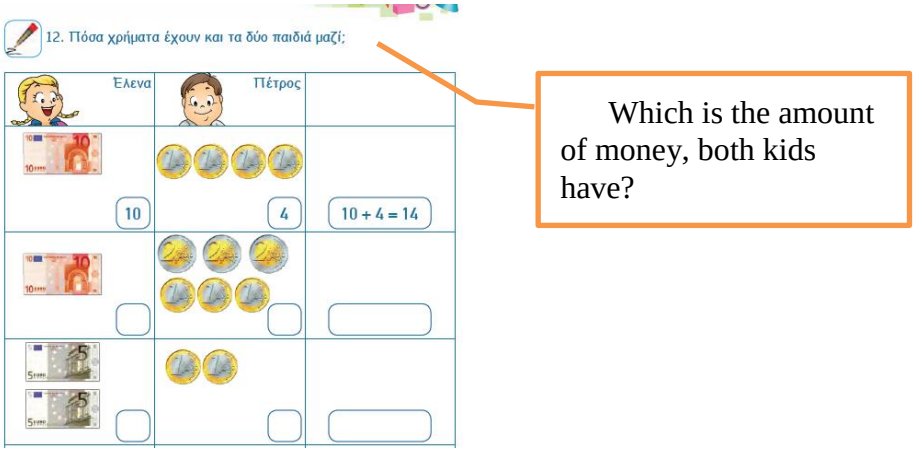
which refer to creativity in the learner's perspective. For example, "creativity in mathematics is not related with the final result, but with the processes which are followed by the student in order to give a result". Especially during the problem solving procedure "students explore different ideas to find a solution". Two of the participants tried to examine creativity in mathematics from the teacher's perspective, suggesting what teachers can do in their teaching to promote mathematical creativity. More specifically, they linked creativity with everyday life and they highlighted the importance of using real life examples to promote creativity in mathematics. They believed that the connection with the real life situations empowered the element of originality because students have to face new and unique situations. On the other hand, one pre-service teacher expressed the opinion that there is a very poor relationship between creativity and mathematics "because creativity has strong relations with subjects such as Art, while mathematics is related with logic". Another one could not find any relation between mathematics and creativity because "only few people are creative and think in a different way, while almost everyone can think mathematically". Those conceptions indicated that although they had not discussed the concept of creativity earlier, they realized the criterion of originality and in few cases their epistemological conceptions about the nature of mathematics seems to be an obstacle.

When they were asked to identify the mathematics textbooks activities which foster students' creativity, half of the pre-service teacher groups presented exploratory activities, while the rest of the groups chose investigative activities which asked the students to present different answers or solutions. For example, a group of three students proposed an investigation where students are urged to use the given numbers (0, 1, 2, 5) and mathematics symbols (+, –, ×, ÷, =) in different ways in order to produce (a) the number 13, and (b) the number 20. They justified their suggestion by saying that there were many different solutions of the problem (fluency), there were many different ideas in order to solve the problem (flexibility) and they assumed that students had not solved a similar problem before.

When the pre-service teachers were asked to change an existing activity from the textbooks so that it promotes students' creative thinking, all of them chose routine activities. The changes they proposed revealed their efforts to present activities which can be solved in different ways or activities which force the students to pose different answers as solutions. For example, one group of two pre-service teachers decided to change an existing routine activity (Figure 3) which asked students to find the amount of money presented in the given diagram. They suggested that the teacher could give the students an empty diagram and ask them to find different combinations of coins and paper money for a specific amount. They justified their suggestion by referring to fluency and flexibility and at the same time they admitted that it is a common activity which is presented usually at the textbooks.

It seems that pre-service teachers understood the major ideas about the mathematical creativity and tried to transfer them into practice when they had specific instructions to follow. They were not able to fulfill the criterion of originality for which they claimed that "only teachers with much experiences are able to find new and interest problem solving context". However, the importance lay in the influence of the knowledge about creativity gained from the course and the students' ability to transfer this theoretical knowledge into practice.

Figure 3
A routine activity from the text book which was proposed to be changed



At the final stage of the study, one of the instructions for their individual work, as part of their final assignment, was to develop two lesson plans which should include at least one activity of exploration or investigation. There was no reminder about the concept of creativity because we wanted to evaluate their tendency to construct creative activities as an ordinary planning teaching procedure. For this reason the specific activities included in the lesson plans which were provided by the pre-service teachers were analyzed in order to identify whether they had presented activities which urge students to think creatively. Qualitative analysis of the manuscripts indicated that all of them used at least one exploration or investigation, according to the instructions which were given to them. All of them, with the exception of two participants, did not develop new exploratory activities of their own; they preferred to use the explorations presented in the textbooks. It seems that they fulfilled the criteria of creative thinking development by using activities with many different solutions. Only two of them tried to fulfill the element of originality by proposing to use technology as a learning tool, as there were not yet during the course any discussions of using technology (this is part of the next course at the following up semester). The global impression was that they preferred to use routine activities and the proposed investigative and exploratory activities presented in the textbooks.

When they presented their work to their classmates they claimed that they did not have the necessary self-efficacy beliefs to propose their own activities for investigation and especially exploration. They did not make any reference to the concept of creativity and when one of them was asked by the first researcher "Why you have not developed an activity of exploration or investigation by you own?" the following up dialogue occurred:

Student: *The creativity cannot be developed easily and it cannot be a goal of a specific teaching plan. It has to be developed through a whole year when we will be a teacher of a specific group of students.*

Researcher: *However I had seen that you had used a cooperative activity. Cooperation is not a general goal of education, as well?*

Student: *Yes, but it is easier to construct cooperative activities. We had done it again. It is not easy to develop something original.*

Researcher: *Teaching is not an easy procedure.*

Student: *We have just learned few things and we have to apply them in order to be convinced.*

Researcher: *What about fluency and flexibility?*

Student: *It is easier than originality. You are trying to pose problems with different solutions. I am not sure whether the students are trying to find out many solutions, especially if they are not asked to do it.*

Researcher: *Why?*

Student: *I've never done it in mathematics. I was trying to find a correct solution.*

Researcher: *Why have you used only activities from the textbooks?*

Student: *I was not feeling confident to construct a new one.*

The above dialogue of one of the researchers with a student (pre-service teacher) during the presentation of his work is indicative of the influence of the lack of experiences on posing new problems (Crespo & Sinclair, 2008) and constructing activities. The students seem to understand that the development of creative thinking is one of the mathematics education goals, however they are not able to transfer the theory they have learned into practice.

Discussion

We consider creativity as a dynamic characteristic that can be developed during the educational process of a student and we strongly believe that the value of creativity in mathematics should not be underestimated (Chamberlin & Moon, 2005). The research presented in this paper is motivated by the belief that teachers are responsible for developing an environment that is supportive and rewarding of creative ideas and pedagogical departments have a serious role in developing pre-service teachers' knowledge of creativity and their ability to propose teaching activities for developing creativity.

Results revealed the initial conceptions of some pre-service teachers that mathematics is not a creative subject and that it is difficult to develop creativity in mathematics. This finding confirms Bolden's et al. (2010) results, where all the pre-service teachers interviewed admitted that they had not viewed mathematics as a creative subject. Probably this is the result of their school experiences with mathematics which actually created an ontological stereotype about the nature of mathematics. Pre-service teachers included in their initial definitions of creativity, only the concept of "originality" – referring to the final product – and the use of different processes in order to investigate and encounter a new situation. When they were asked to identify activities in the mathematics textbooks which foster students' creativity, all of the pre-service teachers groups presented exploratory or investigative activities and they justified their suggestion by referring to fluency, flexibility and originality, probably due to recently acquired knowledge from the attended course. Although the starting point was their concentration on originality, the most serious difficulty they found was to identify or produce original activities. The analysis of their lesson plans was not designed to measure change in pre-service teachers' conceptions of creativity; however, the data suggested that our pre-service teachers' conceptions of mathematical creativity were still limited. This was evidenced by the fact that they preferred to use typical and routine mathematical activities. Only two participants associated creativity with the use of technology, while Bolden's et al. (2010) results indicated that most of the participants associated creativity with the use of resources and technology. Based on the abovementioned results, it seems that there is a gap between pre-service teachers' declarative conceptions about creativity and their respective behavior (Lev-Zamir & Leikin, 2013).

The initial quantitative results of the first phase of this study can be used as indicators for the development of teacher preparation programs which aim to fulfil the goals of the NCTM (2000), according to which mathematics students of all levels should be exposed to thinking creatively and flexibly about mathematical concepts and ideas. We have to prepare teachers to be able to design and implement learning environments that support the development of mathematical creativity (Shriki, 2010). Additionally with regard to pre-service teachers' conceptions of mathematical creativity, it is important to discuss with them how a task may

afford or constrain the promotion of creativity. Pre-service teacher education programs have to be much more explicit in discussing with the prospective teachers what it means to foster students' creative thinking in primary mathematics and in what ways this can be done (Bolden et al, 2010). At the same time pre-service teachers have to experience the value of learning in an inquiry-enhanced environment (Wilhelm & Walters, 2006), and a creative atmosphere in order to develop firstly a creative learning behaviour and then a creative teaching behaviour. The knowledge about creativity is not enough; they need practical indications of how the teaching model of exploration and investigation provides the opportunity to use activities for the development of creativity, they have to correlate theory and action.

Programs with intentional experience in mathematical creativity have to raise prospective teachers' awareness of the fact that mathematics is a creative endeavour and help them to think creatively in their everyday teaching of mathematics in order to make the beauty of mathematics visible to their students. Teacher education programs should be designed in such a way that they assist future teachers to acquire knowledge, positive attitudes and teaching skills associated with the development of students' creativity (Hosseini & Watt, 2010). Current mathematics reform in Cyprus encourages the use of meaningful mathematics tasks including exploratory and investigative activities. Creativity starts with curiosity and we believe that exploratory and investigative tasks can increase the development of students' creative thinking. The understanding of the teaching model which includes investigation and exploration does not guarantee that pre-service teachers are able to relate them with the main emphases of mathematics education, such as critical thinking, problem solving, positive attitudes towards mathematics, the use of technology and creativity.

The preliminary analysis highlights the impact of regulatory practices on pre-service teachers' understanding of themselves as teachers and their beliefs of what it means to teach effectively in the mathematics classroom (Walshaw, 2013). It is important for pre-service teachers to realize their difficulties and limitations on applying their theoretical pedagogical knowledge, as it is the first step on trying to overcome the obstacles. The present study has many limitations in respect to the sample and the procedure which has been used, and its results can be discussed in relation only to the specific context. We have to keep in mind that participants had an extra personal interest on mathematics education. It would be interesting to continue our study by observing the specific participants next year when they will have their first teaching experiences in mathematics classrooms during the course "School Experience" and probably we will be able to investigate the behaviour of some of them on the following up years when they will be teachers at public primary schools. We believe that the longitudinal qualitative analysis of pre-service teachers' and is-service teachers' behaviour will contribute on the study about the better connection of the theory with practice for the construction of educational programs or courses.

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