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Mathematics Teachers’ Specialized Knowledge Model as a Metacognitive Tool for Initial Teacher Education
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Mathematics specialized knowledge models for teachers have been used as a conceptual framework for defining how teachers’ knowledge is implemented in the classrooms, as well as for guiding the design of initial teacher education (ITE) programs. In this communication, besides the design of the ITE program, we present how the model of Mathematics Teacher’s Specialized Knowledge (MTSK) has been used as a metacognitive tool enhancing primary and early-childhood teachers to reflect about their own professional competencies, to self-assess in relation to the different subdomains in the model, and to start acquiring research related skills during a postgraduate ITE program.

Keywords: initial teacher education, MTSK, research skills, specialized knowledge model.

Introduction

Teachers’ knowledge models emerged in the 1980s, mainly from the seminal work of Shulman (1986), as a theoretical framework characterizing the knowledge that teachers need to operate in order to carry out their teaching tasks. In addition to non-specialized models such as T-PACK (Mishra & Koehler, 2006), other models of specialized knowledge were developed in the field of mathematics teaching. Thus, the Mathematical Knowledge for Teaching (MKT) model by Ball, Thames and Phelps (2008) stood out. These authors were interested in the study of professional knowledge, basically because specific knowledge, besides mathematical knowledge, was revealed as necessary to teach mathematics. In other words, a teacher has to know different but not less demanding mathematics than other professionals.

At CERME8, the Mathematics Teacher’s Specialized Knowledge (MTSK) model was presented by Carrillo, Climent, Contreras, and Muñoz-Catalán (2013) as an evolution of the studies of Shulman (1986) and Ball et al. (2008). MTSK considers the specialized character of the teacher’s knowledge in an integral way in every subdomain, whereas MKT included the mathematics teacher’s specialized knowledge into a single subdomain.

The context for this experience is strongly dependent on the introduction of European Higher Education Area in Spain, that opened up the possibility that early childhood and primary education graduates could access to postgraduate programs (master degrees, and maybe further doctoral studies). Master level is not a requirement for becoming an in-service teacher in Spain, but in the recent years is becoming more popular among recent graduates (in part, because the master level is a requirement in other UE countries). In Spain there are master degrees oriented to a specific topic (didactics of mathematics, for example) but for early childhood and primary education graduates most of the master programs are devoted to provide them with general innovation and research skills (since early childhood and primary teacher are generalist profiles in Spain, only specialized for certain topics in primary as Physical Education, Foreign Language, Music and others, but not for
In this context, the current research was designed with a twofold objective. Firstly, to find out whether, at master level, training graduate teachers about models of specialized mathematical knowledge improves metacognition about their professional development and identity as mathematics teachers. Secondly, to find out whether this training (together with other topics) promotes basic research skills. Consequently, two research hypotheses were formulated: (H1) Including models of specialized mathematical knowledge in the syllabus of the master program for graduate teachers favors metacognition about their profession, and (H2) Including models of specialized mathematical knowledge in the syllabus of the master program for graduate teachers promotes research skills in educational research.

This communication is structured as follows: first, a theoretical framework is described and metacognition is framed within the context; later, the methodological design is described together with the population and the sample, and the data collection process; finally, results are presented and, subsequently, the discussion together with the conclusions derived from the study.

**Theoretical Framework**

The MTSK model is fully developed in Carrillo et al. (2018), it is composed of the domains Mathematical Knowledge (MK) and Pedagogical Content Knowledge (PCK), which, in turn, are divided into 3 subdomains each. In addition, the core of the model includes the mastery of teachers' beliefs about mathematics, its teaching and learning, permeating the knowledge and giving meaning to their practice. The MK domain encompasses knowledge of the connections between concepts, structuring ideas, procedure reasoning, proving, and different ways of proceeding in mathematics, also considering the knowledge of mathematical language. Within the MK we find the following subdomains: Knowledge of Themes (KoT); Knowledge of the Structure of Mathematics (KSM); and Knowledge of Mathematical Practice (KPM). On the other side, the PCK refers to teacher's knowledge of mathematical content as an object of teaching and learning. The PCK domain is divided into three subdomains: Knowledge of the Teaching of Mathematics (KMT); Knowledge of the Learning Characteristics of Mathematics (KFLM); and Knowledge of the Mathematics Learning Standards (KMLS).

Additionally, it is convenient to specify the scope of the discussion on metacognition and research skills. The majority of theoretical frameworks used in metacognition focus on two components: those dealing with declarative and procedural knowledge, and those dealing with the regulation of that knowledge when an individual performs a task (Schraw, Crippen, & Hartley, 2006). In our approach, we handle the latter meaning when designing the training activity for the graduate students (Lombaerts, Engels, & Athanasou, 2007). The proposed activity is aligned with what Zimmerman (1990) states as one of the key features which can be seen in most definitions of self-regulated learning, that is, systematic use of metacognitive motivational and/or behavioral strategies. Therefore, we are considering higher evidence of metacognition when the graduate students are not only aware of their own thinking but also use it as an instrument to regulate their own learning experience when doing the task.

On the other hand, according to Spanish Higher Education Qualifications framework, the acquisition of research skills should start in the postgraduate training. In other words, the master
degree is conceived as the prior stage of the research training, which is properly developed during the PhD degree. Then, a master graduate should acquire a minimum level of research skills allowing him/her starting, under supervision, in active research teams. Literature is abundant on so-called research-based learning, especially in the field of STEM (Science, Technology, Engineering and Mathematics) (see a review in Camacho, Valcke, & Chiluiza, 2017), but it is scarce about how to develop this competence for educational research, specifically on how to characterize it during ITE postgraduate programs.

To this end, we align ourselves with the theoretical position defined in Moreno Bayardo (2005), who defines training for educational research in terms of the development of research skills. Specifically, for this experience, we are placed in the so-called “Nucleus G: Metacognitive Skills”, where the author argues that “the human being encounters the need to develop (and, in fact, in many cases he achieves it) metacognitive skills before getting involved in deformation processes for research” (Moreno Bayardo, p. 530). It should be pointed out that, although there are works whose explicit objective is fostering metacognition in the professional development of teachers (e.g., Rojas & Deulofeu, 2013), within the Spanish context there is only one former experience (Pascual & Montes, 2017) using a specialized knowledge model to develop metacognition, but it was during the undergraduate ITE and, therefore, activity did not involve research skills, whereas, our research focus on how to help the graduate students to move from a teacher identity to a potential research identity.

Methodology

Population and sample

The population of this study consists of graduates of Early Childhood and Primary Education who are enrolled in a master degree aimed at research and innovation skills. Several masters with these characteristics are taught in the different Spanish universities, but we have only had access to data from the University of Oviedo, in whose Master Degree in Research and Innovation in Early Childhood and Primary Education in the academic year 2017-2018 there were a total of 35 students enrolled. Therefore, it is an intentional non-random sampling, and the sample is formed by 32 individuals who completed the experience and the survey (response rate of 91.42%).

Educational context

The master degree in Research and Innovation in Early Childhood and Primary Education at the University of Oviedo is oriented to graduates in both educational stages for training them as future researchers and professionals in the field of learning and teaching. The subject in for which the intervention was designed is Research and Innovation in Didactics of Mathematics (5% of credits in the program). We remark this is not a specific master program in mathematics education, but generalist, and this fact hardens deepening into mathematics educational issues. One of the five basic competences of this master program aims to acquire sufficient skills to identify trends in innovation and research in the knowledge areas involved, and discussing their compatibility with the explicit beliefs and theories of the teaching staff. Taking the context into account, we proposed the experience described below for promoting the aforementioned competence.
**Intervention planning**

Previous lectures to the intervention had been developed, during 10 hours, for presenting the meaning of research and innovation in mathematics education, as well as to identify the work that in-service teachers can do within these fields. Among these general ideas, the notion of professional knowledge of the teacher was used, and more specifically, the notion of specialized knowledge in mathematics was implicitly involved to perform different tasks developed by the students. Also, main research lines in mathematics education were described by reading and discussing examples of papers. But, in this communication we focus on the work that was carried out during two work sessions in the classroom in which the activities related to the presentation on the professional knowledge of the teacher and the use of the MTSK model were presented and carried out. In the first session there was a training, led by the professors, on the research problem of models to describe specialized teachers’ knowledge. This session explained the different theoretical positions on teacher knowledge, the differences between content knowledge and pedagogical knowledge and their intersections, the genesis of the first models of specialized knowledge and the role of teacher beliefs and conceptions in their interaction with knowledge. In the second session, the MTSK and its subdomains were dealt with in detail. Afterwards, divided into small groups, the students carried out a work based on the transcription of a fragment of real class of Early Childhood Education (4 years old level) where the teacher worked with geometric bodies. The main objective of the activity carried out by the teacher is the recognition of different geometric bodies and the identification of their elements (faces, edges, vertices, etc.). The graduate students had to identify the subdomains and categories of knowledge of the MTSK present in the class transcription. Finally, they had to respond individually to an anonymous questionnaire, which is presented in the following section.

**Assessment instruments**

In addition to the aforementioned deliverable group task about identification of subdomains of the MTSK model, students had to answer a questionnaire consisting of context questions (age, sex and teaching experience, and whether they had been previously trained or not about the models of knowledge), and of 7 questions for assessing the usefulness of the model or models like it in the professional teaching environment (with Likert scale responses from 1 to 5). Finally, 3 open-ended questions were posed which are based in the nature of subdomains of MTSK. The instrument had been content validated through a pilot carried out in the previous year, which resulted in removing two of the initial open-ended questions (because of redundancy and misinterpretation).

**RESULTS**

The sample (n=32) was composed by 19 women and 13 men, with average age 26.25 years old (median 24). Only 6 students have had experience as formal teachers (5 at primary and 1 at early childhood level), that is, most of the students were recently graduated teachers without further experience than the internship. Also, 6 stated that they had previously heard about teacher knowledge models. And only 1 of the participants stated that he/she was yet aware of specialized models for mathematics. Table 1 shows the mean, median and standard deviation of all the Likert type questions (1=absolute disagreement to 5= absolute agreement with the statement).
As for the open-ended questions, below we point out some of the most significant or frequent ones. To the question “Would you add anything to the subdomains MK and PCK to better describe the activity of the mathematics teacher?”’, the most frequent answer was like “I do not consider myself sufficiently qualified”. One student considered that “the affective aspects of the teacher-student relationship should be more pointed out”. Another one remarked that “it would incorporate the methodologies in a more explicit way, including the different types that exist”.

<table>
<thead>
<tr>
<th>Statement</th>
<th>M</th>
<th>Me</th>
<th>DT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I believe that it is positive for my training as a teacher to know a model that describes the knowledge of mathematics teachers.</td>
<td>4,03</td>
<td>4</td>
<td>0,73</td>
</tr>
<tr>
<td>2. For my daily life as a teacher, I believe that these theoretical models do not improve my training.</td>
<td>2,44</td>
<td>2</td>
<td>1,14</td>
</tr>
<tr>
<td>3. The work about knowledge models has allowed me to reflect on professional aspects that I had not thought about.</td>
<td>3,81</td>
<td>4</td>
<td>1,03</td>
</tr>
<tr>
<td>4. The knowledge models have helped me to structure ideas which I had thought about my profession, but not in such a formal way.</td>
<td>3,16</td>
<td>3</td>
<td>0,92</td>
</tr>
<tr>
<td>5. I find the work on knowledge models interesting, but of little use for my professional future.</td>
<td>2,72</td>
<td>3</td>
<td>1,12</td>
</tr>
<tr>
<td>6. I think knowing these models is interesting as a general culture but it will not be something I will apply when I have to program or teach.</td>
<td>2,91</td>
<td>3</td>
<td>1,26</td>
</tr>
<tr>
<td>7. I consider that these models help to criticize and reflect on my activity as a teacher.</td>
<td>4,06</td>
<td>4</td>
<td>0,86</td>
</tr>
</tbody>
</table>

**Table 1:** Mean (M), median (Me) and standard deviation (DT) of all the Likert-type answers.

Second open-ended question was “Has this model allowed you to reflect on any aspect of your professional development that you had not previously thought about? Which one?”. There were some self-critical answers, from the point of view of metacognition, such as: “that I have insufficient mathematical training” or “about my scarce mathematical and didactic training”. Other answers even advanced in metacognition, at a higher cognitive level. Thus, some students stated that the model has helped them to reflect on specific aspects such as “the importance of knowledge of resources, materials and ways of presenting the content” or “the importance of teacher's knowledge, not only of the subject itself, but also of the didactic part”; and, in some cases students established relations between categories: “the relationship between current and previous contents”, “beliefs about mathematics or its teaching/learning and the scope they may have in the teaching process”, “the need to spin each content of the curriculum with other elements whose relationship does not seem so direct” or “the need to be aware of [...] the learning standards used in other countries”.

Finally, in response to the third open-ended question: “Has the use of this model motivated you to reflect on mathematics as a discipline or on your professional development?”, the most frequent responses referred to “considering my professional development in different facets” or equivalent. Answers with a greater level of deepening, were less frequent: “that research is a source of educational improvement”, “to overcome the myth of difficulty or fear of mathematics” or “I would like to see the analysis of the knowledge that is put into practice in classes of different educational levels”. We particularly highlight the following answer: “[this model] reminds me of the concept of...
metacognition and, in a similar way, I see its usefulness”. Finally, this answer also denotes progress in metacognitive processes: “[the subdomain of] the characteristics of learning mathematics in a specific subject have seemed very interesting to me, and I would have to take it into account when planning my classes”.

**DISCUSSION AND CONCLUSIONS**

Results of the Likert answers are homogeneous in terms of the analyzed context variables (sex, age, professional experience), hence, statistical analyses have not been included. The values of the Likert scale show that there is a high degree of agreement with the statements expressed in positive. Specifically, the agreement is very high in statements 1 and 7. On the other hand, when the statements are posed negatively the agreement is considerably reduced (numbers 2, 5, and 6). In addition, in statement 3 the degree of agreement is also quite high, although the dispersion is greater due to the existence of more extreme values. Finally, with statement 4 a problem of interpretation arises, since values are grouped symmetrically around 3, which indicates that perhaps the duality of the question should be reformulated (this had not happened in the piloting). From these results, we can conclude that, overall, the activity motivated the reflection of future teachers and they considered it useful for their professional activity, which is something authors did not expect initially, due to the generalist background of the graduate students. In addition, the link between research and daily activity as a teacher in the classroom is recognized, albeit less clearly. The metacognitive facet is also implicitly recognized in the answers (statements 3 and 4).

From the analysis of the open-ended questions, we can deduce that students found more difficult to formalize their opinions, since around half of the answers were very short or blank. Based on evidence from longer answers, regarding MTSK subdomains, for most of the students the training was insufficient to be able to critically judge the model; this evidences that explicit training on models was short. Even though, it seems interesting to us pointing out that two students felt that temporal programming is not sufficiently represented in the model. It is also noteworthy the answer referring to the insufficient representation of the affective relationship between teachers and students. This answer can be interpreted from two of the domains of the MTSK model: firstly, the contribution made by the MTSK model in the didactic domain is to link the content of the subdomains to the relevance of the relationship with the mathematical content, so that the affective relationship to which that response refers would not be included in that domain; on the other hand, it could be aimed at mastering the teacher's beliefs, attitudes and emotions towards mathematics and its teaching/learning as central elements, intimately related to professional identity, where the teaching staff give the students a very specific role when working in mathematics. There is a much greater reflection deepening in the answers to the second open-ended question. For example, self-criticism is expressed regarding the background in mathematics and its didactics. Other answers show a deeper understanding of the model, since they reveal relationships between different components of the subdomains (curricular organization, permeability of teachers’ beliefs and conceptions, international learning standards, etc.). Answers to the third open-ended question also go in depth. Especially, those about the use of the model as a metacognitive tool, which seems to be completely aligned with the objectives of this research, or other answers that, without explicitly
expressing metacognition, do it implicitly by the establishing relations between teaching practice and the knowledge of teachers’ knowledge models.

In summary, we consider that data support the veracity of hypothesis H1, about the improvement of metacognitive processes through this activity. This is consistent with Rojas and Deulofeu (2013), although they did not explicitly use a knowledge model. On the contrary, we do not have sufficient evidence to maintain hypothesis H2, related to promotion of research competencies. In this case, we understand that graduate students’ identity is closer to a teacher identity and far from researcher one, which underlines the role of identity, as an important factor in the teacher’s understanding of professional life (Beauchamp, 2009). We also believe that we have had little impact on this facet during the intervention, which resulted in the knowledge model being considered more as a tool for self-assessment or reflection rather than as a field of research.

We believe that, as in Pascual y Montes (2017), it is clear that by encouraging the critical and reflective attitude of students we obtain information that can be used in the design of training, especially in the reorientation of training in research skills. This reflection itself is essential in the professional development of mathematics teachers (Schön, 1983) but, in addition, it also provides us critical information from the user of the ITE program about the validity of the training proposal. In our case, we found that focusing on just one of the nuclei of Moreno Bayardo (2005) has not been enough for training research skills in mathematics education among generalist master students. One limitation of our work comes from the instrument, because Likert scales could miss richer students’ thinking about the task, therefore we plan to overcome this in the future by using semi-structured interviews. Obviously, the sample is also limiting but, in this case, we are constrained by the scope of this educational programs and by the possibility of getting access to other universities.

We consider that this work opens a promising path for future research. Thus, we propose to go deeper into this working methodology for promoting metacognition and constructing recently graduate teachers’ identity as future educational researchers (Hong, 2010). This approach will allow us to obtain a greater connection among the topics of the training and, thus, achieving a better development of researcher identity, which we think it is our main challenge within this ITE master program. In addition, we will also analyze from the descriptive and reflexive points of view the productions of the students in the task of analyzing a transcription of a real class, that was linked to the one presented here. By making this, we will complete the double perspective that we want to study on metacognition: self-assessment (the one already approached here) and peer-assessment. Finally, we also propose to redesign the activity on the basis of the revised Bloom taxonomy (Anderson & Krathwohl, 2001), so that we can cognitively classify the levels of students’ responses.

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