International Journal of Research in Humanities and Social Studies
Volume 3, Issue 7, July 2016, PP 40-48
ISSN 2394-6288 (Print) & ISSN 2394-6296 (Online)

# Improving MPCK in the Teaching of Area Measurement: An Intervention in Greek Kindergarten Classrooms

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## ABSTRACT

The purpose of this study was twofold. The first was to examine the perceptions and knowledge of Greek kindergarten teachers about the mathematics pedagocical content knowledge (MPCK), especially about the construction of 'area measurement'. The second was to enhance the teachers' understanding through an educational intervention at their classrooms. The literature has shown that instructional interventions setup communities of learning, enrich teachers' collaboration and interactions between the trainee teachers and the research trainer and also result to an improvement of teachers' content knowledge about MPCK. The findings of this study showed that when teachers' professional development is supported by participatory, interactive and empirically framed interventions, they can enhance the teacher's MPCK's cognitive fields.

**Keywords:** Mathematics pedagogical content knowledge, instructional intervention, area measurement, teaching practices

## INTRODUCTION

Throughout the 20th century researchers have tried to explain students' learning by investigating the teacher's contribution in the quality of teaching. Especially, since the work of Shulman (1986) and the introduction of teachers' pedagogical content knowledge (PCK) in the literature an increasing amount of research and theoretical studies have been concerned with the crucial implementation of this conceptual construct for the quality of teaching (Melendez -Rojas, 2008; Phelps & Schilling, 2004; Hutchinson, 1997). Many researchers tried to identify its nature and the way it is composed by different kinds of cognitive fields (Hashweh, 2005; Marks, 1990). The available literature about PCK describes three types of knowledge, the content knowledge that links subject matter with both the knowledge of pedagogical strategies and an in-depth understanding of the student (Fennema & Franke, 1992; Carlsen, 1999). PCK is considered as that part of a teacher's knowledge base that combines a thorough understanding of *what* to teach with both *who* is being taught and *how* to teach them (McCray, 2008).

Mathematics pedagogical content knowledge (MPCK) is that unique knowledge domain of teaching that differentiates the teacher who teaches mathematics from the traditional math expert's knowledge. The depth of teachers' understanding of MPCK is distinct because it is augmented by methods for linking it to the students' interests, to illustrate mathematics key concepts and is tailored to the tasks of education (Ball, 2000). Empirical evidence support that MPCK is a determinant factor of teachers' choice of examples, explanations, exercises, items and reactions to children's work (Aubrey, 1996; Ball & Bass, 2000; McNamara, 1991).

The last years an increasing amount of research has been concerned with the key concepts and skills that students need to understand relating to length and area measurement (Barret, Jones, Thornton, & Dickson, 2003; Outhred & McPhail, 2000). Although spatial measurement is a major component of the elementary and secondary mathematics curriculum, many large scale comparative studies such as TIMSS (Hollingsowrth, Lokan, & McCrae, 2003) and PISA (Lokan, Greenwood, & Creswell, 2001)

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have shown that many students face difficulties to fully comprehend them. Some researchers have highlighted the importance of supporting the depth of students' understanding of metric concepts at an early developmental stage (Lehrer, 2003; Nunes, Light, & Mason, 1993). For example, there are arguments (Dougherty & Zilliox, 2003; Outhred & McPhail, 2000) about the effectiveness of the instruction of the spatial concepts in kindergarten and how it could promote the quality of the students' metric concepts developmental process to the next levels of the educational system. Especially, the quality of mathematical teaching at the preschool level is extremely variable (Copple, 2004) and there is a lack of empirical evidence to support any relation between kindergarten teachers' MPCK, their instructional practices and students' learning outcomes.Teaching spatial concepts requires from the kindergarten teacher an appreciation of mathematical reasoning, understanding the meaning of mathematical reasoning, understanding the meaning of mathematical ideas and procedures, and knowing how ideas and procedures connect.

The current study is part of a larger research intervention entitled 'Mathematics pedagogical knowledge and instructional practices in kindergarten: the case of area measurement' that included a participatory approach intervention with observation and video-taping of 33 sessions. In the study presented here we examine the changes in the three components of kindergarten teachers' MPCK in the teaching of area measurement. More specifically our research questions were: a) what are the features of the three cognitive fields (what, who, how) of kindergarten teachers' MPCK in the teaching of area measurement? and b) is it possible to improve the kindergarten teachers' MPCK through an interventionist, participatory approach?

## THEORITICAL FRAME

Space is a continuous quantity and its measurement is based on the notion of 'space filling' (Nitabach & Lehrer, 1996). Teachers with limited understanding of the measurement concepts cannot be effective in developing children's understanding. Various research findings revealed that teachers have a procedural knowledge instead of an adequate conceptual and relational knowledge of area and perimeter (Menon, 1998). A good relational understanding of perimeter includes reasoning based on relationships among the sides of a given figure. Frequently, they assume that there is a constant relationship between area and perimeter and they confuse the two concepts. Commonly, they fail to use square units when reporting measures of area (Baturo & Nason, 1996).

'What should a kindergarten teacher know in order to teach area measurement?'(Knowledge of 'What'). Research in the domain of measurement has highlighted the principles and the key concepts that are important for kindergarten teacher's content knowledge. These are:

- Identification of mathematical actions (McCray, 2008).
- Area's attributes identification (Clarke, Cheeseman, McDonough, Clarke, 2003; Lehrer, 2003; Outhred et al., 2003)
- Conservation of area (NSWDET, 2003)
- The use of formal and informal units (Clarke et al., 2003; Lehrer, 2003; Outhred et al., 2003).
- The knowledge of skills or measurement processes, which are the direct, indirect comparisons, the unit iteration and connection with a numerical result and the structure of an area grid with perpendicular lines (Stephan & Clements, 2003).

'What should a kindergarten teacher know about the possibilities and the misconceptions of young children when measuring area?' (Knowledge of 'Who'). The literature (Lehrer, 2003; Nunes, Light, & Mason, 1993; Piaget, et al., 1960) clearly highlights certain levels of thinking as mediating factors for children's progress, when learning about the notion of measurement. These levels of thinking reflect the key concepts that have been identified by research as important to understanding measurement. Several studies indicated that when teachers have a clear understanding of these frameworks or stages of growth in students' development of understanding measurement, it assists them to develop clear and appropriate learning activities (Clarke et al., 2003). While a cognitive approach supports that at this age the concepts of conservation, transitivity and reversibility are absent and the young children cannot develop the measurement concepts (Piaget & Inhelder, 1972), other sociocultural approaches stress that the use of measurement tools and the measurement activities support the development of measurement skills (Davidof, 1988) and the connection of children's conceptual with the procedural knowledge.

While children play they measure and compare objects, distances, surfaces and they develop a personal informal measurement theory. Similarly, when children participate in measurement activities, conceptual connections occur for the unit-attribute relations, the iteration of the units, the tiling, the use of identical units, the standardization of the unit, the proportionality, the additivity and the origin-zero point (Lehrer, 2003). Most times children select the units because they resemble to the surface figure (resemblance), they are careless if the units are not identical, they prefer to cover the bounds of the surfaces (boundedness) and not the whole surface, they leave gaps when they are tilling the informal units and they have difficulties when they construct an area grid by drawing vertical and horizontal lines (Lehrer, 2003).

'How could a kindergarten teacher can effectively teach the area measurement?' (Knowledge of 'How'). The adequate knowledge of curriculum provides a stable framework for the teaching practices, but research findings found that teachers' curriculum enactments were linked to teacher characteristics, including mathematics content knowledge, beliefs about mathematics teaching and learning (Remillard, 2005).

In Greece, the national early childhood education curriculum recommend teaching strategies which include developmentally appropriate practices and active learning via exploration/discovery. Moving away from the traditional teacher-dominated way of learning to a more child-centered active learning approach, young children are encouraged to participate in their own learning through problem solving activities, discussions, project work, practical exercises and other ways that help them reflect, work in pairs or small groups and generate their findings (Bredekamp, 2009).

According to Outhred et al., 2003 there is a perception that the use of a variety of concrete materials allows young children to practice using measurement in real-life settings and general teaching strategies such as "hands on" activities are suggested. If we refer to the idea of 'intertwining' content and teaching knowledge (Shulman, 1986; Ball & Bass, 2000), teacher's understanding of the nature of area would seem crucial to the way they would teach it.

Greek kindergarten teachers rarely organise and plan activities of area measurement (Kolipetri, 2015) and this is considered to stem from a lack of confidence and may indicate a lack of understanding regarding key concepts and effective teaching strategies generally for length, area, and volume measurement. These findings have also been confirmed for the primary teachers of other countries (Clarke et al., 2003; Sowder, Phillip, Armstrong, & Schappelle, 1998).

This lack of understanding could be addressed by focused professional development activities that would empower kindergarten teachers' educational practices and support them in selecting the most appropriate approach or method under different circumstances (Loucks-Horsley et al., 2009).

## METHODOLOGY

### Participants

The study was conducted throughout the 2012-2013 academic year and the participants were twenty two (*n*=22) kindergarten teachers. Eleven (11) teachers constituted the experimental group and eleven (11) the control group. In the present study we refer to the experimental group as a sample (*n*=11) who participate in the intervention. They are all female and they teach in nine (9) public kindergartens located in the urban region of Thessaloniki, which is the second biggest city of Greece. The ethnicity of the teachers is Caucasian. The participants' years of experience ranged for the experimental group from 6-10 years 1(9%), 11-20 years 3 (27,2%) and 21-30 years 7 (63,6%). All the teachers had a Bachelor degree.

### Data Sources

Three components of MPCK were evaluated: (a) the cognitive field of the knowledge of What (b) the cognitive field of the knowledge of Who, (c) the cognitive field of the knowledge of How. MPCK's cognitive fields in area measurement were measured using pre- and post- test questionnaires.

### Instruments- Measures

A questionnaire was used for all teacher participants administered two times, before and after the intervention. The pre and post-questionnaire included three different teaching scenarios, each of which was relevant to one component of MPCK, fifteen questions (15) and eighty six (86) items for the answers. Especially, the scenarios described measurement activities that could take place in a classroom, dialogues among the children while they were measuring and progressively through them were described all the levels of measurement activities. The first scenario described intuitive measurement strategies and direct comparisons, the second indirect and the third activities which promote the children's conceptual thinking of conservation, transitivity and reversibility. The possibilities and the misconceptions of the children in scenarios were different. The scenarios involved tasks with transformed figures and square units to assess the content knowledge of the teachers.

Initially a pilot study was implemented to examine the instrument's reliability ($a$= .84) and content validity. Teachers' observations and suggestions about various items were also taken into account. The final version of the questionnaire was administered in 40 teachers. Questionnaires were anonymous and the pre-test with the post-test of the same teacher were coded with the same number for the final comparisons.

### Intervention Context

The training of the experimental group included 5 workshops and each participant completed 20-hours theoretical seminars and approximately 15-hours classroom activities. The researcher also had the role of the mentor-trainer. The key structural elements of the intervention were determined on the basis of the three basic MPCK's cognitive components with regard to the area measurement and of the recording of teachers' views that were illustrated in the first questionnaire.

The approach of the intervention can be described as an integrated holistic experience, lasting for a long period of time, as teachers teamed together for three months in a learning community, shared a common goal and a broad knowledge base on metric concepts, and acquired hands-on experience by applying their knowledge, through the implementation of area and length measurement activities. Participants collaborated when they were coping with teaching problems, case studies and the planning of the lessons for the linear and area measurement considering among other programs, the CMIM, (Outhred et al., 2003) and the TAL project (Van den Heuvel- Panhuizen & Buys, 2008). They observed their video-taped lessons, they made profiles of the young children's measuring activities and they were able to reflect upon their teaching practices, to reconsider them and improve them through constructive feedback and discussion processes with their group of colleagues, under the facilitation of the trainer-researcher.

### Data Analysis

For the statistical analysis of the results we calculated absolute and relative frequencies (%), indicators of central tendency (means, medians, variation indicators, maximum and minimum values, standard deviations) and indicators of effect size. For the comparisons of pre and post-test scores the Wilcoxon test was used. The significance level was predetermined at $P \leq 0{,}10$ because the sample of the participants was small. For the statistical analysis was used the SPPS v.15.0 software.

## RESULTS

For the knowledge of 'What' which includes the variables of metric concepts that a teacher should know, the Cronbach's alpha was $a=0{,}663 \geq 0{,}60$ and DI=0,33≥0,20. For the knowledge of 'Who' which includes the variables of the child's possibilities and misconceptions in the metric activities that a teacher should know, the Cronbach's alpha was $a$=0,657and DI=0,32. The knowledge of 'How' consists of the variables of the teaching practices that the Greek curriculum include and a teacher should know to teach area measurement.

Before the intervention a statistically significant correlation was found between the knowledge of 'What' and the knowledge of 'Who' (*rho*=0,496, *P*=0,018), a moderate positive correlation and statistically significant correlation between the knowledge of 'Who' and the knowledge of 'How' (*rho*=0,348, *P*=0,090) and a moderate positive correlation and statistically significant correlation between the knowledge of 'What' and the knowledge of 'How' (*rho*=0,366, *P*=0,094). These results combined with the Cronbach's *α* support the validity of the conceptual construct of the MPCK's cognitive components in the area measurement.

Before the intervention the best score was achieved in the cognitive component of 'How' (*M*=88,9%), the second score was achieved in the cognitive component of 'Who' (*M* =78,6%) and the third score was achieved in the cognitive component of 'What' (*M* =71,8%). After the intervention the best score was achieved in the cognitive component of 'How' (*M=100*%), the second score was achieved in the cognitive component of 'What' (*M* =85,4%) and the third score was achieved in the cognitive component of 'Who' (*M*=76,2%).

The comparison results of the pre and the post-test for the knowledge of 'What' are presented in Table 1.

**Table1.** *Knowledge of 'What'*

| **Knowledge of 'What'** | | | | | | |
|---|---|---|---|---|---|---|
| **Variables** | **Pre** | | **Post** | | **Wilcoxon test** | **Effect Size** |
| | M | S.D | M | S.D | *P* | *ES* (%) |
| 1. Identification of Mathematical Actions | 7,9 79,0% | 1,6 | 8,8 88,0% | 1,8 | 0,077 | 11,4% |
| 2. Identification of Mathematical Concepts | 8,3 83,0% | 1,5 | 9,4 94,0% | 0,9 | 0,039 | 13,3% |
| 3. Knowledge of Area's Dimensions | 0,2 20,0% | 0,4 | 0,8 80,0% | 0,4 | 0,007 | 300,0% |
| 4. Perception of Transformations | 1,8 45,0% | 1,3 | 2,9 72,5% | 1,6 | 0,067 | 61,1% |
| 5. Identification of the Informal Units | 1,5 75,0% | 0,8 | 2,0 100% | 0,0 | 0,063 | 33,3% |
| 6. Knowledge of Measurement Process-Direct Comparisons | 3,2 64,0% | 0,8 | 4,0 80,0% | 0,9 | 0,026 | 25,0% |
| 7. Knowledge of Measurement Process-Indirect Comparisons | 2,0 50,0% | 0,9 | 2,2 55,0% | 1,0 | 0,039 | 10,0% |
| 8. Knowledge of Measurement Process-Iteration of the Units and Connection with a Numerical Result | 1,7 85,0% | 0,5 | 2,0 100,0% | 0,0 | 0,128 | 17,6% |
| 9.Perception of Squared Areas' Transformations | 2,3 76,7% | 0,8 | 3,0 100,0% | 0,0 | 0,016 | 30,4% |
| 10. Structure of an Area Grid | 0,9 90,0% | 9,3 | 0,8 80,0% | 0,4 | 0,496 | -11,1% |

**M: Mean, ST: Standard Deviation, ES: Effect Size*

The results revealed statistically significant differences in eight variables (1, 2, 3, 4, 5, 6, 7, 9). In particular, before the intervention the teachers displayed adequate knowledge of the identification of the mathematical actions and concepts in children's activities, of measurement process-iteration of the units and connection with a numerical result; they also had a good understanding of squared areas' transformations and the structure of an area grid (1, 2, 8, 9, 10). They had less knowledge of the measurement processes with the units (5, 6, 7), and even less knowledge of area's dimensions and perception of transformations (3, 4).

These types of knowledge improved after the intervention in rates from 25% to 33% for the variables 5, 6, and 7 and from 61% and 30% for the variables 3 and 4. With a maximum score for this cognitive component 42 the comparison of the total pre-mean score to the post-mean score evolves from 29,8 to 35,9, the Effect Size was 20,5% and the Wilcoxon test (*P*=0,011) revealed statistically significant improvement in the score.

For the cognitive component of the knowledge of 'Who' as it is presented in Table 2 the results didn't show any statistically significant difference (*P*=0,966) before and after the intervention. With a maximum score for this cognitive component 42 the comparison of the total pre-mean score to the post-mean score evolves from 32,9 to 32,2 and the Effect Size was 0,9%. Top rated were the variables for the identification of the children's misconceptions followed by those of the possibilities.

**Table2.** *Knowledge of 'Who'*

| **Knowledge of 'Who'** | | | **Wilcoxon Test** | **Effect Size** |
|---|---|---|---|---|
| | Pre | Post | *P* | *ES* (%) |
| Min | 25,0 | 22,0 | | |
| Median | 33,0 | 32,0 | | |
| Max | 41,0 | 42,0 | | |
| Mean | 32,9 | 33,2 | 0,966 | 0,9% |
| Standard Deviation | 5,5 | 6,1 | | |
| SE | 1,6 | 1,8 | | |

For the cognitive component of the knowledge of 'How' as it is presented in Table 3 the results revealed that the intervention had an Effect Size 8,7% but the results didn't show any statistically significant difference (*P*=0,276) before and after the intervention.

**Table3.** *Knowledge of 'How'*

| **Knowledge of 'How'** | | | **Wilcoxon Test** | **Effect Size** |
|---|---|---|---|---|
| | Pre | Post | *P* | *ES* (%) |
| Min | 4,0 | 8,0 | | |
| Median | 8,0 | 9,0 | | |
| Max | 9,0 | 9,0 | | |
| Mean | 8,0 | 8,7 | 0,276 | 8,7% |
| Standard Deviation | 1,4 | 0,5 | | |
| SE | 0,4 | 0,1 | | |

## DISCUSSION

The findings of this study indicate that the kindergarten teachers' MPCK's cognitive components are not uniform. The results showed that the *Effect Size* of the instruction intervention was different for the three fields of study. The greatest effect size was on the field of 'What' and the smallest effect size was on the field of 'Who'. More specifically, the teachers had a stronger practical knowledge (Knowledge of 'How') before and after the intervention. This finding can be justified because the knowledge of curriculum provides a stable framework for teaching but it is also supported that the teachers with strong MPCK loosely follow the curriculum (Gencturk, 2012) and the kindergarten teachers pay more attention to the procedures and the teaching practices and less to the conceptual content of the activities (Genishi et al., 2001). This knowledge was further strengthened after the intervention but it is still difficult to identify crucial differences via a post questionnaire, because this knowledge is better recorded in the classroom teacher's activities. The knowledge of 'How' seems to be more general and is linked to general pedagogical strategies and less to appropriate teaching practices that highlight mathematical concepts through appropriate mathematical activities. This finding is also confirmed by other researches (Outhred, & McPhail, 2000). Another reason for this enhancement is the empirical knowledge which the teachers gained by implementing teachings in area measurement and getting feedback from the trainer.

The findings also indicated that the intervention focused on measurement concepts positively influenced gains in kindergarten teachers' content knowledge of the metric concepts (Knowledge of 'What'). Before the intervention teachers displayed a limited knowledge of the measurements processes with the use of the units and the area's dimensions and were improved after the participatory, interactive teachers' experience. This cognitive component of MPCK showed the greatest change compared to the other two.

Even the smallest improvement of the MPCK's third cognitive component (Knowledge of 'Who') is not to be ignored since the literature showed that the kindergarten teachers' knowledge of the children's developmental levels in metric concepts is as important as the content knowledge (Camp, 2007). This finding is justified because the teachers felt insecure with the gaps in the content knowledge and they gave more weight to its own strengthening.

## CONCLUSION

The choice of the instructional intervention for the enhancement of the MPCK of the teachers falling within the experimental group was based on data gathered by empirical studies, the findings of which highlight the importance of continuing professional development (CPD). Professional development, which strongly fosters professional learning, is an important factor that actively encourages teachers to take all necessary steps to enhance their knowledge and change their views and teaching practices in order to become more efficient in teaching mathematics. Professional learning is based on the interactions between the trainee teachers, the learning process framework and the learning object.

The present study confirmed that the participatory, interactive and empirically framed interventions enhance the Kindergarten teacher's MPCK's cognitive fields. This is generally confirmed by other interventions for the enhancement of PCK's cognitive components (McCray, 2008).

The sample size of teachers is small ($n$ = 11) and this limited the representativeness of the study. This study proposes to further explore the mechanisms that contribute to changes in the fields of study of the MPCK of Kindergarten teachers in a larger sample, since this would result in its enhancement with positive outcomes in support of the mathematics education of preschool age children.

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