Primary teachers' embedding educational software of mathematics in their teaching practices

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Abstract: Eight teachers of third, fourth, fifth and sixth grades participated in a one-year-long in-service training on embedding the mathematics software approved by the Greek Pedagogical Institute (PI) in their teaching practices. During this training programme we explored – through grounded theory (GT) research method

a the ways that the teachers embedded the software in their teaching practices
b the impact of teachers' embedding educational software (ES) on their pedagogical content knowledge (PCK) (Shulman, 1986) during their in-service training.

Data analysis revealed that the participating teachers improved their PCK practices and they also embedded the mathematics educational software supportive material in their teaching practices in ways that depended on the softwares' 'open-or not exploratory' types.

Keywords: primary teachers; pedagogical content knowledge; PCK; teaching practices; in-service training; primary mathematics software.

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1 Introduction

During the school-year 2006–2007 in Greece, along with the publication and distribution of new textbooks by the Pedagogical Institute (PI) (Ministry of Education) supportive material was also created for almost every school subject in the obligatory levels of education. This material included the educational software (ES) in mathematics for primary education, consisting of three packages – one for the first and second grades, one for the third and fourth grades and one for the fifth and sixth grades.

The mathematics software for the third and fourth grades, as well as the one for the fifth and sixth grades, is of the 'open-discovery' type of ES. Apart from activities designed for each grade separately, they also include micro-worlds named 'turtlepage', 'statistics', 'knowing the euro' etc.

The PI organised brief intensive training courses (during 2006–2007 and 2007–2008) on the new textbooks but these courses did not at all refer to the pedagogical and instructional utilisation of the aforementioned software.

Given the significance of the role that ES – and information and communication technologies (ICT) in general – play in the professional development of primary school teachers, in 2006–2007 we designed and implemented in-service training for the teachers in two adjoining primary schools, so that they would embed the PI mathematics software in their teaching, and we explored:

a ways the teachers embed the mathematics software in their teaching

b the impact of teachers' embedding ES on their pedagogical content knowledge (PCK) during their in-service training.

The significance of the above research questions is stressed by the fact that, at an international level, and since as early as 2005, the National Council of Teachers of Mathematics (NCTM) and the National Council for Accreditation of Teacher Education (NCATE) have been requesting reports on the way teachers implement technology in their teaching (NCTM/NCATE, 2005).

2 Theoretical background

2.1 In-service training in ICT

Many researchers maintain that teacher training in ICT is essential, since no training at all or insufficient training leads to the failure of the attempt to embed ICT in the educational process (Ogborn, 2002; Teodoro, 2002). According to Teodoro (2002), the critical factor for the success of an innovation is the human factor rather than the artefact. Therefore, in order for ICT to be successfully embedded in the educational process and for the desired reformation to come about, teacher training is of primary importance.

In addition, teacher training in ICT is a common request not only of many international organisations but also the teachers themselves (Eurydice, 2001a, 2001b; ISTE, 2000, 2002, 2008; NCTM/NCATE, 2005; UNESCO, 2002).

From a wide variety of training programmes, in-service training was selected for the present study as it places the school in the centre of attention, in the belief that the school is a developmental environment for the teacher and, consequently, it is the ideal developmental environment for the student (Bolam, 1994; Cooper, 1991; Day, 1987; Eisner, 1979; Keast, 1982). Thus, in-service training is reasonably justified by the rationale of the teacher's professional development and takes the form of in-service collaborative education aimed at the teachers of a school. Besides, it is executed in real conditions, usually within the school environment and, finally, takes into consideration both the specific characteristics of each school community and the practical problems of implementation, often arising on the side of the teachers.

In this paper we focus on PCK and technological pedagogical content knowledge (TPCK) that will be briefly analysed in next paragraphs.

2.2 Pedagogical content knowledge and technological pedagogical content knowledge

Shulman (1986) dealt with the conceptual analysis of teacher knowledge and determined three categories: subject matter knowledge (SMK), PCK and curricular knowledge. SMK is knowledge of the content of the discipline per se [Shulman, (1986), p.9], consisting both of substantive knowledge (the key facts, concepts, principles and explanatory frameworks in a discipline) and syntactic knowledge (the nature of enquiry in the field, and how new knowledge is introduced and accepted in that community). PCK is particularly difficult to define and characterise, conceptualising both the link and the distinction between knowing something for oneself and being able to enable others to know it. PCK consists of "the ways of representing the subject which makes it comprehensible to others… [it] also includes an understanding of what makes the learning of specific topics easy or difficult…" [Shulman, (1986), p.9]. Curricular knowledge "encompasses the scope and sequence of teaching programmes and the materials used in them" [Rowland, (2004), p.1].

The present study, which focuses on the PCK, espouses Shulman's definition (1987) of PCK as "that amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" [Shulman, (1987), p.8].

There are international studies dealing with effective teaching, which suggest that its accomplishment is based on knowing the scientific subject and knowing how to teach it (Bray, 2004; Jegede and Taplin, 2000; Parker, 2004; Rowland 2004; Twiselton, 2000).

While Shulman did not deal with technology and its relationship with pedagogy and knowledge of the scientific subject, later, other researchers (Koehler and Mishra, 2008, Mishra and Koehler, 2006) explored the way technology interacts with pedagogy as technological pedagogical knowledge (TPK), with the content of the scientific subject as technological content knowledge (TCK), and with both as TPCK.

In specific, recent studies emphasise the need for developing teachers' TPCK so that they will manage to embed ICT in teaching mathematics (Groth et al., 2009; Koehler and Mishra, 2008; Lee and Tsai, 2010; Mishra and Koehler, 2006; Niess, 2005). However, there are other studies which connect the teachers' PCK with computer ICT (Angeli and Valanides, 2005, 2009; Margerum-Lays and Marx, 2003). According to these studies, the concepts of scientific subject, pedagogy and technology are interconnected and affect learning and teachers' professional development (Doukakis et al., 2009).

In the present study in-service training, we adopted the conceptual analysis of teachers' PCK, as it was formulated initially by Shulman in 1986 and was later extended by Mishra and Koehler (2003, 2006).

During the eight teachers in-service training in ICT educational scenario (EScs) and micro-worlds were also focused and they will be analysed briefly in next paragraphs.

2.3 Educational scenarios and micro-worlds

Shabajee (1999) reports that the ESc is a semi-structured but flexible design of successive educational activities, which also refers to the ways of using learning tools, the organisation of social structures and the time-space adjustments of the learning environment (Shabajee, 1999).

Kynigos and Theodosopoulou (2001), Kynigos and Argyris (2004), and Makri et al., (2006), referring to the concept of ESc in an environment using digital computational and communication means, state that in the field of education, designing the utilisation of modern technology for educational innovation is a challenge as regards both the application of methods of modern pedagogy and the distancing from limitations placed by the established systemic education. From the above literature for the construction and the research analysis (Makri et al., 2006) scenarios criteria were followed (see Appendix – the first stage out eight of EScs).

The concept of the micro-world was first used by Papert (1980). In an essay entitled 'In search of Piagetian mathematics', Groen and Kieran (1983, p.370) elaborate on Papert's original description of micro-worlds as being "essentially mini-domains of Piagetian mathematics".

Hoyles (1993) defined the micro-world, in a context of artificial intelligence, as a simple and specific aspect of the real world regarding a scientific domain. A micro-world constitutes a group of activities that presuppose a set of design principles: the components of the micro-world model cognitive fields and the developing cognitive processes and strategies are negotiable rather than predetermined. Edwards (1995) agrees with this viewpoint as well stating that micro-worlds represent an idea through an operational abstraction. In other words, the micro-world is a structured integration of mathematical concepts and structures in an operational environment, where the existing tools can construct new objects and structures. These structures reinforce the student's multiple representations of a concept and consequently better comprehension of the concept (Edwards, 1995).

On the basis of the above theoretical approach, the knowledge of eight participating teachers in two adjoining schools was investigated at first. Then their training was designed and organised aiming at the development of the teachers' TPCK, in order to achieve embedding the ES in teaching mathematics by creating and implementing EScs. Thus, the aforementioned research questions were formulated:

a ways the teachers embed the mathematics software in their teaching,

b the impact of teachers' embedding ES on their PCK during their in-service training.

3 Research methodology and methods

The exploration of research questions of the study was carried out in two adjoining primary schools in the broader area of Athens, involving eight teachers of the four upper grades (third, fourth, fifth and sixth grades). The schools were selected after sending request them letters and receiving answers from the teachers and administrators.

The in-service programme implemented for this study was divided in nine consecutive stages.

At first, there was investigation and diagnosis of the teachers' educational needs through the initial semi-structured interviews and then they were asked to create lesson plans for teaching a unit of their choice in their mathematics class. The obtained results formed the basis for the following stages of the study, during which the teachers dealt with the study of the curricula of mathematics and information technology and of the mathematics textbooks. Then, they installed the mathematics ES in the computers of the school lab and were navigated through them. Afterwards, they worked individually and collaboratively to produce five EScs in total (Kynigos and Theodosopoulou, 2001; Makri et al., 2006), which they applied in their teaching. At the end of the research process the final semi-constructed interviews were taken.

For the methodology of the study, the naturalistic paradigm was selected (Bryman, 1988; Burgess, 1984; Finch, 1986; Hammersley, 1992; Lincoln and Guba, 1985; Silverman, 1993) because:

a the intent of the present study was not to examine an existing theory but to develop a theory regarding the way of embedding the PI ES in teaching and learning mathematics

b qualitative research is based on a comparatively smaller number of cases and seeks to construct a representation of the social reality through in-depth case studies.

Moreover, the case-study does not only enable in-depth study, but pursues the systematic analysis of phenomena constituting the life of a unit or a group by observing behaviours in the natural environment (Yin, 1994).

The research data were collected mainly through initial and final semi-structured interviews (Mason, 2003), as well as written material, lesson plans before the in-service training and EScs during the teachers in-service training. The semi-structured interviews took place in the computer lab of the schools, lasted forty five to sixty minutes each, were recorded on a digital recording device and were then fully transcribed. The content of the semi-structured interviews revolved around issues related to the research questions of this study.

In order to analyse and interpret the obtained data, the method of grounded theory (GT) was selected (Glaser and Strauss, 1967; Strauss and Corbin, 1991), since, according to Strauss,"[it] is a style of doing qualitative analysis that includes a number of distinct features, such as theoretical sampling, and certain methodological guidelines, such as the making of constant comparisons and the use of a coding paradigm, to ensure conceptual development and intensity" [Strauss, (1987), p.5].

4 Research data analysis and results

4.1 Ways primary school teachers embedded the mathematics software in their teaching

All the eight teachers of third, fourth, fifth and sixth grades created their own EScs and differentiated substantially both from the lesson plans offered in the teacher's books and from the ones they themselves had created initially during the second stage of the study. Thus, they embedded the ES corresponding with the class they taught as supportive material in their teaching. No one of the teachers embedded the ES as the main teaching resource.

For example, Cleopatra and Nestor (pseudonyms), teachers of the fourth grade, created a geometry ESc entitled 'Children draw parallelograms (squares and rectangles) with the help of the turtle' and utilised the turtlepage micro-world, which is a logolike programme. The approach was realised as follows: First, the students of the fourth grade learned to schedule simple routines, i.e., a strict and logical sequence of orders on how to clean their teeth. Role play followed, with one pupil assuming the role of the turtle and his/her classmates giving orders (specific orders that the turtle obeys) in order to lead him/her to a certain spot in the classroom, i.e., in front of the bookcase. Then the pupils, after recording on worksheets the orders needed for drawing rectangular shapes with the help of the turtle, they went to the computers and the mathematics ES for the third and fourth grades, in the turtlepage micro-world, and drew parallelograms – squares and rectangles (see Appendix – the first stage out eight of EScs).

4.2 The impact of teachers' embedding ES on their pedagogical content knowledge during their in-service training

While embedding ES, all eight teachers modified important parameters of their teaching practices concerning their PCK, such as collaborative learning, active learning, experiential learning, role play and students' initiatives. This is concluded from the sampling of the following quotations from the semi-structured interviews and the EScs that the teachers participating in the study created and applied. In specific, they reported:

Concerning 'teacher as facilitator'

> "I could say I modified my way of teaching, the chalk, the sponge and, generally, the traditional form of teaching offered me possibilities to a certain extent, beyond which the additional goals I set were impossible to attain."
>
> "I was given the chance to confirm that there are different approaches to teaching, which I've been unaware of so far."
>
> "The teacher is closer to the children, a co-explorer himself/herself, a coordinator of group efforts, a facilitator for the children."
>
> "The teacher searches and gathers elements together with the children, encourages them to use the new material and coordinates the groups."

Concerning 'pupils corporation'

> "Working with the software and the computers, the children were more likely to cooperate, they worked in groups more, one of them gathered data, another put them in tables, others keyed them in the computers, they each tried different types of graphs and cooperation was higher than in the traditional way of working."
>
> "The roles interchange in the group and each of the pupils expresses their opinion about the type of graph they believe to be the most suitable for charting the results."
>
> "Teaching is now cooperative, clearly cooperative, while in the past it was sometimes cooperative, practically it was the teacher who did the talking, whereas with the computers it becomes clearly cooperative, that's crystal clear."
>
> "There was a bond between the groups of students, they worked at ease, as if they were in their natural space and perhaps because using the computer is quite familiar to them."
>
> "There is promotion of collaborative learning, social skills development, discovery and exploratory learning."

Concerning 'pupils active role'

> "Learning takes place with the students actively participating, with the use of the internet and the educational software."
>
> "Now students read the graphs critically and discuss the results."
>
> "Now I see that, with software, the children are enabled to participate in the acquisition of knowledge."

> "The children themselves started to gather information, while earlier, if I told them to do something like that, they would express discomfort, because they wouldn't like to sit down and write or draw charts."
>
> "I confirmed that the experiential part is really important, that is, children must get in contact with things they are interested in, things that are part of their daily life."
>
> "Using a computer motivates students as it is closer to their own experience."

5 Discussion and conclusions

Data analysis showed that all the teachers who took part in-service training embedded the mathematics software as supportive material in their teaching, maybe because the mathematics software of the third to fourth grades and fifth to sixth grades are of the 'open-exploratory' type, and included micro-worlds. Thus, the micro-world, as structured embedding of mathematical concepts in an operational environment and as a simple and specific aspect of the real world regarding a cognitive domain, enabled the teachers to embed ES in nearly all the stages of their teaching (Balacheff and Kaput, 1996; Edwards, 1995; Hillel, 1992; Hoyles 1993; Laborde and Strasser, 1990; Papert, 1991). In other words, the fact that the ES was 'open' and 'exploratory' and included micro-worlds determined to a large extent the way they were embedded in the teaching practice.

Moreover, the teachers participating in the study combined the knowledge of software they gained during in-service training with pedagogy. This finding is in accordance with the aforementioned studies, which highlight the need to develop the teachers' TPCK of the cognitive domain, so that the embedding of ICT in teaching mathematics can be achieved (Mishra and Koehler, 2006; Niess, 2005). The simultaneous manipulation of a scientific subject, its pedagogy and digital tools is stressed by recent international studies (Groth et al., 2009; Lee and Tsai, 2010).

Also, researchers such as Margerum-Lays and Marx (2003), Angeli and Valanides (2005, 2009) connected teachers' PCK with ICT. They, too, agree that the gradual invasion of ICT in classrooms obliges teachers to intensify their efforts to enrich PCK in connection with ICT.

Data analysis further revealed that the teachers modified their teaching substantially. This may due to the creation of EScs, that is, alternative semi-structured and flexible plans of sequences of educational activities (Shabajee, 1999), which are an educational innovation with added pedagogical value (Kynigos and Theodosopoulou 2001; Kynigos and Argyris, 2004; Makri et al, 2006). Another interpretation could be the exchange of opinions during in-service training between the teachers and the researcher and the reflective discussions that accompanied the construction of EScs and raised issues of learning theories and their application in teaching. Finally, another interpretation could be the fact that the use of software saved time in the teaching of mathematics, resulting in the teachers adopting experiential forms of learning in their practice, i.e., role play.

As mentioned before, the qualitative nature of the present study does not allow for generalisations about neither the conclusions nor their application in primary education. We therefore consider necessary that more research be conducted on relevant issues.

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Appendix

Educational scenario using mathematics software in the teaching and learning process

ES title:
Children draw parallelograms (squares and rectangles) with the help of the turtle

A Brief description of the ESc

A1 The idea underlying the ESc

Children learn to schedule simple daily routines in a strict logical order and then draw parallelograms with the help of the 'turtlepage' micro-world.

A2 The computer environment and local software proposed for teaching a certain unit

We will to use the mathematics software for the third and fourth grades of primary school and the local software – micro-world 'turtlepage'.

A3 Using supplementary material and other tools

We will use worksheets, where the students will record their actions in a logical order in order to attain the desired outcome.

A4 Pedagogical and learning goals

The students are expected to develop a positive attitude towards Mathematics and familiarize themselves with new technologies (computers).

A5 Methodology

Scheduling daily routines

Role play

Acquaintance with local software – 'turtlepage' micro-world

Activities available in the software

Cross-thematic activities from the software on the link (traffic education)

Assessment of the students through the software unit entitled 'measuring my abilities'

A6 Application strategies

It is estimated that the realization of the educational scenario will take four to five teaching hours.