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RESEARCHING TECHNOLOGICAL, PEDAGOGICAL AND MATHEMATICAL UNDERGRADUATE PRIMARY TEACHERS' KNOWLEDGE (TPACK)

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Twenty-five final-year undergraduate primary education students, who were attending a six month course on mathematics education, participated in a research project during the 2009 spring semester. The course, based on the Technological, Pedagogical and Content Knowledge framework and design experiment procedure, was organised so as to incorporate educational software and educational mathematical scenarios in teaching approaches created by undergraduate students. This article presents the course design, the research procedure and some research results concerning the integration of educational software and mathematical scenario in students' teaching approaches.

Keywords: Mathematics, TPACK, Undergraduate Primary Education students

INTRODUCTION

Over the past few decades, one of the most important issues related to educational change and educational innovation is the integration of Information and Communication Technologies (ICT) (Hoyles, Noss, & Kent, 2004). ICT constitute an essential tool for teachers, since it can be used as: a) an educational method to support student learning; b) as a personal tool to prepare material for his/her lessons, to manage a variety of projects electronically and to search for information; c) as a tool to collaborate with other teachers or colleagues (Da Ponte, Oliveira, & Varandas, 2002). The 2003 reformed Greek National Curriculum in Mathematics has been implemented in the nine-year compulsory education since 2006, as 'Cross Curricular/Thematic Framework (CCTF)'. One of its general principles is "to prepare pupils to explore new information and communication technologies (ICT)" (Official Government Gazette, 2003, p.1). The Pedagogical Institute (Ministry of Education) has developed a compulsory national mathematics textbook for each school year, which is accompanied by national educational software. This is the case for all teaching subjects in the nine-year compulsory education. Despite significant political will and spending by governments on technical equipment and teacher training, ICT integration in schools is often low (Jimoyiannis & Komis, 2007).

Therefore, from a constructivist viewpoint (von Glasersfeld, 1995; Cobb, Stephan, McClain, & Gravemeijer, 2001), integration of educational software into undergraduate students' teaching practice is a crucial factor for teachers' future 'establishment' and improvement in classroom practices. During the 2008-2009 spring semester, a six-month course on primary maths teaching during practicum (school attachment) was organised by the researchers with the aim of integrating ICT

and especially-designed mathematical scenarios (Kynigos, 2006) in students' teaching approaches.

LITERATURE REVIEW

Cobb *et al.* (2001) explain - according to a constructivism theory - how learners make sense of their environments and experiences to create their own knowledge, while Schoenfeld (1998) argues that whenever the student is actively involved in an activity then s/he is more likely to learn its content. However, this process requires teachers to pose meaningful and worthwhile tasks to facilitate students' learning. Nowadays, research in educational technology suggests the need for Technological Pedagogical Content Knowledge (TPCK or TPACK) so as to incorporate technology in pedagogy (Mishra & Koehler, 2006; Angeli & Valanides, 2009). TPACK is based on Shulman's (1986) idea of 'pedagogical content knowledge', which is related with the Knowledge Quarter (Rowland, Turner, Thwaites, & Huckstep, 2009). This interconnectedness among content, pedagogy and technology has important effects on learning as well as on professional development.

Mishra and Koehler (2006, p. 1020) suggest that

“...a curricular system that would honour the complex, multi-dimensional relationships by treating all three components in an epistemologically and conceptually integrated manner”

and they propose an approach which is called 'learning technology by design'.

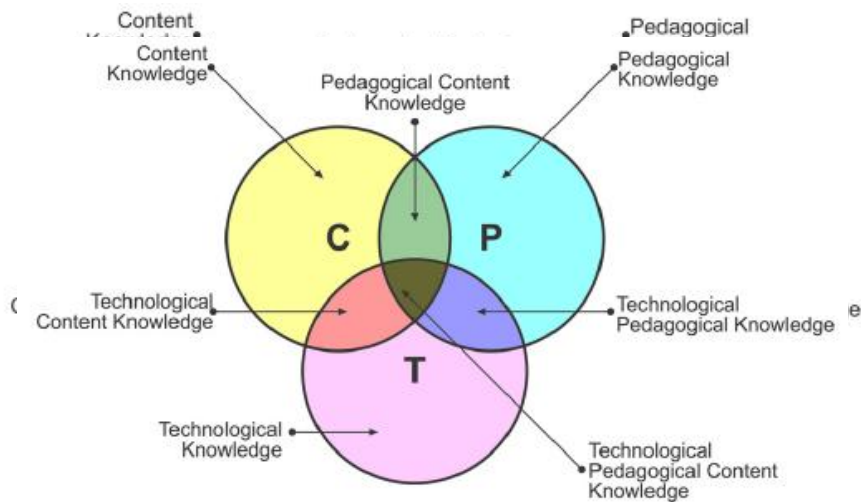


Figure 1: Diagram representing the overlapping components of technological pedagogical content knowledge (Source: Mishra & Koehler, 2006, p. 1025)

They propose a model suggesting three unitary components of knowledge (content, pedagogy and technology), three dyadic components of knowledge (pedagogical content, technological content, technological pedagogical) and one overarching triad of knowledge (technological pedagogical content). Therefore, Pedagogical Content

Knowledge (PCK) is the knowledge of pedagogy that is applicable to the teaching of a specific content (Mathematics). Technological Content Knowledge (TCK) is the understanding of how technology and content both aid and limit each other. Technological Pedagogical Knowledge (TPK) is the understanding of how teaching and learning changes when particular technologies are used. The authors have represented TPACK through the use of a Venn diagram (Fig. 1), where the individual circles represent the knowledge components of content (C), pedagogy (P), and technology (T) and the overlapping area of all three circles represents TPACK.

During the last two decades many research projects have made significant contributions to the teaching and learning mathematics. For example, researchers claim that when students are working with ICT, they are more able to focus on patterns, connections between multiple representations etc. (Laborde, 2002), but the integration of ICT progresses slowly in everyday school practices (Artigue, 1998; Laborde, 2002). In Greece, where technological tools are used, they are often used by teachers in whole class teaching rather than by the students themselves (Jimoyiannis & Komis, 2007).

Concerning TPACK in mathematics classrooms, research projects have already been done, exploring a) teachers' development model on TPACK (Niess, 2005), b) pre-service teachers' TPACK development (Cavin, 2007) and c) the use of TPACK to teach probability topics and data analysis (Lee & Hollebrands, 2008).

RESEARCH METHODS

In order to explore the development of TPACK, we have employed design experiments which constitute an effective methodology for studying teacher development in the setting of an education university department (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). The researchers have taken a triangulation multiple-method approach (qualitative and quantitative) to ensure greater validity and reliability.

The participants were 25 final-year undergraduate primary teachers (16 females and 9 males) in the Department of Primary Education at the University of the Aegean, who were attending the compulsory course 'Teaching Mathematics - Practicum Phase' during the 2008-2009 spring semester. The first two authors used to have a three-hour meeting with the participants in mathematics lab, twice a week. The lab held twelve PCs, with Windows XP, MS Office 2003, internet access, mathematical software (Educational Software of Pedagogical Institute for Mathematics (ESPIM), Geometer's Sketchpad) and presentation tools. The need for a technologically elaborate working environment that would encourage students to use technology led the research team to use many technological tools (the author's website, the course's electronic mail, Moodle as the course and learning management system, a forum, a blog and mobile SMS).

The research work was developed into five stages:

Working Group 15

1. During the first stage and before the beginning of the first lesson, quantitative data regarding undergraduate primary teachers a) background (studies etc.); b) individual learning style according to index of learning styles instrument (Felder & Silverman, 1988); c) attitudes towards ICT, based on Greek computer attitudes scale (GCAS) (Roussos, 2007); d) self-efficacy in ICT according to Greek computer self-efficacy scale (GCSES) (Kassotaki & Roussos, 2006); e) attitudes towards ES - for this purpose, we have designed an educational software attitudes scale (ESAS) based on Roussos' GCAS; f) self-efficacy in mathematics according to the content principles of the CCTF were gathered (GMSES). The same data were gathered from the participants at two more instances (after three months and at the end of the semester), in order to measure possible quantitative differences.

2. Cobb *et al.* (2003) experiment design procedure constituted the second stage. In particular: a) The participants were given a suitable student's worksheet and they worked on geometry tasks about square, rectangle, polygons, cube and parallelepiped (area, perimeter, volume, edge etc). b) After or before their paper and pencil work, they tried to work the same tasks by using the national ESPIM. Each lesson consisted in the teaching of those strategies that incorporate the usage of ICT, so as to involve undergraduate primary teachers in the investigation of geometrical shapes and forms. Teaching was limited to the investigation of geometry problems so that when the teachers come up with their own teaching scenarios (Kynigos, 2006) they will be able to use suitable technological tools that are both efficient and investigatory. The microworlds used were: geo-board, 3D solid manipulation (solid-board), calculator and table tracking from the ESPIM. c) In each lesson, researchers used technological tools while the teachers participated as students taking a lesson in class. d) At the end of each lesson, the teachers were asked to fill out an electronic feedback form, contributing thus further to a discussion of the three-hour lesson that had just finished. The form focused on the development of TPACK in mathematics, with questions on technological tools, teaching strategies and benefits gained from the lesson. This procedure was repeated eight times during the spring semester 2008/2009. For example, one of the worksheets proposed the following task to the students:

“An a-edge cube is transformed to another one with n-times the edge. What happens with the volume of the new cube?”

While the students worked on this worksheet it turned out that some of them had misunderstood the concept of the volume, so according to Cobb *et al.* (2003) procedure, an alternative design worksheet was given to the students to work on it and overcome this misunderstanding. A circled procedure like the latter one was followed by the researchers when it emerged from students needs.

3. The teachers had to write a first assignment that consisted in the search for all geometry problems, activities and exercises involving geometrical shapes and solids in the national math textbooks for the grades 5 and 6, as well as the grades 7, 8 and

Working Group 15

9. They also had to work on two activities, two exercises and two problems of their choice (from the above units) using ESPIM. Furthermore, they were asked to create a lesson plan spontaneously for teaching the "area of a parallelogram" chapter or "the volume of a parallelepiped" for grade 6 mathematics.

4. The teachers had to be taught the notion of the 'educational scenario (ES)' so they were asked to participate and act as students in an educational scenario created by the research group for the purposes of the lesson. The title of the scenario was 'Creating Mobile Phone Networks' and it constituted a holistic picture of a learning environment, without limitations but with the ability to focus on those aspects that the educator judged to be of importance (Kynigos, 2006). Then the teachers were asked to create their own ES, to be used with the chapter of the lesson plan they had already created. Therefore, with the theoretical and practical knowledge and the experience gained, the teachers produced their own ES over the following two weeks. Each ES was presented to their peers, who acted as students of a class. The latter provided feedback and assessed the ES on an especially designed form by the researchers. After that, the teacher, creator of the ES, having taken his/her peers' comments into consideration, returned two weeks later and presented his/her improved ES version. Security and originality were safeguarded as all ESs had been posted before the beginning of the presentations. ES presentations were audio recorded on a digital camera so they could be further analysed. Finally, the teachers were self-assessed and gave feedback on their own ES. In their fourth assignment (assessment) students had to create an ES to be used with the chapter of the lesson plan they had already created for grade 8 students.

5. During the above process, semi-structured interviews were conducted very frequently. The initial students' interview took place after the submission of the first assignment and the final interview was conducted after the completion of the second presentation of the ES. The purpose of these interviews was twofold; on the one hand, to investigate procedures followed by the teachers during the writing up of their first assignment and their ES, their perceptions of TPACK in math and the reasons for their inclusion or non-inclusion of ICT in the lesson plan. On the other hand, the purpose of the interview was to determine whether or not this constructivist design experiment procedure was personally suitable for them. Interviews were recorded for further analysis.

6. During the last meeting, the teachers were asked to anonymously complete a questionnaire regarding their satisfaction with the course. Twenty-four completed questionnaires were returned out of the twenty-five that were handed out.

7. Finally, we evaluated the teachers in "paper and pencil" and ESPIM work.

During the next school year (2009-2010), 11 out of 25 participants were hired as primary education teachers. Having completed their first year of teaching, we asked

them to fill out an online questionnaire to investigate if and how they integrate ESPIM and ES in their teaching.

In the next section, the results from a) the analysis of quantitative data on students' computer attitudes, self-efficacy in ICT, attitudes toward educational software, and self-efficacy in math, and b) the analysis of quantitative data on course satisfaction of participants will be presented.

SOME RESEARCH FINDINGS

In order to analyse the quantitative data gathered about course satisfaction of participants we applied a set of powerful ordinal regression methods. The most important results focus on the determination of the course weak and strong points, according to the MUSA methodology (Grigoroudis, & Siskos, 2002). The teachers' global satisfaction with the course was characterized as extremely high. The mean satisfaction value, as measured by the method, reached 98%, while it is of great importance to note that all comments were positive. The teachers also appeared satisfied in the partial (per criterion) satisfaction survey (Table 1), where negative comments were sparse.

Criteria	Satisfaction
Educational Program	90.02
Professor	97.10
PhD Researcher	92.05
Mathematics Lab	97.00
Educational Material	97.09

Table 1: Satisfaction per criterion

The research results from the study of the teachers': a) attitudes towards ICT (GCAS), b) self-efficacy towards ICT (GCSES), and c) self-efficacy towards mathematics (MSES) are the following:

a) The 30 items of GCAS (Roussos, 2007) were summed to provide a total score (from 30 to 150) representing the participants' overall attitude toward computers. Descriptive statistics of the first and last GCAS scores are reported in Table 2. The results show an improvement of teachers' attitudes toward ICT, which was not statistically significant [$F(1.4, 32.28)=2.28, p=.13$].

b) The GCSES (Kassotaki & Roussos, 2006) scores represent the participants' self-efficacy toward ICT (scores ranged from 29 to 145). The results (Table 2) again a statistically non-significant improvement [$F(1.57, 36.26)=1.43, p=.25$].

c) Finally, in order to explore the teachers' self-efficacy toward math (GMSES), we used the 7 content principles of the CCTF (problem solving, numbers and operations, measurement and geometry, gathering and processing data, statistics, ratios and

proportions and equations). The GMSES provided a total score representing the participants' self-efficacy toward math (scores ranged from 7 to 35). The results (Table 2) show that the teachers' self-efficacy towards math improved significantly during the semester [$F(1.58, 36.44)=3.98, p=.036$]. Post hoc comparisons using t-tests with Bonferroni correction demonstrated a statistically significant difference between the first and the second measurement stages ($p=.021$).

GCAS	Measurement Stages	Mean	SD	N
	1	103,08	20,61	24
	3	109,25	18,60	24
GCSSES		Mean	SD	N
	1	109,17	24,12	24
	3	113,46	20,74	24
GMSES		Mean	SD	N
	1	22,58	5,70	24
	3	24,21	5,32	24

Table 2: Means and standard deviations of the four scales for the two measurement stages (beginning and end of semester)

DISCUSSION AND CONCLUSIONS

Regarding to our final-year undergraduate primary education students' attitudes and self-efficacy towards ICT, it seems that the participants had already acquired the necessary knowledge of ICT usage before entering university or during their university studies and they were comfortable with its use, as the GCAS and GCSSES means from the research were consistent with Roussos (2007) and Kassotaki & Roussos (2006) research findings. Additionally, these findings were consistent with the Bahr, Shaha, Farnsworth, Lewis, and Benson (2004) results, who reported that pre-service teachers had positive attitudes towards technology and technology integration. Moreover, it seems that the participants of the present study had already reached high level knowledge of technology (TK). These findings are also consistent with the Wentworth, Earle, and Connell (2004) results. The positive attitudes towards ICT and ES had a positive impact on the university faculty who organise educational technology courses (Jimoyiannis & Komis, 2007). Moreover, it seems that the course experiment design and the involvement of undergraduate primary teachers with educational software for math improved their self-efficacy towards math. Also, undergraduate primary teachers improved their mathematical content knowledge. It seems, therefore, that the teachers' attitudes and self-efficacy constitute a force that needs strengthening if ICT is to be incorporated into their teaching practices.

Working Group 15

The extremely high results on students' satisfaction lead us to posing of new research questions. The high satisfaction level might be attributed to: a) The small number of undergraduate primary teachers-participants (Krentler & Grudnitski, 2004); b) The support the teachers received during the entire course via blog, forum, website and e-mail services. It is worth mentioning that the professor and the PhD researcher gave responses at the latest within the next day to the 400 e-mails received during the course. Furthermore, the forum received 140 messages (not counting those sent by the professor and the PhD researcher); c) The everyday communication between the teachers and two individuals (the professor and the PhD researcher); d) The possibility of 'self-defensiveness' on the part of the participants might have resulted in inaccurate responses since this was their first time to participate in a satisfaction research study.

It is our belief, therefore, that undergraduate primary teachers' satisfaction in a learning environment that combines teaching in the university classroom and support via an appropriate learning environment plays a crucial role in the sustenance of programmes that incorporate ICT in teaching and learning. Additionally, the correlation between satisfaction and undergraduate primary teachers' characteristics (learning style, attitude towards ICT and self-efficacy in the use of ICT) constitutes a crucial parameter in the improvement of the education provided. On the other hand, teachers' characteristics, their method of making undergraduate primary teacher contact and their teaching style seem to affect the teachers' satisfaction. The above mentioned findings reveal that each new educational establishment needs to adopt an evaluation programme for its provided services, in order to obtain, amongst others, the necessary data on undergraduate primary teachers' satisfaction about the course services (Elliott & Shin, 2002) so that a circled process will take place for the new course improvement.

In addition, it seemed that the crucial factors for the integration of educational software and scenarios into the teaching of mathematics are the students' positive attitudes towards ICT and educational software and the self-efficacy in technological tools and math. Further analysis of qualitative data (interviews, narrative observations and essays) concerning these quantitative research findings and also the students' scenarios structures, is currently under way so that these triangulation research methods will deeper our understanding of primary teacher training on Technological, Pedagogical and Content Knowledge in Mathematics education.

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Working Group 15

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