
Researching technological and mathematical knowledge (TCK) of undergraduate primary teachers

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Abstract: Twenty-five final-year undergraduate students of primary education who were attending a six month course on mathematics education participated in a research project during the 2009 spring semester. A repeated measures experimental design was used. Quantitative data on students' computer attitudes, self-efficacy in ICT, attitudes toward educational software, and self-efficacy in maths were collected. Data analysis showed a statistically non-significant improvement on participants' computer attitudes and self-efficacy in ICT and educational software, but a significant improvement of self-efficacy in mathematics. In addition, it seemed that the crucial factors for the integration of educational software and scenarios into the teaching of mathematics are positive attitudes towards ICT – educational software and self-efficacy in technological tools and mathematics.

Keywords: undergraduate primary teachers; educational scenarios; TPACK; attitude; self-efficacy; mathematics; ICT; educational software.

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1 Introduction

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 a national educational software (ES). 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 teachers' training, ICT' integration in schools for learning and teaching is often low in everyday school practice (Chionidou-Moskofoglou et al., 2007; Jimoyiannis and Komis, 2007).

Meanwhile, it is well known that recently, research in educational technology has suggested the need for *technological pedagogical and content knowledge* (TPACK), which is based on Shulman's (1986) idea of *pedagogical content knowledge*, so as to incorporate technology in pedagogy (Hoyles et al., 2004; Hennessy et al., 2005; Niess, 2005; Mishra and Koehler, 2006; Cavin, 2007; Angeli and Valanides, 2009).

Therefore, from a constructivist viewpoint (von Glasersfeld, 1995; Cobb et al., 2001), ES integration 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 with the aim of incorporating ICT and especially-designed mathematical scenarios (Kynigos, 2006) in students' teaching approaches.

Taking into consideration, the significant research relation between the development of technology content knowledge (TCK) and self-efficacy and attitudes towards mathematics, ICT and ES (Polly et al., in press) we ran a six-month research project investigating themes:

- a students' attitudes towards ICT
- b students' attitudes towards ES
- c students' self-efficacy in ICT
- d students' self-efficacy in mathematics on the development of technology knowledge (TK), content knowledge (CK) and TCK.

Moreover, with qualitative methods we gathered data regarding their TPACK development. In this paper, we present quantitative results concerning the above four research themes.

2 Theoretical background

According to the constructivism theory, Cobb et al. (2001) explains 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.

As it has already mentioned, research in educational technology suggests the need for TPACK, which is based on Shulman's (1986) idea of 'pedagogical CK', so as to incorporate technology in pedagogy (Niess, 2005; Mishra and Koehler, 2006; Cavin, 2007; Angeli and Valanides, 2009). This interconnectedness among content, pedagogy and technology has important effects on learning as well as on professional development.

Mishra and Koehler (2006) suggest "...a curricular system that would honour the complex, multi-dimensional relationships by treating all three components in an epistemologically and conceptually integrated manner" (p.1020), and they propose an approach which is called 'learning technology by design'. They have proposed a model that suggests three unitary components of knowledge (content, pedagogy and technology), three dyadic components of knowledge (pedagogical content, technological content, technological pedagogical) and one overarching triad (technological pedagogical CK). Furthermore, according to Gill and Dalgarno (2008), undergraduate primary teachers are influenced by teaching styles they experience and, as a result, often employ those teaching approaches they were exposed to during their own education.

Apart from ICT availability in schools, teachers' positive attitudes towards ICT and ES are also important so as to include them in the every day school curriculum (Becta, 2004). The development of TPACK and the incorporation of ES into the future teaching practice are directly correlated to the attitude of the undergraduate primary teachers (Myers and Halpin, 2002; Khine, 2001). Attitudes depend on a variety of issues such as the usefulness of ICT and ES (Rovai and Childress, 2002), training and knowledge of ICT (Tsitouridou and Vryzas, 2003), anxiety and confidence in using them (Roussos, 2007). Furthermore, in a study of 184 pre-service teachers, Khine (2001) found a significant relationship between computer attitude and its use in university laboratories. Kumar and Kumar (2003) report that teachers themselves believe that their experience in using ICT will positively affect their attitude towards ICT. Teo (2008) examined a sample of 139 pre-service teachers for their computer attitudes with regard to four factors: affect (liking), perceived usefulness, perceived control, and behavioural intention to use the computer. It seems, therefore, that the study of undergraduate primary teachers' attitudes towards ICT and ES plays an important role in its incorporation into the teaching practice. In Greece, Roussos (2007) constructed the Greek computer attitudes scale (GCAS). Results from four Greek samples, indicated that:

- 1 both the reliability (internal consistency and test-retest) and validity (concurrent) of the GCAS were adequate
- 2 the relationship between age and GCAS was not significant, whereas sex did not have a significant effect on GCAS scores
- 3 perceived computer experience and confidence with computers were strongly related to favourable attitudes toward computers.

This research tool was used in this research study.

However, as has already been mentioned, undergraduate primary teachers' self-efficacy in using ICT constitutes another factor in the formulation of their attitudes and eventually in incorporation of ICT in the classroom. In order to have a complete student-teacher profile, the ICT and the mathematics self-efficacy of undergraduate primary teachers formed one more parameter of our research. According to Bandura (1997), who first proposed the notion of self-efficacy, "perceived self-efficacy refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p.3). As suggested by Bandura (1997), self-efficacy is specific to a particular set of behaviours and comprises two components, efficacy expectations and outcome expectations which respectively relate to belief in personal capacity to implement a behaviour and belief that the behaviour will result in a particular outcome. Self-efficacy beliefs have been found to be significant contributors to

motivation and performance in mathematics (Malpass et al., 1999; Pietsch et al., 2003; Stevens et al., 2004; Usher and Pajares, 2006).

Moreover, ICT self-efficacy constitutes an important factor in the teachers' decision to use ICT in class (Hill et al., 1987). Harrison et al. (1997) claimed that ICT performance seems to be related to ICT self-efficacy. A Greek instrument including several sub-scales for self-efficacy in relation to particular aspects of computer use has been developed and validated by Kassotaki and Roussos (2006) with students, teachers and members of the general Greek population. This research tool was the second one which was used in this research study.

Taking the above in consideration, the aim of this study was to explore if there would be changes in undergraduate primary teachers' self-efficacy and attitudes towards mathematics, ICT and ES during our teaching course and how these changes would relate to the development of TCK. Data collection methods and research results are presented in the following paragraphs.

3 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 et al., 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 nine 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. Undergraduate primary teachers had been informed about their participation in the project as well as the confidentiality of the data gathered.

Two of the researchers used to have a three-hour meeting with the undergraduate primary teachers in the 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, Mathematica] and presentation tools. The need for a technologically elaborate working environment that would encourage undergraduate primary teachers to use technology, led the research team to use many technological tools (the educator's website, the course's electronic mail, Moodle as the course management information system, a forum, the research team's blog and SMS). In using the above electronic services, two parameters were taken into consideration: technophobia and the need to strike a balance between security and privacy of information (Stamatellos, 2009).

The research work was divided into five stages during the spring semester 2008/2009:

- 1 During the first stage and before the beginning of the first lesson, quantitative data regarding undergraduate primary teachers:
 - a background (studies, family background, etc.)
 - b individual learning style according to Felder and Silverman's (1988) instrument: index of learning styles
 - c attitudes towards ICT, based on Roussos' (2007) GCAS

- d self-efficacy in ICT according to Kassotaki and Roussos' (2006) Greek computer self-efficacy scale
- e attitudes towards ES; for this purpose we designed a scale (educational software attitudes scale, ESAS) which was based on Roussos' GCAS
- f self-efficacy in mathematics according to the content principles of the CCTF were gathered.

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.'s (2003) experiment design procedure constituted the second stage; in particular:
 - a Undergraduate primary teachers were given a suitable worksheet and they worked on mathematics and geometry problems.
 - b After their paper and pencil work, they tried to solve the same problems by using the national ESPIM. Each lesson consisted of 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 undergraduate primary teachers come up with their own teaching scenarios (Kynigos, 2006; Etheris and Tan, 2004) they will be able to use the suitable technological tools that are both efficient and investigatory. The ES used consisted of the microworlds: 'geo-board', '3D solid manipulation (solid-board)', 'calculator' and 'table tracking' from the ESPIM.
 - c In each lesson, researchers used technological tools while undergraduate primary teachers participated as students taking a lesson in class.
 - d At the end of each lesson, undergraduate primary 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 the technological tools, the teaching strategies and the benefits gained from the lesson.

This procedure was repeated eight times during the spring semester 2008/2009.

- 3 Undergraduate primary teachers had to write an assignment (first assignment) that consisted of the search for all geometry problems, activities and exercises involving geometrical shapes and solids in the national maths textbooks of 5th and 6th grade as well as 7th, 8th and 9th grade; they also had to work on two activities, two exercises and two problems of their choice (from the above units) using ESPIM. Furthermore, and without any assistance by the researchers, they were asked to create a spontaneous lesson plan for teaching the chapter of area of a parallelogram or the volume of a parallelepiped from 6th grade mathematics [Kassoti et al. (2006), (pp.149–150, 157–158)].
- 4 Undergraduate primary teachers had to be taught the notion of the 'educational scenario' 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 undergraduate primary teachers were asked to create their own educational scenario, 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, undergraduate primary teachers produced their own educational scenario over the following two weeks. Each educational scenario was presented to their peers, who acted as students of a class. The latter provided their feedback and assessed the scenario on an especially designed form by the researchers. After that, the undergraduate primary teacher, creator of the scenario, having taken his/her peers' comments into consideration, returned two weeks later and presented his/her improved scenario version. Security and originality were safeguarded as all scenarios had been posted before the beginning of the presentations. Scenario presentations were audio recorded on a digital camera so they could be further analysed. Finally, undergraduate primary teachers were self-assessed and gave feedback on their own scenario.

- 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 educational scenario. The purpose of these interviews was twofold; on one hand, it was to investigate the procedures followed by undergraduate primary teachers during the writing up of their first assignment, as well as of their scenario, their perceptions of TPACK in mathematics and the reasons behind 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 constructivism design experiment procedure was suitable for them personally. Interviews were recorded for further analysis.

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

In the next section, the results from the study concerning students' attitudes and self-efficacy are presented.

4 Research data analysis and results

This section presents the analysis conducted on undergraduate primary teachers':

- a attitudes towards ICT (GCAS)
- b self-efficacy towards ICT (GCSES)
- c attitudes towards ES (ESAS)
- d self-efficacy towards mathematics (MSES) to explore the effects of the stage of measurement (beginning, middle and end of semester).

The 30 items of GCAS (Roussos, 2007) were summed to provide a total score representing the participant's overall attitude toward computers (scores ranged from 30 to

150). Descriptive statistics of the three GCAS scores are reported in Table 1. As can be seen, the results show an improvement of undergraduate primary teachers' attitudes toward ICT. However, this was not statistically significant [$F(1.4, 32.28) = 2.28, p = 0.13$].

The GCSES scores represent the participants' self-efficacy toward ICT (scores ranged from 29 to 145). The results (Table 1) again show a statistically non-significant improvement [$F(1.57, 36.26) = 1.43, p = 0.25$].

Similar results were obtained from the ESAS. The ESAS scores ranged from 31 to 155. The results (Table 1) showed that undergraduate primary teachers' attitudes towards ES improved, but the improvement was not statistically significant [$F(1.75, 40.34) = 2.37, p = 0.11$].

Finally, in order to explore undergraduate primary teachers' self-efficacy toward mathematics, we used the seven content principles of the CCTF (problem solving, numbers and operations, measurement and geometry, gathering and processing data, statistics, ratios and proportions and equations) (Official Government Gazette, 2003). The GMSES provided a total score representing the participant's self-efficacy toward mathematics (scores ranged from seven to 35). The results (Table 1) showed that undergraduate primary teachers' self-efficacy towards Mathematics improved significantly during the semester [$F(1.58, 36.44) = 3.98, p = 0.036$]. Post hoc comparisons using t-tests with Bonferroni correction demonstrated a statistically significant difference between the first and the second measurement stages ($p = 0.021$). Moreover, the second measurement stage and the third one did not significantly differ ($p = 0.81$).

Table 1 Means and standard deviations of the four scales for the three measurement stages (beginning, middle and end of semester)

<i>GCAS</i>	<i>Measurement stages</i>	<i>Mean</i>	<i>SD</i>	<i>N</i>
	1	103.08	20.61	24
	2	106.58	15.80	24
	3	109.25	18.60	24
<i>GCSES</i>	<i>Measurement stages</i>	<i>Mean</i>	<i>SD</i>	<i>N</i>
	1	109.17	24.12	24
	2	110.08	19.89	24
	3	113.46	20.74	24
<i>ESAS</i>	<i>Measurement stages</i>	<i>Mean</i>	<i>SD</i>	<i>N</i>
	1	106.54	14.25	24
	2	108.75	14.32	24
	3	112.54	18.89	24
<i>GMSES</i>	<i>Measurement stages</i>	<i>Mean</i>	<i>SD</i>	<i>N</i>
	1	22.58	5.70	24
	2	23.83	5.00	24
	3	24.21	5.32	24

5 Discussion and conclusions

Research results from a study of undergraduate primary teachers' self-efficacy and attitudes towards mathematics, ICT and ES, are presented in this paper.

With regard to their 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 were comfortable with their use. These findings were consistent with the Bahr et al. (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 reach high level knowledge of technology (TK). These findings are consistent with the Wentworth et al. (2004) results. The positive attitudes towards ICT and ES had a positive impact on the university faculty who organise educational technology courses (Jimoyiannis and Komis, 2007). Undergraduate primary teachers' attitudes concerning ES seemed to improve after experiencing and reflecting on the affordances and benefits of ESPIM. This suggests that with time to experience and reflect (Kurz et al., 2004) undergraduate primary teachers' should improve their attitude concerning ES.

Moreover, it seems that the course experiment design and the involvement of undergraduate primary teachers with educational software of mathematics improved their self-efficacy towards mathematics. Also, undergraduate primary teachers improved their mathematical content knowledge.

It seems, therefore, that undergraduate primary teachers' attitudes and self-efficacy constitute a force that needs strengthening if ICT is to be incorporated in their teaching (Mishra and Koehler, 2006). Nevertheless, effective pedagogical technology integration around mathematics requires developing a dynamic relationship between technology, pedagogy and content. The pedagogy knowledge (PK), which is not included in this paper due to lack of space, is studied with qualitative methods.

Further questions rise concerning classroom practices and we believe that further research is necessary on teachers' training. Moreover, research is needed on the impact these research findings have on pupils' maths skills acquisition.

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