The interaction between the use of leT and mathematics teachers' professional knowledge base for teaching

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With the increased availability of the new technology] in our schools, it is important to examine how teachers use it in their instruction. This paper describes a study that involved a number of secondary mathematics teachers who had been using the new technology in their teaching for a number of years. A possible theoretical framework is presented and then used in the analysis of the data collected.

Introduction

Interest in teachers' .subject matter knowledge and pedagogical content knowledge has risen in recent years (Cochran *et ai,* 1993, Meredith, 1993, Even *et ai, 1996).* With the increased availability of the new technology in our schools, it is important to examine how these components of teachers' professional knowledge base affect and are affected by its use in teachers' instruction (Zehavi, 1997, Simmt, 1997).

Background

The work described here is part of my PhD research whose focus is the mathematics teachers and the interaction between their use of ICT and their professional knowledge base for teaching. This paper reports on a pilot study that involved a number of secondary mathematics teachers who regard themselves as confident and competent users of ICT in their mathematics lessons.

A possible theoretical framework

Lee S. Shulman once described the teaching profession as *"Those who understand, teach"* (1986, pp. 5). But, what do teachers need to understand in order to teach? Researchers have attempted to investigate the professional knowledge base for teaching from a variety of perspectives. Wilson *et al* (1987) proposed a model of the components of the professional knowledge base for teaching described as being *"the body of understanding, knowledge, skills and dispositions that a teacher needs to*

1 throughout this paper, terms such as *the new technology* and *leT* will be used interchangeably in order to refer to graphics calculators and computers together with applications such as: spreadsheets, graphics packages, computer algebra and dynamic geometry systems.

perform effectively in a teaching situation" (p. 106). They found that teachers, in the course of preparing lessons and teaching, draw upon many types of knowledge when making decisions about the content of their lessons. They obviously make use of the extent and depth of knowledge of the subject they teach, called subiect matter knowledge in this model. Many researchers have explored teachers' subject matter knowledge and the role it plays in teaching (e.g. Shulman, 1986, Even, 1990). Researchers also pointed to the importance of teachers having curricular· knowledge (knowledge of instructional materials, of programs designed for teaching a particular topic, the materia media). Another component of the professional knowledge base for teaching is knowledge of other subiect matter and how they relate to the subject taught. Other researchers proposed including in this model teachers' knowledge of learners (knowledge of group dynamics, behaviour, how they interact and co-operate, responsiveness to learning tasks) and more generally, knowledge of school context (of other teacher, of classrooms, of teaching resources, of departmental policies, of school ethos). Knowledge of education plays an important role as it provides teachers with the means to construe and interpret classroom experiences and to reflect on them. Others researchers approached the study of the teaching profession by focusing on teachers' general pedagogical knowledge which is knowledge of pedagogical principles and techniques that are not bound by topic or subject matter, and more specialised pedagogical knowledge, namely pedagogical content knowledge. This last component is enhanced by all the types of knowledge mentioned above and represents knowledge about how to teach mathematics and how to transform and represent mathematics ideas and topics to pupils.

In the following I will focus on the two knowledge domains most central to the professional knowledge base for teaching, namely subject matter knowledge (SMK) and pedagogical content knowledge (PCK).

SMK consists of knowledge of the extent and depth of the subject, the structure, knowledge of procedures and strategies (Shulman 1986). Findings of a significant number of studies on effective teaching have resulted in a widening of the definition of SMK. Researchers such as Ball (1988) and Ernest (1989) suggested that subject matter needed for teaching mathematics should include both knowledge of mathematics as well as knowledge about the nature of mathematics and understanding of what it means to know and do mathematics. Even (1990) criticised the research in teachers' SMK area as being too general and not topic-specific, therefore she suggested that teachers should have knowledge and understanding of the concept to be taught, essential features of this concept, different representations and alternative approaches. Grossman *et al* (1989), Ernest (1989) and Thompson (1992) suggested including here teachers' beliefs about the subject matter they teach as they contribute to the ways in which teachers think about the subject they teach and the choices they make in their teaching.

The other knowledge domain central to this model is the pedagogical content knowledge (PCK) which represents knowledge of how to teach mathematics, how to transform and represent maths ideas and topics to pupils. Pedagogical knowledge of mathematics includes knowledge of approaches to school mathematics topics, different ways of presenting mathematics including problem-solving, knowledge of children's methods, conceptions, difficulties and common errors, knowledge of mathematical tasks, activities, explanations, test items, etc (Ernest, 1989).

Research evidence indicates that subject matter expertise influences the pedagogical reasoning of a teacher. Studies show that teachers with limited SMK transform their SMK poorly (Smith and Neale, 1989), whereas a deep SMK could lead to teachers accommodating new ideas, new pedagogical conceptions, despite the traditional approach they adopted before the innovation programmes was introduced (Loyd &Wilson, 1998). However, very good SMK does not necessarily mean good PCK (Grossman *et ai*, 1989). PCK is more than this; it involves the transformation of SMK. In fact, this is at the heart of PCK. Thus teachers have to have a representational repertoire for the subject matter they teach, different ways of representing and formulating the subject that makes initiating understanding in their students likely.

There are difficulties with using such a model in practice. Researchers have used Shulman's characterisation of pedagogical content knowledge productively, but have done little to clarify it. McNamara (1990) and Marks (1991) pointed out the difficulty of making a clear distinction between SMK and PCK as it all depends on how statements about mathematics teaching and learning are interpreted.

The teacher education area

Coming back to Shulman's quotation, it could be restated to describe the teacher education profession as *Those who understand* the components of the professional knowledge base for teaching mathematics, train teachers *to teach* mathematics. But today's schools are infiltrated with the new technology and there is evidence to suggest that the capabilities of such resources could enhance the teaching and learning process.

It is therefore desirable that teachers (teaching any subject) are trained to make use of these resources in their teaching. Thus, by understanding how the components of the professional knowledge base for teaching interact with the new technology, teacher educators are better prepared to train teachers teach in today's schools.

Reviewing the literature regarding the effectiveness of ICT courses in teacher education programmes, my observation is that research has failed to regard the teacher as learner when it comes to the use of the new technology. For example, Simmt (1997) mentions the fact that studies involving graphing calculators and computers tend to be focused on student learning. These studies looked at the effect the use of ICT has on students' learning (they are the learners!), whereas teachers

were expected to attend a one or two day training course in the use of ICT and then implement it into their teaching.
It is equally important to look at teachers' learning experiences of doing mathematics supported by the use of ICT as this might give an insight into why teachers use or do not use ICT in their instruction and why they use it the way they do.

The survey

The literature review suggests that those teachers who teach in schools with a good provision of ICT, where there is a relatively easy and immediate access to it and who have been using ICT in their mathematics lessons for 3 years or more are more likely to use ICT as an integral part of their teaching and are more likely to reflect critically upon the ways ICT has been used in their mathematics lessons (Marcienkievicz, 1994, Mandinach, 1994).
To identify these teachers, the NCET mathematics and ICT database 'Curriculum IT Support for mathematics' was consulted. The database comprises reports from surveys in schools across the UK. It was intended for secondary mathematics teachers in the UK who wanted to know about interesting ICT developments in other schools. Each school in the database gave a brief description of the good features of the use of ICT within their mathematics departments, as well as mentioning those mathematics topics where ICT was being used. At the time when I accessed the database, there were around 70 records, with 3 secondary schools in the same area. 6 out of the 13 mathematics teachers from School A and 4 out of the 9 mathematics teachers from School B filled in the questionnaires.
In order to investigate in more depth their use of the new technology in their teaching, interviews were carried out with 7 teachers, six females and one male (TAl, TAl from school A and TBl, TB2, TB3, TB4, TB5 from school B) out of the 10 teachers teaching in the two schools who agreed and found the time to be interviewed. The semi-structured nature of the interviews yielded the following categories of teachers' answers regarding their use of ICT: types of hardware available in schools and accessibility, software & resources on the use of ICT and departmental policy. Other responses gave an account of teachers' reasons for starting to use ICT, reasons for using ICT in their mathematics lessons as well as reporting on teachers' views regarding the value of using ICT with respect to today's school mathematics, teaching of mathematics and teachers' knowledge of the subject matter they teach.

Some findings

In the following I will discuss a number of the teachers' answers which I regard to point out to the interaction between the use of ICT and their components of the professional knowledge base for teaching, especially the interaction between teachers' SMK, PCK and their use of ICT.

When filling in the questionnaires, the teachers agreed that the new technology enriched their knowledge of the subject matter (7- strongly agree, 3-agree). In the interview, some teachers expanded on how they felt ICT has enriched their mathematics.

For TB5, the use of ICT " ... *helps me with further maths - plotting curves".* The graphics capabilities of the new technology enriched her understanding of further mathematics through the new, visual representations enabled by them.

Another teacher started to explore fractals with LOGO and now presents his work at conferences. His SMK has thus been enriched by adding to it a new mathematics topic. The extension of this teacher's mathematical knowledge was enabled by his experience of doing mathematics supported by ICT.

Some of the teachers felt that the new technology does not enrich the mathematics of which they already have a good understanding but it enriches the mathematics they did not understand before using ICT. *TAl* believes that " ... *{Geometry Inventor} really made my geometry much more intuitive ... thinking about, rather than like a whole lot of facts which is how I did it at school"* and TB3 stated that *"spreadsheets help me see the algorithms, really see the mathematics working, in action".* It seems that the use of ICT helps teachers better understand the mathematics they did not understand very well or they learnt by rote such as algorithms, recursive procedures, even geometry. Teachers' answers in the questionnaire and interview also suggest that using ICT to perform algorithms and numerical calculations or to teach recursive procedures and geometry is very common in their mathematics lessons. This indicates that teachers reflect on their experiences as learners of mathematics and try to find better approaches to teaching those topics they did not understand very well. Teachers' answers suggest that their representational repertoire has been enriched by the use ofICT with "better ways" of teaching some areas of mathematics which they now use in their instruction.

The teachers were also asked their opinion on whether or not they felt the use of ICT challenged their mathematics. TBI feels that her knowledge of school maths is not challenged, whereas *"It is only when I use it for myself that it really actually challenges my mathematics".* Could this be an indication of teacher's knowledge of mathematics being challenged when ICT is being used? Lloyd (1998) remarked that teachers do not separate their ideas about a particular topic from notions about how to teach that topic, thus could this statement suggest that this teacher's pedagogical content knowlegde, her ideas about how to transform and teach the topic are in fact challenged when ICT is being used?

The next step

There are these questions prompted by the analysis of teachers' interview that I will investigate further in my research. By looking at teachers' own learning experiences of doing mathematics supported by the new technology an insight into whether and how teachers' SMK and PCK are affected by their use oflCT and vice versa could be

- Cochran, K.F., DeRuiter, J. A. and King, R. A. (1993) *Pedagogical content knowledge: An Integrative Model for Teacher Preparation,* in Journal of Teacher Education. Vol. 44, no.4, 263-272.
- Ernest, P. (1989) *The Knowledge, Beliefs and Attitudes of the Maths Teacher: a model,* in Journal of Education for Teaching, vol. 15, no. 1.
- Even, R., Tirosh, D., Markovits, Z. (1996) *Teacher Subject Matter Knowledge and Pedagogical Content Knowledge: Research and Development.* In L. Puig and A. Gutierrez (Eds) Proceedings of the 20th Conference of the International Group for the Psychology of Mathematics Education, vol. 1, 119-134.
- Grossman, P.L., Wilson, S.M. & Shulman, L.S. (1989) *Teachers of sustance: Subject matter knowledge of teaching.* In M. C. Reynolds (Ed) *Knowledge base for the beginning teacher,* 23-36, New York, Pergamon Press.
- Mandinach, E.B. 7 Cline, H. (1994) Classroom Dynamics. Implementing a technology-Based Learning Environment. Lawrence Erlbaum Associates, Publishers, Hillsdale, New Jersey.
- Marcinkiewicz, H.R. (1994) *Computers and Teachers: Factors Influencing Computers Use in the Classroom,* in Journal of Research on Computing in Education, vol.26, no.2, 230-235.
- Meredith, A. (1993) *Knowledge for Teaching Mathematics: some student teachers' views,* Journal of Education for Teaching. 19(3), 325-338.
- Simmt, E. (1997) *Graphing Calculators in High School Mathematics.* Journal of Computers in Mathematics and Science Teaching, 16 (2/3), 269-289.
- Shulman, Lee S. (1986) *Those who understand: Knowledge growth in teaching.* Educational Research. vol. 15, no. 2,4-14, 1986.
- Thompson, A. G. (1992) *Teachers' Beliefs and Conceptions: A Synthesis of the Research,* in Grouws, D. A., Handbook of Research on Mathematics Teaching and Learning. A Project of the National Council of Teachers. 1992, Macmillan Publishing Company.
- Zehavi, N. (1997) *Changes That Computer Algebra Systems Bring To Teacher Professional Development,* PME 1997, Finland, 4-307/313.
- Wilson, M. Suzanne, Shulman, Lee S., & Richert, Anna E. (1987), *'150 Different Ways' of knowing: Representations of knowledge in teaching* in *Exploring teachers' thinking,* by James Calderhead. ISBN 0-304-31383-1. Published by Cassell Educational Limited.