DEVELOPMENT OF PRE-SERVICE MATHEMATICS TEACHERS' PROFESSIONAL KNOWLEDGE AND IDENTITY IN WORKING WITH INFORMATION AND COMMUNICATION TECHNOLOGY[1]

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ABSTRACT. This paper describes the work undertaken in a course in communication and information technology in a pre-service program for secondary school mathematics teachers. This course aimed to help pre-service teachers develop a positive attitude regarding ICT and use it confidently. It focused on the exploration of educational software and of the Internet's potential as a means of research and production of web sites. We discuss how the pre-service mathematics teachers evaluate their work concerning their commitment, difficulties they found, learning they identified, and personal relationship. We also analyse the effects of the course on the development of their professional knowledge and identity.

KEY WORDS: Information and communication technology, pre-service teacher education, mathematics teacher education, professional knowledge, professional identity

INTRODUCTION

Mathematics teachers need to know how to use the tools of information and communication technology (ICT), including subject-specific educational software and general software (NCTM, 1991). This technology enables the development of new perspectives about mathematics teaching, as it stresses the role of graphic language and new forms of representation and puts less emphasis on computation and symbolic manipulation. It also allows the teacher to propose more activities and projects that include exploration, investigation, and modelling. As a result, ICT may enhance pupils' development of important competencies, foster better attitudes towards mathematics, and stimulate a wider vision of the nature of this science (NCTM, 2000).

The Internet may be regarded as a "metatool" where one can find information about new developments in mathematics and mathematics education, software, sample tasks for pupils, ideas for the classroom, reports of experiences, and news about meetings and other events. In addition, the Internet allows for the dissemination of personal productions such as

texts, images, video sequences, applets, and hypertext documents. Rendering synchronous and asynchronous communication possible, it is a very useful tool for collaborative work. Facilitating and stimulating personal interactions, the Internet supports human development in the personal, social, cultural, recreational, civic, and professional dimensions. It is an essential working tool in present days, playing an increasingly important role in education.

Pre-service mathematics teachers need to be acquainted with the potential of ICT for mathematics teaching and to develop confidence in using it. In our university, this is problematic since most pre-service teachers arrive at this stage of their professional preparation with very little previous contact with this technology. Many of these pre-service teachers are quite suspicious of the use of ICT in education and are uncomfortable about handling it, even for their own personal use.

This paper is about the work carried out in a course that was created as an attempt to change this situation, offering pre-service mathematics teachers a positive working experience with ICT. Since this technology involves many dimensions and is constantly evolving, careful choices have to be made concerning the curriculum. It is also essential to pay great attention to the aims and working modes involved in the use of ICT. We assume that learning about ICT and its use in mathematics education should help pre-service mathematics teachers develop their professional knowledge regarding this domain as well as their knowledge about learning and teaching mathematics, as both aspects are interrelated (Berger, 1999). In addition, working with ICT may help pre-service teachers to develop a professional identity by stimulating the adoption of a standpoint and values that are appropriate to a mathematics teacher. So, in this paper we describe the activities carried out in this course, report on the evaluation done by the participants, and discuss the role of such work in the preparation of pre-service mathematics teachers.

ICT AND THE DEVELOPMENT OF PROFESSIONAL KNOWLEDGE AND IDENTITY

ICT is an increasingly important tool in mathematics teachers' activity that has several dimensions. It may be regarded as: (i) an auxiliary educational means to support pupils' learning; (ii) a mathematics teacher's tool of personal productivity, to prepare material for classes, carry out managerial tasks, and search for information and materials, and (iii) a *medium* for interacting and collaborating with other teachers and educational partners. Teachers need to know how to use ICT; evaluate its potential, strengths, and weaknesses; and develop an awareness of its social and ethical implications.

In pre-service mathematics teacher education, participants must become acquainted with applications such as word processing, database management systems, image processing software, spreadsheets, statistics software, presentation software (like Powerpoint), electronic

mail, educational software concerning the learning of specific topics, and the Internet in terms of information search and production. However, a recent study about the ICT preparation offered in teacher education programs in Portugal shows that the competencies and knowledge acquired by pre-service teachers are far from satisfactory (Ponte and Serrazina, 1998). These competencies are clearly insufficient regarding, for example, statistics software, databases, Internet navigation, and use of electronic mail.

ICT can be used to reinforce teacher-centered practices as well as to facilitate educational change. In fact, even today, many people regard the teacher's role as one of providing pupils with information, controlling the discourse and managing the class. But curriculum documents increasingly advocate the teachers' role as one of creating stimulating learning situations, challenging pupils to think, supporting their work, and encouraging diversification of learning routes. Therefore, pre-service teachers must develop not only various technical competencies but also a sound educational perspective regarding the use of ICT in the mathematics classroom.

The Internet also makes specific challenges regarding the teacher's role. Its use requires that the teacher pay great attention to pupils' development of a critical stance. In using the Internet, students may simply follow a consumer orientation, looking for the information that is already available. Students using this resource also may be oriented towards production—creating new information, materials, and documents that may in turn be appropriated and changed by a whole community of users.

Thus, ICT poses specific challenges to the mathematics teachers' professional knowledge. Such knowledge may be regarded as a blend of declarative, procedural, and strategic knowledge that is used in situations of practice (Shulman, 1986). This knowledge has tacit and personal dimensions and develops through experience and personal reflection (Elbaz, 1983; Schön, 1983). Among its structuring elements are the conceptions that frame the way a range of objects, processes, and problems are handled (Ponte, 1994; Thompson, 1984). Professional knowledge concerns not just the teaching practice in the classroom but also other professional roles such as tutoring students, participating in school activities and projects, interacting with members of the community, and working in professional groups. For these roles, mathematics teachers need to (i) have knowledge of educational theories and issues; (ii) be competent in their teaching domain, and (iii) have a strong preparation in mathematics education, the specialized field that concerns their activity. This involves developing perspectives about curriculum, student learning, classroom instruction, and student evaluation (Boero, Dapueto, and Parenti, 1996).

However, it is not enough for pre-service mathematics teachers to have knowledge of mathematics, educational theories, and mathematics education. Experience with these matters established on a purely theoretical level, in terms of declarative knowledge, does not guarantee

an effective acquisition of professional knowledge. The fact that this knowledge is deeply personal and connected to action and to reflection upon experience (Fiorentini, Nacarato, and Pinto, 1999), implies that for its development pre-service teachers need imaginative and varied working environments as well as experience of situations as close as possible to real professional practice.

As ICT changes the environment in which teachers work and the way they relate to other teachers, it has an important impact on the nature of the teachers' work and therefore on their professional identity. The development of a professional identity involves assumption of the essential norms and values of a profession. Also related to a strong professional identity is an attitude of commitment to self-improvement as an educator and willingness to contribute towrads the development of the educational institutions where one works. A mathematics teacher should be able to carry out the proper professional activities of the teacher and identify personally with the teaching profession. That means assuming a teacher's point of view, internalizing the teacher's roles and ways of dealing with professional issues. For example, the ability to decide on the value of a variety of resources available and learn to use them promptly is, increasingly, an important part of the teacher's work. It requires, for instance, knowing how to explore software and web sites as well as flexibility and confidence in using computers (Berger, 1999).

Berger and Luckman (1966) regard the development of a professional identity as an aspect of the development of secondary socialization. According to these authors, primary socialization refers to a person being introduced to society, becoming a part of it. The child internalizes the roles, attitudes, and values of significant others, with scarce possibility for critical distance. Secondary socialization comes later on, with the internalization of "institutional worlds", involving the acquisition of specialized knowledge (including professional knowledge). This specialized knowledge is constructed with reference to particular fields of activity that draw on specific symbolic universes.

In the view of Dubar (1997), the construction of social identities involves two complementary processes. One, the biographical process, is the personal construction by individuals, throughout time, of social identities, using the different categories offered by the institutions in their environment. It involves a transaction between inherited identities and desired identities. The other is the relational process that involves external transactions between individuals and significant others. It concerns the acknowledgment of identity at a given moment and the legitimization of the space of the identities related to knowledge, competencies, images, and values stated in various action systems.

Research carried out in the last few years shows that ICT may actually play an important role in teacher education, thus contributing to the professional and personal development of pre-service teachers. For example, a study by Robinson and Milligan (1997)

aimed to investigate how to influence pre-service teachers' conceptions about mathematics, technology, instruction, and evaluation strategies in a pre-service teacher education course. This course was designed to take place in a totally electronic environment. It was structured in modules with three types of activities: (i) developmental, to acquaint participants with technological resources; (ii) experimental, to expand participants' mathematical knowledge through technology, and (iii) instructional, to have participants apply what they learned (namely using new software) in the development of instructional material. The results of this study show that the pre-service teachers changed their conceptions about the classroom environment, the teacher's and pupils' roles, and the learning strategies.

Another study, conducted by Yildirim and Kiraz (1999), aimed to analyze how electronic mail can be used by the different actors in the pre-service teacher education process. The authors found that the participants viewed electronic mail as an important communication tool, although their level of use was quite variable. They also state that the participants revealed a certain degree of anxiety regarding computers but that trainees were more at ease using ICT than their supervisors. The authors conclude that electronic mail has several advantages, the main ones being to promote mutual development, overcome time and distance limitations, and encourage the exchange of ideas among teachers.

Finally, drawing on several principles of adult education, Rogan (1996) states that pre-service teachers are more likely to engage in learning situations that involve participation where there is mutual respect among participants (students and instructors). This author stresses the role of collaborative activity with distributed leadership, where both pre-service teachers and instructors learn, in a process geared towards personal liberation and action. He also highlights the need for critical reflection, that we analyze the grounds of our conceptions regarding the learning that is taking place. Finally, Rogan underlines the need to aim to develop self-oriented "apprentices" with great initiative and ease. In the development of this course we were concerned about taking into account these experiences, as we strived to construct a learning environment that would foster the development of positive attitudes regarding ICT and its use in mathematics teaching.

AN ICT INTRODUCTORY COURSE CENTERED ON THE INTERNET

The course discussed here is a one-semester course included in the fourth year of the program for middle and secondary school pre-service mathematics teachers at the Faculty of Sciences, University of Lisbon. This program prepares teachers for middle (grades 7-9) and secondary school (grades 10-12). The first three years of the program are dedicated to mathematics itself, and the fourth year to educational preparation; the fifth year is a paid *practicum* carried out at a middle or secondary school. In the fourth year, besides this course the pre-service

teachers also take courses in the history and philosophy of education, psychology of education, sociology of education, pedagogy, mathematics education, and an optional subject. They also have an introduction to professional practice based on the observation of educational situations in schools.

In 1998/99 and 1999/2000 this course, meeting four hours a week, was offered as an introduction to ICT. Its main objective was to help pre-service teachers to develop a positive attitude regarding ICT and use it competently, from an educational perspective, focusing on the exploration of specific mathematics educational software and the potential of the production and publishing of web pages. In 1998/99, 66 pre-service mathematics teachers attended the course and in 1999/2000 this number rose to 94. There were two instructors, each with two classes. The classroom had 6 computers in the first year and 9 in the second, all connected to the Internet.

Pre-service teachers got to know a range of ICT tools, especially those directly related to the Internet (browsers and html editors). They also had the opportunity to learn to work with educational software that is particularly important to mathematics, such as the *Geometer's Sketchpad* (GSP) and *Modellus*[2], as well as with general tools like spreadsheets and word processors. This course does not deal with predefined mathematics topics. Participants can choose to work on the topics they want and are encouraged to look at them from the point of view of history, applications, and connections with other topics.

The activities carried out in class with GSP and Modellus were intended to give pre-service teachers a general view of the possibilities of the software for mathematics teaching. Generally, classes started with an investigative task, to be carried out by the groups and ended with a whole-class discussion considering how ICT was used and how the task could be adapted to the mathematics classroom. Pre-service teachers got acquainted with this software and its educational applications within present mathematics curricula in Portugal.

Pre-service mathematics teachers used the software GSP to do geometrical constructions and to study invariant properties of different types of transformations, as well as other mathematics topics. In this course, pre-service teachers explored GSP mainly from an investigative perspective, starting with simple mathematical questions about properties of triangles and quadrilaterals, then moving on to some features of conics and, finally, invariant properties of certain geometrical transformations. Pre-service teachers also learned about Java Sketch, which was useful for including animations with GSP in their web pages. They also used Modellus for constructing mathematical models of different kinds of phenomena. Such models were particularly useful in showing the dynamics of the phenomena over time, using a variety of representations. This software was also used in some groups' projects.

However, as already mentioned, the main activity proposed to pre-service teachers was to develop a project that involved the creation of a group web page dealing with a

mathematical theme taken from the middle or secondary school curricula that could be of interest to teachers or pre-service teachers. More specifically, we suggested that in this web page, besides developing the main theme, they should refer to other sites related to the theme, comment on the remaining activities carried out in the course, and also make a brief presentation of the group. In order to do this, the pre-service teachers were required to learn how to use the software Frontpage, to do research in the Internet, and to pay special attention to the page design. In their research, pre-service teachers also used traditional sources of information such as scientific and professional journals, books, and textbooks.

During the whole semester, they usually worked in groups—this was considered to be a desirable but also inevitable feature due to the limited number of computers available. Besides the work carried out during class, pre-service teachers could use the classroom in their own time, and in fact much of their work was done autonomously and independently.

This course is eminently practical. Most of the time was spent on practical activities carried out by the pre-service teachers while the instructor supported each group, checking on their progress and trying to help them solve their problems. The instructor focused on the introduction of new concepts and explaining the basic workings of the various software.

The work in this course assumed that pre-service teachers could appropriate a new tool and language—in this case ICT, stressing Internet as a means of production and expression—through a process based on two main types of activities: exploring materials and resources and carrying out a project. These activities included (i) periods of practice, in which pre-service teachers worked on tasks proposed by the instructors or carried out specific tasks of their own initiative; (ii) periods of discussion, whether in group, between the group and the instructor or involving the whole class, and (iii) periods of creative activity, in which pre-service teachers were designing and developing an educational project. This activity was included in the specific preparation required for teaching their subject, since the task required the re-elaboration of mathematical issues from a teaching perspective.

The web pages produced by pre-service mathematics teachers during these two school years cover topics such as numbers, geometry, trigonometry, history of mathematics, probability, logic, functions, derivatives, conic sections, sequences, and equations. Next we refer briefly to some of these web pages so as to show the work carried out by the course participants.

One of these web pages, "The World of Fractals" (www.educ.fc.ul.pt/icm/icm99/icm14), is a resource for those intending to learn about some aspects of fractal geometry. These pre-service teachers make a reference to Benoit Mandelbrot and briefly explain what a fractal is; in the "Fractal Gallery" they also present a chronology of the most representative fractals. In this gallery the user may also listen to fractal music and download certain parts of this music. There also is reference to chaos theory and its relation to fractal geometry. Fractals also are

connected to the secondary school curriculum. In the "Activities" item, a set of working proposals is presented for pupils at this level. Among these the most interesting are the construction of a fractal from cuts on a sheet of paper and the construction of the Koch curve with the GSP software.

The "Pascal Triangle" web page (www.educ.fc.ul.pt/icm/icm99/icm48) stands out for the pleasant and suggestive way in which the pre-service teachers organized its presentation. This page deals not only with the Pascal triangle but also with some of its properties that are related to particular sets of numbers. Therefore, detailed reference is made as to how to find prime, figurative, Fibonacci, and Catalan numbers as well as the powers of 2 and 11 in the Pascal triangle. The page also shows the relation between the structure of the Sierpinski triangle and odd numbers in the Pascal triangle. In the "How to construct" item, we may learn how to construct the Pascal triangle. An application is also available to the user who wants to visualize a triangle with a given number of lines. This web page also includes an item on problems.

The web page "The Fibonacci World" (www.educ.fc.ul.pt/icm/icm99/icm31) has interesting information concerning sequences, with special consideration to the Fibonacci sequences. In the item "Applications of the Fibonacci sequences", besides the traditional problem of rabbit reproduction, the pre-service teachers present some examples on the relation of this sequence to nature, to the Pascal triangle, and to the golden sections. This item also presents a set of application proposals regarding the eighth and eleventh grade curricula. This web page includes another section called "Fibocuriosities", where a trick with Fibonacci numbers is presented. It also suggests further research into this theme through a number of links related to the Fibonacci sequence.

Finally, we mention the web page "Decomposition of Figures and the Pythagoras Theorem" (www.educ.fc.ul.pt/icm/icm99/icm25), designed mainly for eighth grade teachers and pupils. Besides brief reference to basic geometrical notions, this web page illustrates the situations it presents with a strong graphic component. It has a section dedicated to puzzles where the tangram and the pentominoes are explored. This is a web page that fosters user interaction through animations produced with GSP. It presents a Java Aplet that allows users to work on the tangram pieces and construct the suggested shapes. Technically speaking, this page is very good and reveals quite a sophisticated use of the software presented in this course.

Pre-service teachers were especially interested in the GSP, which several groups used in their web pages. Some even used Java Sketch to produce animations. Due to time constraints, we did not cover all the software that could be relevant. We felt it was better to study in depth some good pieces of software, as pre-service teachers may explore other software later on. In their pre-service education, the important thing is that they thoroughly

appreciate the features of a few good examples of software that may be used in mathematics teaching.

Working with ICT involves many unforeseen technical obstacles (faulty computers, problems with the local server, network problems, and problems with external communication). At times these problems disturbed the class process and forced the instructors to change their plans. Producing the web pages often took pre-service teachers much more time than initially envisaged. These obstacles and problems show the need for careful planning and monitoring in this type of course.

During classes, the instructors tried to pay attention to the way pre-service mathematics teachers were involved in the different activities, joining in their projects, helping to solve problems, and making suggestions. At times the instructors would sense a strong concern among the pre-service teachers as to whether it would be possible for them to finish their projects within the established deadlines. In moments like these the instructors' role was to help them overcome their specific difficulties. Also, and probably most importantly, the instructors encouraged the pre-service teachers and made them believe in their capacity to deal with the problems they were facing. At the end of the semester, the work carried out in the course, especially the web page produced, was discussed during an hour with each group.

STUDY METHODOLOGY

The observations carried out by the instructors during classes, the discussions with pre-service teachers at the end of the semester, and the reflection regularly undertaken by the instructors provided a general evaluation of the course. We were concerned with what went well and what went badly with our approach and with understanding the meaning of this educational experience for the participants.

In order to study in more depth the effect of the work carried out in the course on the pre-service teachers we also administered a questionnaire including the following items:

1. How do you define your current relationship with ICT? What evolution occurred in this regard during this semester?
2. Did this course provide you with the development of perspectives about the role of ICT in mathematics teaching? Specify.
3. How do you see the future of ICT in schools?
4. How do you evaluate the work that you carried out in this course?
5. Comment on the working methodologies used in this course.
6. What suggestions can you give to improve this course?

This questionnaire was handed out in the last class and included six free-response questions with ample space to answer them. This questionnaire addresses pre-service teachers' relation to ICT, their views on the role of ICT in mathematics teaching and in school, the evaluation of the work that was carried out, and the working methodologies used in the course. The free-response format was chosen to capture pre-service teachers' own perspectives regarding their experiences in this course and, indeed, most of them provided lengthy answers to the questions proposed.

A set of categories and sub-categories was developed in order to code the answers. For example, pre-service teachers' views encompassed commitment, difficulties, identified learning, and personal relations. Perspectives about these issues were gathered from the responses to all six questions. The same was done for the categories of professional knowledge and professional identity. We used the NUDIST (version 4.0) data analysis software to code the data and to provide the corresponding reports.

In the following sections, first, we seek to identify the way pre-service teachers view the work they carried out and their own evolution; next, we discuss to what extent this work helped them develop their professional knowledge and identity.

PRE-SERVICE TEACHERS' VIEWS ON THE COURSE

At this point we show the assessment pre-service teachers make of the work they carried out. Namely, we refer to the commitment they put into their work, the difficulties they encountered in fulfilling it, what they learned and, finally, the evolution of their relation to the computer.

Commitment

The pre-service mathematics teachers were unanimous in stating that this subject demanded a lot from them, not only due to the amount of hours they spent constructing their web pages but also because of the obstacles they had to overcome, which often corresponded to intense learning moments. Generally speaking, they describe their involvement in this subject in terms of the need for a lot of commitment and effort. As one pre-service teacher states[3]:

> … I tried really hard in this subject for several reasons. First because some of the new technology we used was totally unknown to me and I had to learn (that took a lot of hours). Secondly, I felt motivated to learn, I thought it was great to do a web page for the Internet.

Their comments also show us that at the end they felt successful and that, looking back at the whole process, they feel personally fulfilled. As one of the pre-service teachers says:

> The work involved a lot of effort, a lot of research, a lot of commitment and some tiredness, but I can say it was really gratifying. My "scope" of knowledge increased significantly with this work.

Difficulties encountered

The drawbacks pre-service teachers encountered, mostly technical ones, were viewed as a major limitation because they used up too much time, a lot more than seemed reasonable to the teachers. Despite this situation, in general they praised this course, revealing that the positive aspects, namely regarding what they learned, outweighed these obstacles:

> Sometimes I actually felt an excessive and unpleasant pressure (lack of time, faulty computers, software that didn't respond as required). In any case, looking back, I think I learned so much, so much, that it was really useful.

The positive way in which they evaluate this experience is closely associated to the degree of satisfaction with the final result of their work, when their web pages were published in the Internet.

Identified learning

Many of the pre-service teachers took a truly important qualitative leap regarding the use of the Internet, where many of them had never even done any research. After considering all the effort involved in the process, one of the pre-service teachers in these circumstances stated:

> For me it was a great conquest never to have navigated on the Net and to wind up, after three months, editing a web page that now cruises the whole world. This reality seemed so remote to me at the start of the school year! ...

> I must say it was a challenge which, like all challenges, made me sweat, but fortunately all ended well. Once again, I think the fact that I attended this course really thrilled me and taught me things that will stay with me for the rest of my life.

Besides what they learned regarding the use of the Internet, many also refer to the opportunities for exploring educational software, which they consider to be quite relevant in the present mathematics teaching context.

Concerning the project they developed, the pre-service teachers considered that the most important aspects of their experience are those directly related to the process of constructing a web page; however, they also stress their work on mathematical themes. The level of familiarity with these themes varied: sometimes one theme was chosen because the pre-service teachers already were interested and felt at ease in that area; at other times the intention was to learn more about subjects that were practically or totally unknown to them. Some pre-service teachers stressed the fact that they could study topics that are not usually part of the

curriculum and they could study them in a different way, through explorations with ICT. They indicated that this work promoted their mathematical development: "it allowed me to expand my mathematical knowledge". By exploring these themes on their own, pre-service teachers developed a broader sense of internal and external connections, history and applications.

Evolution of the personal relationship

Finally, we analyze the way these pre-service teachers talk about their relationship to ICT and the evolution of this relationship. This is a theme about which they talk a lot and willingly. Their responses show that the majority changed their attitude regarding ICT and established a better relationship with the computer. In many cases, this change occurred in terms of their readiness to learn to work with the computer, enhancing their self-confidence. An example that illustrates this quite well is the following:

> If at first I was mainly scared (almost) to touch the computer, nowadays I am more comfortable doing so, which doesn't mean I don't make mistakes, but it is an easier relation.

When they attempt to describe their present attitude towards new technology the pre-service teachers use terms like "more comfortable", "less formal", "positive", "closer" and "new". In general they also point to a very positive evolution of this relationship. In some cases this evolution in the way they view the computer is also apparent with the disappearance of a negative metaphor – the "beast" (and in certain cases the "hideous beast").

> Throughout the program two other courses have put me in touch with that "beast", but only this year … did I lose my fear of computers and stopped viewing them as "beasts".

Ignorance regarding the basic aspects of using a computer is one of the reasons pointed out by the pre-service teachers when explaining their insecurity and a certain attitude of rejection towards the computer from the start. Much of the computer's important potential was also unknown to some of them:

> The start of the semester coincided with me buying a computer. At the beginning I just used it as a typewriter, whereas now I use it as a computer, capable of doing much more than a simple typewriter.

A great many of the pre-service teachers declare that, prior to this course, ICT did not arouse their interest in the least and sometimes they began with poor expectations related to work in this course: "When the semester began my expectations of the work I would be doing were low. This is because my experience of new technology was frankly limited." This is one

of the aspects where an evolution was most felt. Interest in ICT grew throughout the semester and at the end pre-service teachers were eager to learn more in this field, though most consider what they have already learned to be very positive:

> So I think that this year, in this course, I learned a lot and I feel much more at ease. I don't consider myself an expert, far from it, I still have plenty to learn. But I'm much more motivated to learn more.

The will that some pre-service teachers express to investigate new software is yet another indicator of having developed a stronger relationship to new technology:

> I think I sort of trivialized my fear for computers. Working constantly with a computer allowed me to develop curiosity and pleasure in discovering new software. So I underwent a very positive evolution in relation to new technologies.

Another very important evolution is found in some pre-service teachers who go from a bad relationship to frequently using ICT, even on a personal level:

> My relation has improved quite a lot, for before having [this course] I was suspicious of computers and now I'm "almost" totally dependent. A day doesn't go by without turning on the computer and seeing something on the Internet.

DEVELOPMENT OF PROFESSIONAL KNOWLEDGE AND IDENTITY

Next, we discuss the role of this course in pre-service mathematics teachers' education. We analyze to what extent pre-service teachers developed their professional knowledge in two fields—their conceptions about ICT in mathematics teaching and the impact of working methodologies—and how they show certain aspects that refer to the development of their professional identity.

General perspectives about ICT in mathematics teaching

The first question we discuss is the contribution of the course to the development of a general perspective about the role of ICT in mathematics teaching.

Pre-service teachers acknowledge that this course clearly made a difference in their professional preparation through raising their awareness of the potential of ICT for mathematics teaching. Many of them probably had heard talk in the media about the increasing importance of this technology in society and in school, but they knew little else besides this.

According to their answers, it is possible to conclude that they evaluate the new perspectives the course provided very positively, especially because they feel the educational system expects mathematics teachers to be well prepared in this field:

> In fact, since the beginning of the semester, the educational issues I learned enabled me to make some progress regarding the use of new technology. So even though in the beginning I didn't quite understand what the computer was for in the classroom, today my opinion has not only changed but it has really enriched, through discovering software and techniques to apply in mathematics classes.

Most pre-service teachers refer to the Internet, GSP, and Modellus as facilitators of the teacher's role. Many of them regard these tools as sources of motivation: "ICT in the mathematics class is a must. This is the only way to make mathematics approachable and attractive to our pupils in the future." Others feel that the software explored in the course will be useful to support learning of specific topics, such as geometry. As one of the pre-service teachers puts it: "Using GSP showed me that when pupils use it they understand geometry better, so I think it's important to apply GSP in middle and secondary school classes". In fact, many pre-service teachers believed that this software would offer great possibilities for mathematics teaching.

Another aspect revealed by pre-service teachers' answers is that many of them feel that the use of ICT in mathematics teaching offers the possibility of promoting a new vision of mathematics, notably because this technology can make mathematics applications more visible. This goes along with the development of a perspective of ICT use that values the pupils' active role in learning and autonomous work, showing a high regard for experimentation and exploration in the mathematics classroom. Two pre-service teachers commented in this respect:

> By using new technology we can portray a smoother view of mathematics, so that pupils feel more motivated to "discover" mathematics, since nowadays any kid can have access to a computer.

> We can use the computer, the Internet, GSP, to carry out different activities through which we allow pupils to explore mathematics by themselves, because when they themselves make a discovery, classes become active and autonomous and this is the only way for them to construct their own learning.

Another pre-service teacher pointed how computer representations can help to "visualize abstract concepts that are difficult to understand". Others acknowledged the technical possibilities the computer holds for mathematics teaching regarding the visualization, exploration and manipulation of objects:

> The movement that can be created in a PC is impossible to illustrate in a book, such as geometrical figures turning, or seeing three-dimensional graphs under other angles, and so on.

> New technology in school may facilitate the whole teaching-learning process in the sense that they enable an enormous range of exploration, visualization, and experimentation that would otherwise be practically impossible.

Pre-service mathematics teachers also valued the work carried out on searching for information and developing pages on the Internet. They consider that this activity has great potential for both teachers and pupils. As one of them says: "using the Internet we can easily have access to contents from all over the world and this expands our knowledge, including mathematics". As for the pupils, one pre-service teacher says they "can learn a lot by searching in the Internet". Pre-service teachers regard the research activity on the Internet as inquiry and point out the possibility of drawing a parallel with pupils' learning processes. One comments that: "it was also important to get to discover the Internet more 'intimately' because that enabled me to see how it may be applied in research projects that can easily be developed in a mathematics classroom". The uses of the Internet in the mathematics classroom foreseen by many of the pre-service teachers imply a different role for the teacher.

Pre-service teachers indicated that they would like to use ICT in their teaching. They tend to agree that this technology will have a very strong role in the school of the future. Regarding the current situation in schools, they expressed strong concerns, mentioning the limited number of computers available and perceiving a dominant opinion in teachers against the use of technology. However, some visits to schools that they undertook in various field experiences of the teacher education program showed them that the use of computers in schools is possible when there is a group of teachers committed to put innovative activities into practice.

Impact of working methodologies

The second question that concerns us is the contribution of this course to pre-service mathematics teachers' development of an appreciation for working methodologies that value the pupil's active role, research, collaboration, and group work.

At the beginning of the semester most pre-service teachers found the tasks extremely challenging, mainly due to their lack of knowledge and familiarity with computers. As we have already mentioned, they felt that in order to meet these challenges, they needed a lot of determination, both in individual and group work. The pre-service teachers' evaluation of the level of involvement required reveals that some of them finished the course with a sense of personal development, namely with a more positive attitude towards new learning situations. As one of them tells us:

> At first, and speaking for myself, it was a blend of fun (when we solved a problem) and outrage (when the computer decided to be "mean" at inappropriate moments). But above all it was positive to "sweat" until we managed to get where we wanted. Once again I think having attended this course was something I really enjoyed and it taught me things that will stay with me for the rest of my life.

Pre-service teachers considered that the work carried out in this course was essentially practical and did not feel that the approach was directive or transmissive. In some of them we also find a change in perspective about how to learn to work with ICT:

> Throughout the whole semester I progressively lost my fear of the computer and abandoned a wrong idea I had. I thought that to work with a computer you needed a course, which is totally wrong, because it's the computer that teaches you.

> I think that [the work] carried out was productive. . . When I say productive, I am especially referring to the fact that I learned through my own experience, discovering with my group partners and/or by myself, and therefore what I learned will not "get lost" easily.

Their responses emphasise learning by doing and learning by discovery through their own experience, as the work with the computer involves the students' active involvement in the learning process.

Several pre-service teachers explicitly recognize that the student-centered nature of the methodology used led them to participate actively and promoted exploration and experimentation. Some thought of it as an example of "teaching through discovery" which sought to facilitate meaningful learning. The following comment shows this:

> I think the methodology that was used, which often or almost always led the pupil to discover things for himself (or in a group) and to investigate, is very fruitful, for through it we develop capacities that will be useful in new situations we will have to solve by ourselves.

> Working with the Sketchpad was important because it made us think and discover geometrical properties about the matters we had to study. It is a good methodology that we, future teachers, can adopt in mathematics teaching, if possible.

The projects and research carried out in this context stand out as the most relevant aspects of the course activity. Some pre-service teachers were pleased with the opportunity they had to choose the theme for their project and learn more about it, emphasizing the inquiry

process. For instance, one of the pre-service teachers evaluates group work in the following way:

> An interesting work on an interesting theme which is still not well known … . Research work was performed at several levels and after collecting information it was "filtered" and presented in the form of a web page.

As a result of the research that was carried out within their projects, some pre-service teachers mentioned that they began to do Internet searches more often and that they developed a taste for investigating new software by themselves.

Many pre-service teachers feel that group work was a very positive aspect of the course and had several explanations for this. For example, one of them considered that group work improved the quality of the final product: "I think that with my colleagues' collaboration, with the work we did together, the result was a really successful web page." In some cases positive reference is also made to the discussions within the group:

> Group work is a fundamental working methodology. Of course there is or there may be a clash of opinions… But this clash leads to a "discussion" and intensive exchange of opinions until we reach a consensus.

Besides this, some of the pre-service teachers see group work as a preparation for their professional activity in schools. For example, one of them says that the experience acquired in this field will be extremely important in the future "as collaboration among teachers is fundamental for the evolution … of mathematics teaching".

Development of a professional identity

A third point of interest is the impact of the activity on the development of a professional identity. Pre-service teachers' responses show aspects of this process, especially as they assumed new perspectives and values that they related to their future professional role. The development of a professional identity as a mathematics teacher involves, among many other things, the biographical process of establishing a personal relation with ICT and developing perspectives about the mathematics teacher's role regarding this technology. The following statements illustrate this process:

> Contrary to my initial opinion, I think that the way one acquires more knowledge is not having always someone helping us but discovering on our own. It was what happened with GSP and it worked perfectly with me.

Right now, my relationship with technologies is very good, because I try to do as much as I can of my work with the computer and I do not have problems investigating new software or new technologies.

At the beginning I did not see the ICT course as a useful one … . Today, with the familiarity that I acquired, all that I do involves the use of the computer and the Internet, where I find countless things that I need and that have become indispensable for carrying out my "job" well as a student and that, for sure, I will use in the future in the same way as a teacher.

As well as GSP, there is other software equally useful in mathematics teaching and I think that teachers should learn how to use them to innovate their classes, make them less teacher-centered and lead pupils in exploring and discovering.

Explicitly or implicitly, these statements project future activities and roles as well as assessments of past ideas and perspectives that pre-service teachers no longer value. There is evidence of a great change in their relationship with ICT as well as in recognizing its importance in mathematics teaching. Many of them claim that they developed new perspectives about how learning takes place, emphasizing discovery learning versus transmissive teaching. These experiences led participants to anticipate their future role as teachers and to relate this to what they think is happening in schools. These statements mark aspects of pre-service teachers' biographical identity defining processes, involving transactions between inherited and envisioned identities as they reflect upon past ideas and conceptions and start showing appreciation regarding what their future work as mathematics teachers will be.

In other responses we see influences of relational processes involving pre-service teachers' interactions with others, including their instructors and other pre-service teachers:

The class went by so fast and. . . we were left to ourselves, given freedom to work and to solve our own problems. When we needed the instructor, she was always there to help us.

The instructor-student relation couldn't have been better, whenever we needed help the instructor would run to our rescue, but would always encourage us to try to solve the problem we were facing by ourselves first. The work carried out with Frontpage developed us as researchers.

Of course, we may have a big mismatch of opinions [within the group] but they're easy to solve. But this clash leads to a "discussion" and intensive exchange of opinions until we reach a consensus.

> And in the future, [the fact that we worked in groups] will be extremely important, as collaboration among teachers is fundamental for the evolution... of mathematics teaching.

This relational process led pre-service teachers to appreciate the value of group work, despite all its inherent difficulties, and to value the teacher-student relation as a complex interplay involving both support and challenge. They acknowledge the need for negotiations involving different people in order to reach some level of agreement. They also indicate their appreciation of collaboration, an important aspect of mathematics teachers' professional identity.

CONCLUSION

In this paper we present the work developed in a one-semester course on ICT in a pre-service mathematics teacher education program. The orientation we adopted led to successful changes for those pre-service teachers whose initial attitudes were of fear and suspicion and who developed a remarkably positive relationship with this technology. This course led pre-service teachers to stop feeling menaced by ICT and to become confident users of the Internet.

Pre-service teachers take this course in the beginning of the fourth year in the program. The course is concerned with developing ideas about teaching and learning but it does not aim directly at a preparation for using ICT in the classroom. That preparation will come later, in the next semester, in a mathematics methods course that builds upon the issues discussed here. The course aims to promote a positive relationship with ICT in pre-service teachers who tend to know very little about this technology and are suspicious about its use in education. It deals with mathematics in a cultural and educational perspective but it is not a mathematics course that uses ICT to promote the learning of some mathematics topics. The work carried out helped pre-service teachers to grasp more connections among mathematics topics, their historical development, applications, and aspects of classroom learning processes.

The technical quality of the pre-service teachers' web pages exceeded our expectations. In general, these pages have an excellent presentation and many include interesting solutions in their effects and general structure. Content-wise, the production of these pages represents a very important moment in the process of assuming a professional perspective, as pre-service teachers increasingly seek to deal with mathematical themes from a teacher's point of view. In this work, there was plenty of inquiry, reflection, and discussion among pre-service teachers and between them and the instructors. That was apparent in their conceptual evolution.

Pre-service teachers got a good idea of the multiple educational possibilities of this new tool. Some seemed to become somehow disturbed with the fact that they did not thoroughly discuss the teaching activities that they should propose in the future to their pupils. This is a common concern that they carry to all their courses at this point of their preparation, regarding which it could be premature to provide the type of answers they are looking for. Even so, pre-service teachers developed new perspectives on the use of ICT in mathematics education and some appreciation for working methodologies that promote active learning. Both are important aspects of the professional knowledge necessary for teaching mathematics. Pre-service teachers also took important steps in assuming professional values and attitudes, such as the need to discover and investigate by themselves and the important role of discussions and collaboration in carrying out professional tasks. These are undoubtedly important aspects that characterize mathematics teachers' professional identity.

The course described in this paper aimed to change the personal relationship of pre-service teachers with respect to ICT and to provide them with a general perspective about the uses of this technology in mathematics education. It used a rather open-ended approach, especially in the project phase, assuming that pre-service teachers need to appreciate the value of learning by exploring and carrying out supervised projects. We regard this experience as an important foundation to help participants reflect on the role of the teacher in a technologically rich classroom.

The pedagogic approach used in this course, which focused on pre-service teachers' exploration and discovery and on group production of a project, was effective in supporting the objectives that were set out. Specific educational software for mathematics was also dealt with. However, contrary to what often happens in introductory ICT courses (see, for example, Robinson and Milligan, 1997), we deliberately decided to work in-depth with a very small number of software (browsers, Frontpage, GSP, and Modellus). Our option allowed pre-service teachers to master the software they studied and, at the same time, to develop the capacity to explore other software by themselves in the future.

The course's aims, structure, and contents were targeted at the characteristics of the participants. The course design is not original or unique, but the evaluation carried out showed that it constituted an innovative and reasonable response to our particular working conditions, contributing to the development of the professional knowledge and identity of the participants. Of course, as technology develops and its uses diversify, many aspects will have to be reconsidered in terms of global planning, activities proposed, and discussions about the educational aspects of ICT.

As we mentioned previously, anxiety regarding technology is a significant issue for pre-service teachers (Yildirim and Kiraz, 1999). By gaining confidence in the production of web pages, the participants in this course became not only consumers but also potential producers

of contents for the Internet. This is quite an important *nuance*. The production of web pages about projects, studies, centers of interest, etc., is one of the most promising possibilities this resource provides both for the teachers' work and for the pupils themselves. Here, pupils may find an important way of expressing their activity, interacting with other pupils, teachers, and members of the educational and non-educational communities. Thus, the school is provided with new possibilities, the development of which can be facilitated through teachers' pre-service (and inservice) education. The results achieved suggest that in the future we may expect many teachers to be not only consumers of Internet contents but also producers and co-producers of web pages with their pupils, sharing their explorations of mathematics themes and their teaching-learning experiences in this course.

ICT is not just a simple auxiliary tool. It is an essential technological element that shapes the social environment, including mathematics teaching. Therefore, it influences the mathematics teacher's evolution regarding professional knowledge and identity. Future teachers must develop confidence in using ICT and a critical attitude towards it. They need to be able to integrate ICT within the goals and objectives for mathematics teaching. The task of pre-service teacher programmes is not to help participants learn how to use this technology in an instrumental way, but to consider how this technology fits into the development of their professional knowledge and identity. The curriculum of this course was intended to provide pre-service teachers with comprehensive experiences of working in ICT projects, but other contexts must be created that take into account other aspects of this quickly expanding technology, in particular its potential in terms of long distance interaction and collaborative work.

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[2] The Geometer's Sketchpad is a dynamic geometry software that allows studying properties of figures that remain invariant in different kinds of transformations. Modellus is a software that allows the construction of mathematical models using different representations and the simulation of physical phenomena.

[3] Pre-service teachers' quotations are translations from Portuguese. The expressions used in the original words are often idiomatic and involve imprecise use of words (such as using "perspectives" to mean "expectations"). We opted for an interpretive and not a literal translation to enable a better understanding by English speaking readers.