INFORMATION TECHNOLOGIES AND THE DEVELOPMENT OF PROFESSIONAL KNOWLEDGE AND IDENTITY IN TEACHER EDUCATION[1]

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This paper addresses the preparation in ICT of preservice mathematics teachers. We describe the aims, assumptions, and work carried out in a course offered at the University of Lisbon and briefly discuss the processes involved in the development of professional knowledge and the formation of professional identities. Using a qualitative methodology, based on the administration of free-response questionnaires to the student teachers enrolled in the course in 1999-2000, we analyze their general perspectives about ICT, the implications of the use of ICT in their view of teaching methodologies, and their development of a professional identity. This work provides suggestions for teacher education practice and for further research.

INTRODUCTION

Mathematics teachers may use in their practice a great variety of educational ICT (Information and Communication Technologies) materials and resources, including general-purpose tools and educational software (NCTM, 2000). The World Wide Web may be regarded as a "metatool" where one can find information about new developments in mathematics and mathematics education, software, sample tasks, classroom ideas, reports of experiences, news about meetings and other events, etc. Preservice teachers need to be acquainted with these resources and to develop confidence in using them (Bottino & Furinghetti, 1999; Ponte & Serrazina, 1998). In Portugal, this is quite problematic since they often arrive at this stage of their professional preparation with previous little contact with new technologies. Not surprisingly, they are rather suspicious regarding the role of ICT in education and have little confidence using it.

Since ICT is an ever expanding world some choices need to be made regarding what is most important to know. In addition, learning about ICT and its uses in mathematics education must assist preservice teachers in their process of developing professional knowledge regarding this domain as well as concerning

[1] Ponte, J. P., & Oliveira, H. (2002). Information technologies and the development of professional knowledge and identity in teacher education. In J. Novotná (Org.), *Proceedings of II European Conference in Mathematics Education* (CERME II) (pp. 310-321), Univerzita Karlova v Praze, Pedagogická Faculta, Praga, República Checa.

teaching and learning mathematics, since all these aspects are interrelated (Berger, 1999). Also, it may help to develop a professional identity, stimulating the adoption of a standpoint and values of a mathematics teacher. The purpose of this paper is to discuss the effects of a university course dedicated to the use of ICT in mathematics teaching in student teachers' perspectives about ICT and classroom methodologies and their development of a professional identity.

THE ICM COURSE

In Portugal, the school system is made up of several "cycles". Basic education is compulsive and includes three cycles (cycle I for pupils aged 6-9, II for pupils aged 10-11, and III for pupils aged 12-14). Secondary level education is optional, has different strands and is attended by pupils that may be 15-17 years old or older (if previously retained in one or more grades). Mathematics is a separate subject taught by a specialist teacher from the beginning of cycle II, that is, from grade 5 onwards.

The mathematics teacher education program at the University of Lisbon prepares teachers for grades 7 to 12 (that is, to teach cycle III of basic education and secondary education). This program includes three years of mathematics studies, followed by one year of educational studies and a last year of practicum in a school. Usually, 110-120 new candidates are admitted every year in the program.

The ICM course[2] which constitutes the focus of this paper integrates the 7th semester of this program—the first semester dedicated to educational studies. We focus on the work done in 1999-2000. The aims of ICM are to facilitate the acquisition of competencies in ICT and to promote the development of new perspectives about its use in mathematics teaching. The main idea is that pupils can learn mathematics by doing explorations and investigations and that the processes of discovery and proof are at the core of mathematical activity. The use of ICT in mathematics teaching can be very useful to emphasize those processes. We decided to work with a limited number of pieces of software (The Geometer's Sketchpad [GSP] and Modellus), as we intended student teachers to explore them in depth. They got acquainted with these software and their educational applications within present mathematics curricula in Portugal.

Student teachers used GSP in several activities to see its possibilities for studying geometry, always through an investigative perspective. Their mathematical preparation leads them to use a deductive approach to solve all kinds of problems, and we used GSP as a powerful tool to show that the perspective of mathematical creativity has many forms other than deduction (de Villiers, 1997). Student teachers started with simple mathematical questions about properties of triangles and quadrilaterals, then they explored certain features of conics and later they investigated invariant properties of some

[2] ICM stands for "Interdisciplinaridade Matemática-Ciências".

geometrical transformations. Finally, we explored Javasketch's possibilities for including animations with GSP in webpages.

Modellus is a software for constructing mathematical models of all sorts of phenomena, showing their evolution in time through different types of representations. Some student teachers used it in their group project. And the Internet was explored in many of its features, research techniques and elementary publication techniques and, at the same time, we reflected upon its use in schools.

At the beginning of the year most preservice teachers have limited experience with ICT, especially with the Internet. Besides lacking competencies in this area, they also lack confidence to work with computers. This prompted us to opt for two main characteristics for the course's methodology: (i) extensive practical work with computers and (ii) collaborative group work. The role of the instructors was to create stimulating learning situations, to challenge student teachers to think, to support their work, and encourage the diversification of learning routes.

The course was attended by 95 preservice teachers. They were divided in four classes that met twice a week for two hours. The classroom was equipped with 9 computers connected to the Internet that permitted the work in small groups of two or three preservice teachers at each computer. They had free access to the computers when there were no classes in the room.

The main component of the work carried out in ICM was the development of a project, consisting of the creation and publication of a group homepage focusing on a mathematical theme that could be of interest to teachers and preservice teachers. Each group was responsible for the choice of the theme and for searching materials. The preservice teachers were encouraged to do their research on the Internet and to find other sites related to their theme, mainly in Portuguese, so that they could have some public impact. In their research, the groups also made extensive use of traditional materials such as books, textbooks, and journals.

The Web pages produced cover a large variety of topics in geometry, functions, numbers, algebra, probability, and combinatorics, presenting theoretical information and practical work. There is a general concern for presenting historical background about the theme and to show some applications to the real world and other sciences[3].

[3] The pages can be found at the address: http://www.educ.fc.ul.pt/icm/pagalunos.htm.

THE DEVELOPMENT OF PROFESSIONAL KNOWLEDGE AND PROFESSIONAL IDENTITY

Mathematics teachers' professional knowledge may be regarded as a blend of declarative, procedural, personal and strategic knowledge that is used in situations of practice (Shulman, 1986). This includes classroom teaching, but also other professional roles such as tutoring pupils, cooperating in schools' activities and projects, interacting with members of the community, and working in professional groups. Teachers of mathematics need (i) to know about educational theories and issues, (ii) a good foundation in their subject, and (iii) a strong preparation in the specialized field that concerns their activity: the didactics of mathematics. This includes perspectives about curriculum, students' learning, and classroom instruction and assessment (Boero, Dapueto, & Parenti, 1996). Teachers' knowledge is rooted in such beliefs and conceptions about mathematics and its teaching (Ponte, 1994; Thompson, 1984). To challenge such ideas can be regarded as a central aim in teachers' professional development (Carrillo, 1998).

Teachers' professional knowledge may also be viewed as mainly tacit and originating from practice through a process of personal reflection (Elbaz, 1983; Schön, 1983). Therefore, it is not sufficient merely for student teachers to have knowledge of mathematics, educational theories and didactics. Since professional knowledge is deeply personal and related to action, its development requires diversified working contexts and the experience of situations as close as possible to professional practice.

ICT is increasingly important in the activity of mathematics teachers, (i) as educational media to support pupils' learning, (ii) as professional productivity tools, to prepare materials for classes, to carry out managerial duties, and to search for information and materials, and (iii) as an interactive *medium* to interact and collaborate with other teachers and educational partners. Teachers need to know how to use the new equipment and software and also what their potential strengths and weaknesses are. These technologies, changing the environment in which teachers work and the way they relate to pupils and to other teachers, have an important impact on the nature of the teachers' work, that is, on their professional identity.

Developing a professional identity involves assuming the essential norms and values of the profession and an attitude of commitment to improve oneself as an educator and the educational institutions. A mathematics teacher must carry out the proper professional activities of a teacher and identify personally with the teaching profession. That means assuming a teacher's point of view, internalizing the teacher's role and ways of dealing with professional issues in a natural way. For example, choosing to decide about the value of a variety of resources available for teachers and learning to use them is an increasingly important part of being a teacher. It requires knowledge of exploring software

and Web sites. It requires an attitude of openness and confidence in using computers (Berger, 1999).

Berger & Luckman (1973) regard the development of a professional identity as an aspect of the development of secondary socialization. According to these authors, primary socialization refers to the introduction of the individual to the society, becoming part of it. The child internalizes the roles, attitudes and values of significant others, with little possibility for critical distance. Secondary socialization comes later on, as the internalization of "institutional worlds" and involves the acquisition of specialized knowledge (including professional knowledge). Such specialized knowledge is constructed with reference to particular fields of activity that draw on specific symbolic universes.

The construction of social identities is seen by Dubar (1997) as involving two complementary processes. One, the biographical process, is the internal construction by individuals through time of the social identities using the different categories offered by the institutions in their environment. It involves a transaction between inherited and desired identities. The other, the relational process, involves external transactions between the individual and significant others. It concerns the recognition in a given moment and legitimizing space of the identities related to knowledge, competencies, images and values expressed in the underlying action systems.

METHODOLOGY

In this study, data was gathered through a written questionnaire completed anonymously on the last day of classes by the preservice teachers who attended this course. The questionnaire included six free-response questions and ample space was provided to answer them:

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?

A set of categories, subcategories and subsubcategories was developed to code the answers. The data analysis software NUDIST (version 4.0) was used to classify them and to provide reports. In this paper only a few categories are used, those most related to the questions we discuss.

ANALYSIS

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

1. Evolution of student teachers' perspectives. They recognize that this course made a difference to their professional preparation regarding the potential of ICT for mathematics teaching. Many of them probably had heard the media talking about the importance of ICT in society and in schools, nowadays, but not much more than that. According to their answers, it is possible to conclude that they evaluate the new perspectives that the course brought to them very positively, especially because they think the school system expects teachers to be well prepared in this area:

> "In fact, since the beginning of the semester, the educational issues that I learned enabled me to move on regarding the use of new technologies, somehow. So, if in the beginning I did not understand very well what was the purpose of the computer in the classroom, today this opinion not only changed as it enriched a lot, through discovering software and techniques to use it in mathematics classrooms."

2. ICT in the classroom. Most student teachers refer to the Internet, GSP, and Modellus as facilitators of the teacher's role. Many of them regard these instruments as sources of motivation: "it is indispensable to use new technologies in the mathematics classroom. This is the only way we can make mathematics accessible and attractive to our future pupils". Others consider the software explored in the course useful to support learning specific themes, such as geometry. As one student teacher says: "The use of GSP showed me that when pupils use it they understand geometry better. Therefore I find it important to use GSP with all age level classes". In fact, this software is referred to by many student teachers as having a lot of possibilities in mathematics teaching.

Another aspect revealed by the data is that many preservice teachers consider that the role of ICT in mathematics teaching goes beyond motivating pupils. They see it offering the possibility of promoting a new vision of mathematics for them, on the one hand, because ICT can make applications of mathematics more visible and, on the other, because the use of ICT stimulates pupils' autonomous work. One preservice teacher commented, in this respect:

> "By using new technologies it is possible to provide a smoother perspective of mathematics, so that pupils feel motivated to "discover" mathematics, since today any youngster can have access to a computer."

Student teachers regard the work carried out on searching information and publishing pages in the Internet highly. This is considered to be an activity with a lot of potential for teachers and pupils. As one of them says: "by using the Internet we can easily have access to information from all over the world, which enables us to expand our knowledge, also in mathematics". Regarding the pupils, one student teacher says that they "may learn a lot searching in the Internet". Student 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 discover the Internet in a more "intimate" way, since that enabled me to see its application in research projects that is easy to develop in a mathematics classroom".

3. Perspectives about learning with ICT. Some preservice teachers show strong evidence of having developed a perspective of ICT use that values experimentation and exploration, and pupils' active role in learning. One of them put it very nicely:

> "We can use the computer, Internet, and GSP to do several activities through which our pupils may explore mathematics themselves, since as they made the discoveries, the classes become active and the pupils become autonomous and only in that way may they construct their own learning."

This vision about mathematics teaching, emphasizing exploration and investigation, that permeated ICM's classes, has a strong influence on student teachers' perspectives. As one of them says:

> "The work undertaken with the Sketchpad was important since it helped us to think, to discover by ourselves geometrical properties regarding the topics that we were given. It is a good methodology that we, future teachers, may use in mathematics teaching, if possible."

Impact of working methodologies. The second question that concerns us is the contribution of this course towards the development in preservice teachers of an appreciation for working methodologies that stress an active role of the learner, inquiry, collaboration, and group work.

1. Preservice teachers' involvement. At the beginning of the course, most of them found the tasks very challenging, mainly due to their lack of knowledge and familiarity with computers. They consider that to face the challenges they needed much determination and hard work, individually and in group. The active involvement of the learner is an indispensable condition to significant learning; two student teachers testify how much they were committed to their work:

> "I can say that personally I felt much involved. (...) Looking back, I think that I learned so much, so much, that it was very useful."
>
> "It was a very interesting work, that required much devotion, but that ended up as something very gratifying."

The preservice teachers' evaluation of the level of involvement required reveals that some of them ended up with a sense of personal development, namely, having a more positive attitude regarding new learning situations. As one comments:

> "First of all, and speaking for myself, it was a mixture of fun (when we solved some problem) with deep disgust (when the computer decided to 'play' at improper hours). But, most of all, it was positive to sweat until we got where we wanted (...) I think that the fact that I attended this course was a lot of fun and taught me things that will stay for all my life."

2. Project work. The projects and the research carried out in this context emerge out as the most relevant aspects of the course activity. Some preservice teachers were pleased with the opportunity they had to choose the theme for their project and to learn more about it, and clearly emphasize the inquiry process. For instance, one evaluates the work carried out in the following way:

> "An interesting work on an interesting theme that is still little known (...) There was a research work at several levels and after that information was collected, it had to be 'filtered' and presented in the form of a Web page."

Resulting from this research, carried out within their projects, some student teachers comment that they started to do Internet searches more often and that they developed a disposition to investigate new software by themselves.

3. Group work. Many student teachers consider group work as a very positive aspect of the course. For some, it increases the quality of the final product: "I think that with my colleagues' cooperation, with the work that we developed together, the result was a very successful page". In some cases, there is also a positive reference to the discussions within the group:

> "Group work is a fundamental working methodology. Of course, we may have a big mismatch of opinions... However, such mismatches lead to a "discussion" and intensive exchange of opinions until we reach a consensus."

Besides, group work is regarded as a preparation for professional activity in schools. One student teacher says that his experience in this field will be of great importance in the future "as the collaboration of teachers is indispensable for the evolution (...) of mathematics teaching."

Development of a professional identity. A third point of interest is the impact of this activity on the development of a professional identity. Student teachers'

responses show aspects of this process, especially as they assume new perspectives and values that they connect to their future professional role.

1. Biographical process. Let us consider the following statements:

> "Looking back, I think that I learned so much, so much..."
>
> "All along this semester (...) I abandoned a wrong idea that I had..."
>
> "This course... taught me things that will stay for all my life."
>
> "[My] opinion (...) enriched a lot, through discovering software and techniques to use it in mathematics classrooms."
>
> "The use of software in ICM classes helped me to have the notion of the diversity of means that we have available to teach our pupils mathematics contents using new technologies."

Explicitly or implicitly, these sentences have a projection of future activities and roles as well as assessments of past ideas and perspectives that are no longer valued. They mark aspects of student teachers' biographical identity defining processes, involving transactions between inherited and envisioned identities as they reflect about past ideas and conceptions and show appreciation regarding what will be their future work as mathematics teachers.

2. Relational process. In other responses we see influences of relational processes, involving interactions of student teachers with others, including their teachers and other preservice teachers:

> "I enjoyed the instructor's method, always available, and giving us freedom to work."
>
> "The relation between teacher and student could not have been better. Whenever we needed, the teacher 'ran' to help us, requiring, however, that we first try to solve the problem that we faced. The work carried out with Frontpage developed us as researchers."
>
> "Of course, we may have a big mismatch of opinions [in group work]... However, such mismatches lead to a 'discussion' and intensive exchange of opinions until we reach a consensus."
>
> "The collaboration of [school] teachers is indispensable for the evolution of (...) mathematics teaching."

This relational process led preservice teachers to appreciate the value of group work, despite all its inherent difficulties, and value the teacher-student relationship as a complex interplay of supporting and challenging. They recognize the need for negotiations involving different people to reach some level of agreement. They also indicate their appreciation of collaboration, an important aspect of mathematics teachers' professional identity.

CONCLUSION

Work carried out with ICT based on sophisticated software raises many technical problems that may jeopardize the development of the classes according to the instructor's plans. This requires much capacity for on the spot decisions. In this course, such problems were common since preservice teachers wanted to include rather complex visual effects in their Web pages. Consequently, the production of pages tended to take more time than they expected. All this strongly suggests the need of careful planning in such a course.

Despite these problems, data collected in this study shows that the experiences provided in this course led student teachers—who often begin their educational preparation with rather negative attitudes towards computers—to develop confidence in their use of ICT. They also developed new perspectives about the use of ICT in mathematics education and an appreciation for working methodologies that foster students' learning. Both are important aspects of the professional knowledge necessary for mathematics teaching. Student teachers also took important steps in assuming professional values and attitudes, such as the need to discover and investigate by themselves and the constructive role of discussions and collaboration in undertaking professional tasks.

ICT is not just a simple auxiliary tool. It is an essential technological element that shapes the social environment, including mathematics education. Future teachers need to develop confidence in using this technology and a critical attitude regarding it. They need to be able to integrate ICT within the goals and objectives for mathematics education. The task of preservice teacher programs is not just to help student teachers learn how to use this technology in an instrumental way, but to consider how it fits into the development of their professional knowledge and identity. The design of this course was intended to provide student teachers with deep experiences of working in ICT projects. Other working contexts need to be created, taking into account the myriad features of this expanding technology, especially its potential for long distance interactions and working in a collaborative way.

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