Preparing Future Mathematics Teachers to Teach with Technology

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Abstract: The use of technology in the classrooms brings out new teaching methodologies, especially in teaching mathematics. In a teacher preparing program at undergraduate level of instruction, besides working out examples of activities and training students to use technological equipments, it is necessary to educate future teachers about the potentialities of technology as teaching aid, and the right choice of teaching strategies. The recommendations for profile of a modern teacher of mathematics, from Teacher Standards of many countries including Brazil, cite the importance of the recognition of technology as powerful communication media to be taken into teaching/learning situation. Also, the Standards point out the importance of calculators and educational software as teaching/learning aid, especially in problem solving with real data. Consequently, these recommendations require a proper preparation of future teachers to be able to select the right technology for each educational situation and to analyze the information, in order to take the best advantage of new methodologies. The main objective of this paper is to contribute to the discussion on the introduction of technology in content and methodology into the curriculum of mathematics teacher preparation program, which could effectively change the attitudes and abilities of teachers in their profession. We present a description of a course from the curriculum of mathematics teacher preparation program of Federal University of São Carlos that is designed to attend this aspect. The paper discusses the objectives of the course, its contents, the outcomes and the reactions from the students.

Key words: Teacher preparation course, Technology in teaching mathematics.

Introduction:

The recent documents on Teacher Standards from many countries, particularly Brazil, have included recommendations that refer to the importance and the role of technology in educational context. We refer to (MET, 2001), (PCNEM, 1999), to mention only few. These recommendations reflect the increasing attention that the presence of technology in educational context has deserved from teachers and educational researchers worldwide, with the establishment of new research area in mathematical education.

The influence of recent development of educational paradigms regarding competencies and abilities for teaching is also noticed in the guidelines for teacher standards and curriculum reforms, especially in Brazil. For instance, the official document 'CNE/CP no. 1' of National Council of Education of Brazil regulates the directives of curriculum and formation of teachers of basic schools

(upper-elementary and secondary levels) in Brazil. This document, effective since 2002, shows clear agreement with the theory of competencies, as developed in (Perrenoud, 2000). In particular, the Chapter 8 of this reference discusses the 8th competency for teaching exactly as the use of technology in teaching. One important consideration made at the end of this chapter (page 139) is the inquiry about the attitude of teachers in the presence of technology, whether they will use the technology simply as didactical aid to illustrate their lectures, or the technology will serve as media "to change paradigms", conducting to "the creation, organization and regulation of learning situation".

Therefore, it is an important task for institutions that educate future teachers to perform a curriculum reform adapted to modern requirements of the profession. The profile for modern teacher demands a proper education of future teachers and also a continuing education of in-service teachers, especially in the presence of technology that can change attitudes and concepts about teaching/learning processes. In order to the recommendations and regulations could be accomplished effectively, much research has to be done throughout many aspects, from theoretical educational research to practices in the classrooms and changes in evaluation systems. Also, the feedback from experienced in-service teachers constitutes a rich field of investigation to support further actions.

The research subject is quite wide, and in this work we will be focusing our attention on undergraduate education of future teachers.

The aim of this paper is to contribute to the discussion about the crucial questions concerning the preparation of future mathematics teachers in the presence of technology:

- How to educate future teachers in necessary content as well as in different methodologies that come up with the use of technology?
- How to educate future teachers about the change of attitudes required by new competencies regarding the constant updating of technology?

We will start the discussion with some consideration about the use of technology in teaching/learning context and then will present the description of a specific course designed to complete the formation of future teachers that would permit a better understanding of the role of technology in teaching/learning activities.

1. Technology in the curriculum of mathematics teacher preparation program.

As already stated in the Introduction, one of requirements for undergraduate education of future teachers is the preparation of teachers aware of the didactical potential of technology in teaching /learning context and skilled to use appropriately the different technological resources.

About the importance of technology in professional development of teachers, Oldknow (Oldknow, 2000) says, "…the effective use of PCT (Personal Computer Technology) in supporting the mathematics curriculum is in the hands of teachers. They need to know more about the use of technology than can just be found from manuals, teaching materials and other information sources" (page 36).

Therefore, simple training of equipments and learning technicalities of software are not the real aim of education of teachers with technology. It is very important to distinguish the technology as an educational aid, with development of correct approaches to diverse teaching/learning methodologies. In this process, one realizes that besides the proper mathematics content of basic school curriculum, the technology-based teaching/learning activities require from a future teacher a deeper understanding of mathematical concepts that are characteristic of the language of technology. Important examples of such concepts include units, scaling of units, significant figures,

approximation/numerical methods, different graphical representations, structure of algorithms, etc. It is also very important to remark that the understanding of the connections between algebra, geometry and analysis in their basic conceptions is required to capacitate a teacher to distinguish the real objectives of an activity from technicalities of used technology.

Then, a solid mathematical background turns up to be the central requisite to master the pedagogical methodologies with the use of technology. In (Lingefjärd & Holmquist, 2001) the authors say "teachers of today need an understanding of mathematics that allows them to produce and interpret technology-generated results, to develop and evaluate alternative solution paths, and to recognize and understand the mathematical limitations of particular technological tools" (page 206).

Therefore, in order to accomplish the objectives of teacher preparation, it is very important to both faculty of teacher preparation programs and future teachers to understand the different roles played by technology in the educational context: first as communication media, second and more important, as a tool to understand the mathematics and an aid to the process of building knowledge.

During the first years of undergraduate mathematics teacher preparation program, a future teacher is a learner of specific content of mathematics and sciences together with pedagogical theories. In the specific course units that develop these content, the instructor can integrate the appropriate technology in the lectures and lessons. In this way, a future teacher can develop sensibility and technical criticism about the mathematical knowledge necessary to teach and learn *with and without technology*.

The educational software (computer algebra systems, dynamic geometry systems, etc), programming languages and algorithms, use of websites, educational videos and others, play an important role in modernizing the classrooms of these first courses of the curriculum. The lectures and learning activities on specific mathematics/ sciences content should be the first examples of the use of technology in educational context, when the future teacher experiences them as a *learner*. The syllabi of these courses with technology-based activities will not be described in this paper, for the limitation of page numbers. In (Baldin, 2003) the author presents an analysis of the limitation of technology as an important aspect of mathematical formation of teachers willing to use diverse technology in their profession. The mathematical topics treated in this reference suggest part of what could be treated in the specific mathematics courses for future teachers. In (Baldin, 2000), the author considers an integrated instruction of algebra and geometry, at undergraduate level, enhanced by the use of technology.

Preparing a future teacher to become a sensible user of technology as a *teacher* demands a synchronization of specific knowledge with the education of competencies and abilities. To accomplish this general objective of teacher preparation demands then course units that develop different teaching methodologies and practices in the presence of technology.

The Department of Mathematics of Universidade Federal de São Carlos offers mathematical courses of didactical orientation, such as problem-solving techniques and concrete didactical materials, while the Faculty of Education offers traditional courses of pedagogical nature, such as didactics, pedagogical planning, teaching methodologies, school organization, etc. Since these courses are not designed to carry out the objective cited in the paragraph above, a new course unit has been offered, since 2001. The general objective of this new course is to provide the future teacher a critical overview of technology available in educational context along with practices in planning technology-based lessons and activities suited to basic school mathematics.

The next section discloses the experiences from this course unit.

2. The course: 'Applied informatics in mathematics teaching'.

2.1 Brief history of the course.

In this section we outline the history of the creation of the course unit 'Applied informatics in mathematics teaching', to legitimate its proposal and its place inside the curriculum of mathematics teacher preparation program, in accordance with the paradigms of formation of teachers.

The Universidade Federal de São Carlos, Brazil, has been offering, since the 70's, two tracks for mathematics majors to follow. One prepares mathematics majors that will either continue graduate studies to pursue academic careers, or will face the job market to occupy positions of professional mathematicians. The other track prepares future mathematics teachers of basic schools, at upper elementary and secondary levels. Both programs are responsibility of Department of Mathematics, with collaboration of other Departments, which offer specific disciplines of the curricula. Especially, the teacher preparation program has strong collaboration of the Faculty of Education.

In 1988, there was a curriculum reform of undergraduate programs in mathematics of Universidade Federal de S. Carlos, when the main guideline was to distinguish the teacher preparation option from the academic oriented one. This guideline was based on critical reflection about the professional profile. Before that time, the course units with mathematical content of teacher preparation program had little difference with those taken by Engineering/Sciences students and other research-oriented mathematics majors. The pedagogical preparation to become teachers were quite separate from mathematics content, and the integration between mathematics and teaching methodologies was somewhat unsatisfactory.

The consideration about the professional profile has dealt with both options for mathematics majors, and this process has produced new curricula, with two different pedagogical plans.

The proposal of new curricula at that time has reflected also the technological innovations of 80's, which brought personal computers and educational software into teaching environment. The possibility of bringing new insights in teacher preparation program has created expectations. Then, the Department of Computer Sciences offered a new course, named 'Applied informatics in mathematics teaching', with the objectives of introducing future secondary school teachers to algorithms and programming activities related to mathematics content of secondary school level.

Gradually, the advances of educational technology and the improvement of educational conceptions about the role and the potentiality of technology in teaching/learning situation have permeated the research on mathematical education. We can see the recognition of the technology as important communication medium in education, in several documents and research articles. Actually we have seen the growing of a new research area in mathematical education.

The research projects of some faculty members of the Department of Mathematics, starting 1996, have dealt with the introduction of technology in educational context of undergraduate programs for Engineering and Sciences majors (Cordeiro et ali, 1996). Some research results of these projects have been extended to very successful outreach projects towards basic schools. These projects have brought the updated reality of basic mathematics education in elementary/secondary schools to the consideration of teacher preparation program. The existing course on the use of technology in mathematical education has turned up insufficient.

The presence and the influence of technology in the society have also changed the profile of students attending undergraduate courses, thus the modernization of curriculum was more than necessary by the end of 90's. In 2001, the Department of Mathematics started a redesigned course unit 'Applied informatics in mathematics teaching', with the objectives of synchronizing the latest achievements of mathematics education research on the use of technology with the necessary

mathematics content of basic schools. This course unit surprises the prospective teachers for provoking new insights about the educational role of technology, and since the first time it has caused good impact on the future teachers.

2.2 The description of the course unit.

The course 'Applied informatics in mathematics teaching' is planned for students attending the senior year (4^{th}) of the teacher preparation program, and it covers 60 hours of practices in one semester unit.

The syllabus of this course is composed as:

1. Analysis of educational software, communication technology and existing teaching material available in basic schools;
2. Planning classes and learning material in informatics environment for basic schools;
3. Exploring technological resources like calculators, personal computers, multi-media equipments in educational context;
4. Making adaptations of scientific programs to the context of basic schools.

Each instructor elaborates specific teaching plan to be executed, upon the items of the syllabus.

The execution of this course unit is little different from the traditional mathematics courses because, while there are no mathematics topics to be covered a priori, the course still requires a careful selection of activities that integrate important mathematics topics of basic schools with technology.

The main concerns of a instructor in planning this course unit are: a) synchronizing the operational knowledge of technology with the knowledge of mathematical content; b) providing the means by which the students recognize the properness of specific technological activities in didactical transposition of mathematical content; c) providing opportunities to educate critical attitude about different communication ways through which the education can be developed. Ultimately, the course aims to educate future teachers prepared to constant updates of technology and capable of appropriate adaptation to classroom activities.

The instructional activities of this course cannot be training sessions of equipments and software. They must provide situations in which the discovery of construction of mathematical knowledge is facilitated by the didactical potential of technology. The instructional instruments must bring forth new significances to mathematics and sciences content of the curriculum, as well as they must complete the teaching methodologies learned from pedagogical courses.

The strategy used in this course consists in introducing students to equipments and software proposing different teaching situations, like: simulation of problems to motivate the reasoning; modeling; algebraic approach to solution when appropriate; geometric approach to solution when possible; validating solutions; investigating variations of solutions; conjecturing and guessing; activity of introducing concepts; exploring properties; and more. In each case, the characteristics of each program are pointed out, a comparative analysis among the possibly used software is done, and an analysis of the activity itself is done, regarding its efficiency, usefulness and properness in the classrooms. The limitation of technology is also discussed, either from the difficulties raised by students, or suggested by the instructor to call the attention of the users. After each activity, a group discussion is done about the mathematical content developed in the activity, the technology used in it, other educational possibilities, personal difficulties and impressions, self-evaluation, etc and

finally, a written individual report is delivered. Writing a report is very important to consolidate the critical reflection on the subject and to help preparing to the next steps of the course.

The activities of the course, as described in the paragraph above, are strongly relied on the instructor. By conducting the laboratory-type activities with selected topics, the instructor is responsible to lead the students to the process of awakening to the possibilities of technology in educational context and to the realization of the importance of mathematical background. Regarding this aspect, it is remarkable that students usually start thinking of doing mathematical activity with technology as transcription of traditional lectures and lessons to informatics environment, without exploring the didactical possibilities offered by technology. In (Baldin, 2002) the author presents an analysis of the use of technology in classroom activities through a classification of different ways of communicating mathematics, stressing the importance of integration of mathematical knowledge with teaching/learning methodologies. This reference has been helpful to widen the students' understanding about the subject.

One of most convincing activities to motivate the students is the *problem solving* with educational software, when the potential of technology as didactical aid can fully be explored. In this activity, the instructor has a right opportunity to have everyone involved effectively in each step of the process of problem solving: a) reading and understanding the problem; b) simulation of the situation, theoretically and with given data; c) recognition of underlined mathematical concepts; d) modeling; e) solving; f) interpretation of mathematical solution and answering the question; g) confirmation of the solution; h) speculation of further developments related to the initial question, as variations of data or different approaches, and other possibilities.

The critical attitude about what, when and why the technology may be used with advantage upon paper and pencil can be developed during each part of the process above.

Other convincing feature of technology that attracts the students is the possibility of doing *interdisciplinary activities*, bringing together mathematics and other sciences, arts, etc, attending this way to the profile required for accomplished teacher.

After the students learn about the procedure to analyze the didactical potential of software through different methodologies, they apply the critical attitude in exploring the websites, freeware, videos, etc, writing a report after the sessions.

The activities described above prepare the student to the final step, when the student develops the ability to use technology in planning his/her teaching units. Each student is assigned with a theme chosen from the elementary/secondary school curriculum, and he/she prepares a didactical activity using any of educational technology available in schools. The final project is presented to the colleagues as simulation of a teaching session. The student, the colleagues playing the part of learners and the instructor evaluate the presentation in its pedagogical efficiency, correctness of mathematical content and the properness of the choice of technology.

A final report on the project and its presentation constitute the essential part of requirements for the grading. This report must contain the development of mathematical content, the description of activity, justification of the use of technology and the choice of methodology, the results and the conclusion.

Actually, this part of the course is the most challenging and innovating aspect for the students, because this activity is intended to capacitate the student to become a versatile teacher, with autonomy and ability to adapt his/her teaching skills to continuously changing technological environment. Then, an important outcome of this part of the discipline is the growing of self-confidence about own capability as a future teacher.

Regarding this aspect, the following sentences are translation of excerpts from a final report of a student, and they represent quite well the general thought of students after they experience this course:

"Before I enrolled in this course (Applied informatics to mathematics teaching) and also at the beginning of the lessons, I was quite skeptical about the objective 'learn to teach mathematics when I become a teacher', because I hadn't known about the importance of the technology in teaching/ learning process. Also, I had always considered myself unable to teach any mathematical content using technology, for I had not had familiarities with computers and programs…"

"…When I knew I would have to prepare a technology-based activity and to present it to my colleagues my first thinking was to drop out the course. But, as the lessons were developed I have gradually realized that the technology is a new teaching strategy, which could greatly help me when I would be teaching, because the technology can be used to approach the real life of students to mathematical content…."

"The students can visualize the application of abstract concepts". "By using technology, a teacher can explore different ways to study a specific theme. For example, with the problem I presented in my simulated classroom activity, a teacher can explore besides the congruency of triangles, the properties of symmetry in quadrilaterals and also go further to trigonometry, etc." "I have realized that it is not so difficult to include the technology into teaching activities…".

2.3 Examples of activities and teaching projects.

The first part of the course takes usually 34 to 36 hours. The subjects worked out in 2001 comprised: a) modeling of word problems (problems stated without mathematical formulas) with algebraic and geometric solutions, use of computer algebra systems (CAS) and dynamic geometry systems (DGS); b) conics and geometric constructions, applications to conical mirrors, use of CAS and DGS; c) graphical studies of functions (implicit and parametric representations), comparative analysis between CAS and DGS; d) curve-fitting activity (secondary school level) to data given by a table, connected to the concept of function, analysis of regression methods, concepts of error and approximation, use of CAS, spreadsheet programs, graphic calculators; e) exploration of educational websites in Internet, learning to classify the existing material on webs according to the potential use in basic schools, discussion about their quality, usefulness, correctness, accessibility, etc; f) analysis of freeware available from Internet; g) analysis of some selected educational videos.

The problems, activities, videos vary each time the course is offered, and new topics suggested by students are added, as well as new problems that the instructor includes in order to help specific needs and difficulties of students.

Interesting teaching projects have come out from the second part of the course, which takes 24 to 26 hours, including the planning, preparation and presentation. During the planning and the preparation of technology-based activities the students can work in groups, and the instructor assists them, both in mathematical content and methodology. The presentation is individual.

The following list shows some teaching projects, selected among those well planned and presented:

1- A problem of combinatorics with the aid of geometry: "Consider seven people meeting in a room and suppose that they greet each other shaking hands. How many shakings have been made?" Simulation with DGS, solution with DGS considering a 7-polygon and counting its sides and diagonals. Algebraic deduction of the formula of combinatorics and generalization to n people.

2- The classical problem of treasure-island: “A treasure map was found with the indication: *In the island I, look for the tall palm tree. Starting from the palm tree, walk straight to the big rock, then turn right 90 degrees and walk the same distance as between the tree and the rock. Mark the place and return to palm tree. Then, walk straight to the entrance of big cave, then turn left 90 degrees and walk the same distance as between the tree and the cave. Mark the place. The treasure is buried at the mid-point between two marked places*. When arrived to the island the palm tree had disappeared. Can you find the treasure?” Simulation with DGS, dynamic manipulation of possible positions of the data and the invariance of the solution, discovery of geometric properties of involved constructions, justification of the solution. The same problem could as well be solved analytically with adequate coordinate system, but the possibility of finding geometric properties in the setting was considered more attractive to the students.
3- Concepts of similarity, applications to problems like ‘planning the roads crossing’ and ‘calculating the height of a tall building’. Construction of concepts step by step with DGS, application to a word problem in the context. Good use of dynamical manipulation of geometric data to reinforce the properties of similarity and proportions.
4- The properties of reflections in the plane and application to the billiard table problem. Another example of exploration of geometric properties with DGS and application to a problem in the context of real life.
5- An activity on the interactive use of presentation program with spreadsheet program, with applications. The activity showed an interesting possibility of presentation of concepts and texts with slides, linked to a spreadsheet worksheet to work with changeable data. The application problem was a standard problem of uniformly accelerated rectilinear movement from Physics, in the context of a problem of police chasing the car of thieves.
6- Construction of the concept of ‘angle’ for elementary class with the aid of LOGO. This activity was also tested in real classrooms in basic schools, twice.
7- Geometric analysis of solutions of linear systems, in the context of problem solving at elementary level. Good use of manipulation feature of DGS with coordinate systems to analyze the meaning of the existence of solutions of a linear system. The problem that illustrated the activity was: “Mary went to a burger-shop. She took 1 burger and 1 soda for $8.00. Next day she went again with a friend and they had 2 burgers and 2 sodas. They paid $16.00. First question: ‘is it possible to know the prices of burger and soda?’ On other day, Peter went to the same shop with a friend. There was a discount offer of the day, and they took 2 burgers and 2 sodas for $15.00. Second question: ‘can you calculate the prices of burger and soda, knowing the total amounts paid by Mary and Peter?’ Without getting any discounts, Joe went to the same shop and bought 2 burgers and 3 sodas. He paid $17.50. Third question: is it possible to calculate the prices of burger and soda, knowing the total amounts paid by Mary and Joe?”
8- Another nice application of linear systems with DGS was the problem motivated by the methodology of *teaching with history of mathematics*: the famous tale about the great Archimedes of Syracuse, when he solved the problem of the composition of gold and silver in the royal crown, establishing the hydrostatic law.

9- Polar coordinates and polar equations of curves, with DGS. This is a subject hardly considered in secondary schools, yet the concept of polar coordinates is more intuitive than Cartesian coordinates in many real life situations, such as map consulting. The DGS facilitates the understanding of this concept.
10- Geometric construction of external tangents to two circles, applied to the problem of calculating the length of chain necessary to fit to the wheels of a bicycle. Activity with DGS.
11- CAS activity with graphic calculator to study the division of polynomials, at secondary school level.
12- Application of congruency of triangles to solve the problem of calculating the distance of two objects with an obstacle in between. Nice activity with DGS, elementary level.
13- Application of linear programming to systems of linear inequalities, applied to a problem of secondary school level, with DGS.
14- Spreadsheet activity to teach the properties of exponentiation, geometric progressions and exponential function.
15- Classical problem of maximizing the area of a quadrilateral plane figure, given a fixed perimeter, in the context of a word problem.

We remark that many teaching projects have also been tested in actual classrooms in local basic schools where the students were developing their practices, under the supervision of Faculty of Education. These experiences have brought a good feedback to analyze properly the effectiveness of the activities. The success contributes to the consolidation of self-confidence of future teachers about the use of new methodologies.

There are many other good projects, including those intended to introduce mathematical concepts, to explore geometric constructions and its properties, for example trigonometry, complex numbers, congruency of figures, sine and co-sine laws, etc. Still, what the students considered the most attractive in the projects has always been the methodology of developing technology-aided activities on *modeling and solving a word problem*, because it brings about the potential of technology to refresh the traditional classroom practices. Although the students felt, in general, more comfortable with DGS rather than CAS or spreadsheet programs, activities suited to the characteristics of these programs were also explored. The Graphic Calculators are not very known in Brazil yet, but the prospective and in-service teachers, as well as the basic school students, have accepted them very well in all experiences.

3. Conclusion.

The nice feature of the course ‘Applied informatics to mathematics teaching’ is the good environment in which one can explicitly integrate the mathematical content of curriculum, many times taught and learned in fragmentary way during the undergraduate education, with new teaching methodologies that include problem solving with technology. During the preparation of own technology-based activity the future teacher realizes the importance of mathematical background, without which he/she would not be able neither to prepare a meaningful activity nor to be a good user of technology available in the media.

We hope that this course that has already prepared more than 60 prospective teachers will be improved with more experiences and will help to attain the modern paradigms of mathematical education of teachers.

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