LEADING TEACHERS TO PERCEIVE AND USE TECHNOLOGIES AS RESOURCES FOR THE CONSTRUCTION OF MATHEMATICAL MEANINGS

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This paper presents the early results of an on-going research project on the use of technology in the mathematics teaching and learning processes. A first aim of this project is to understand how deeply math teachers do perceive the opportunities technologies can bring about for change in pedagogical practice, in order to effectively use them for the students' construction of mathematical meanings. Secondly, the research aims at verify if teachers realise that, in order to successfully deal with perturbation introduced by technologies, they have to keep themselves continuously up-to-date and to acquire not only a specific knowledge about powerful tools, but also a new didactical and professional knowledge emerging from the deep changes in teaching, learning and epistemological phenomena.

INTRODUCTION

Due to the continuous spread of technology in the latest years, challenges and expectations in the everyday life, and in education in particular, have dramatically changed. Within this context of rapid technological change the world wide education system is challenged with providing increased educational opportunities. The use of Information and Communication Technology (ICT) in the classroom, however, seems to be, in the majority of cases, still based on a traditional transfer model characterised by a teacher-centred approach (see for example: Midoro, 2005).

But, according to Hoyles *et al.* (2006; p.301):

> «…a learning situation had an economy, that is a specific organization of the many different components intervening in the classroom, and technology brings changes and specificities in this economy. For instance, technological tools have a deep impact on the "didactical contract"…».

That is, the technology-rich classroom is a complex reality that necessitates observation and intervention from a wide range of perspectives and bringing technology in teaching and learning adds complexity to an already complex process (Lagrange et al. 2003).

Moreover, as underlined by Mously et al. (2003; p.427),

> «…technological advances bring about opportunities for change in pedagogical practice, but do not by themselves change essential aspects of teaching and learning ».

As research underlines (Bottino, 2000), indeed, innovative learning environments can result from the integration among educational and cognitive theories, technological opportunities, and teaching and learning needs. However, it is extremely important

for teachers to confront themselves with the necessity to understand how the potential offered by technology can help in the overcoming of the everyday didactical practice complex problems.

I believe that for technologies to be effectively used in classroom activities teachers need, not only to "accept" the presence of technologies in their teaching practice but also to see technologies as learning resources and not as ends in themselves. Moreover, learning activities involving technologies should be properly designed to build on and further develop mathematical concepts. Hence, an "adequate" preparation is essential for teachers to cope with technology-rich classrooms, so that using computers not merely consists on a matter of becoming familiar with a software.

This paper presents the early results of an on-going research project on the use of technology in the mathematics teaching and learning processes, investigating mathematics teachers' perceptions of ICT and of their usefulness in promoting a meaningful learning.

A first aim of this project is to understand how deeply math teachers, both pre-service and in-service, do perceive the opportunities technologies can bring about for change in pedagogical practice in order to effectively use them for the students' construction of mathematical meanings.

Secondly, the research aims at verify, whether or not, teachers realise that, in order to successfully deal with perturbation introduced by technologies, they have to keep themselves continuously up-to-date and to acquire not only a specific knowledge about powerful tools, but also a new resulting didactical and professional knowledge emerging from the deep changes in teaching, learning and epistemological phenomena.

THEORETICAL FRAMEWORK AND RELATED LITERATURE

Many researchers in the latest years are answering the challenge to provide educational opportunities by studying teaching and learning mathematics with tools (Lagrange et al., 2003).

Results of both empirical and theoretical studies have also led to the elaboration of the idea of "mathematics laboratory" as reported, for example, in an official Italian document prepared by the UMI (Union of Italian Mathematicians) committee for mathematics education (CIIM):

> «A mathematics laboratory is not intended as opposed to a classroom, but rather as a methodology, based on various and structured activities, aimed to the construction of meanings of mathematical objects » (UMI-CIIM MIUR, 2004; p.32).

In this sense, a laboratory environment can be seen as a Renaissance workshop, in which the apprentices learned practicing and communicating with each other. In particular in the laboratory activities, the construction of meanings is strictly bound,

on one hand, to the use of tools, and on the other, to the interactions between people working together (without distinguishing between teacher and students).

According to this approach, and as in Fasano and Casella (2001), I believe that technological tools can assume a crucial role in supporting teaching and learning processes if they allow teachers to create suitable learning environments with the aim to promote the construction of meanings of mathematical objects. Moreover, in agreement with this point of view, I consider important to highlight that, again quoting the UMI-CIIM document (p.32):

> «The meaning cannot be only in the tool per se, nor can it be uniquely in the interaction of student and tool. It lies in the aims for which a tool is used, in the schemes of use of the tool itself. The construction of meaning, moreover, requires also to think individually of mathematical objects and activities.»

Furthermore, as claimed by Laborde (2002; p.285),

> «…whereas the expression integration of technology is used extensively in recommendations, curricula and reports of experimental teaching, the characterisation of this integration is left unelaborated.»

In particular, she underlines the idea that the introduction of technology in the complex teaching system produces a perturbation and, hence, for teacher to ensure a new equilibrium he/she needs to make adequate, non trivial choices. Integrating technology into teaching takes time for teachers because it takes time for them, first of all to understand that, and how, learning might occur in a technology-rich situations and, then, to become able to create appropriate learning situations. This point of view is based on the idea that a computational learning environment could promote the learners' construction of situated abstractions (Noss & Hoyles, 1996; Hölzl, 2001) and on the "instrumental approach" as developed by Vérillon and Rabardel (1995).

Within the instrumental approach, the expression "instrumental genesis" has been coined to indicate the time-consuming process during which a learner elaborates an instrument from an artefact: it is a complex process, at the same time individual and social, linked to the constraints and potential of the artefact and the characteristic of the learner. If, according to the instrumental approach, learners need to acquire non-obvious knowledge and awareness to benefit of a instrument's potential, I firmly believe that teachers need to take into account the student's instrumental genesis (Trouche, 2000).

Finally, I consider worthy of note the concept of "instrumental orchestration" proposed by Trouche (2003) aiming at tackling the didactic management of the instruments systems in order to conceive the integration of artifacts inside teaching institutions. In particular, he underlines that pre-service and in-service teacher training should take in account the complexity of this integration at three levels (Trouche, 2003; p.798):

« - a mathematical one (new environments require a new set of mathematical problems);

- a technological one (to understand the constraints and the potential of artifacts);

- a psychological one (to understand and manage the instrumentation process and their variability). »

METHODS, CONTEXT AND PROCEDURE

The research I'm going to present consists in two main phases. The first has been carried out with a rather small group of in-service teachers at the University of Bari and a larger group of pre-service teacher at the University of Basilicata. The second involved another small group of pre-service teachers at the University of Bari.

Teachers belonging to the first group at the University of Bari were 16 high-school teachers. Although some of them already taught mathematics, on the whole they were qualified to teach related subject and they were attending a training program in order to get a formal qualification to teach mathematics.

At first, a preliminary anonymous questionnaire was submitted to them with the aim to know if they were able to see technologies as learning resources, as well as if they were available to continuously bring up-to-date in order to properly design and manage with technology-rich classroom activities. Key questions in the questionnaire included the following:

1 Do you think ICT could be useful for your teaching activities? Why?

2 Do you think that the use of ICT can somehow change the learning environment? And the way to teach? And the dynamics among actors in the teaching/learning situations?

3 Which difficulties do you think can be encountered when designing and developing a math lessons using somehow ICT?

4 As a teacher, do you think you need to have some didactical competences in order to properly use ICT? Eventually, which ones? And anyway, why?

Within the training program they attended, a thirty hours course was focused on didactical reflection aiming at helping student teachers to understand how to make the most of the use, in mathematics teaching and learning activities, of general tools such as spreadsheets, multimedia and Internet, as well as mathematics-specific educational software such as Cabri. In order to explain them that the changes produced by the introduction of a technological tool will not necessarily per se bring the students more directly to mathematical thinking, particular attention was devoted to stress the role of the a-didactical milieu in authentic learning situations, as in the known Brousseau's (1997) "theory of didactical situations". Furthermore, they were asked to analyse and discuss both successful and questionable examples of teaching/learning mathematics activities in which an important role has been played by the use of ICT.

At the end of the course student teachers designed a teaching/learning activity involving somehow the use of technology: in this way I intended to verify how deeply they have perceived the opportunity to effectively exploit the usage.

A further anonymous questionnaire, free from constraints, was later submitted with the aim to find out any signal for changes in their conceptions to have been occurred. Key questions in this further questionnaire were exactly the same.

Pre-service teachers involved in the research project at the University of Basilicata were a larger number (97). They were only asked to fill in the first questionnaire.

During the second phase, a group of 16 pre-service teachers at the University of Bari, instead, interacted with the researchers/educators in the same way of the first group of in-service teachers: to this further group of teachers a preliminary anonymous questionnaire was submitted; then, they were invited (during a thirty hours course) to reflect on didactical aspects of the use of technologies as well; at the end of the course they were asked to design a teaching/learning activity in which technology played an essential role; finally I analysed the extent of their changes in looking at the integration of technologies in the teaching/learning processes.

According to the results obtained during the first phase (that I'm going to present and discuss in the next paragraph), in the second phase I asked student teachers, not only to design a teaching/learning activity involving the use of technology, but also to put in action the activities they have designed, having as student sample their colleagues: in this way they proved themselves as "actors" in a technology-rich learning "milieu".

FINDINGS AND DISCUSSION

Findings from the first anonymous questionnaire revealed that in-service student teachers perceived that technology can bring support to their teaching (see Fig.1), but only as much as it is a motivating tool enabling students understanding per se (see Fig. 2).

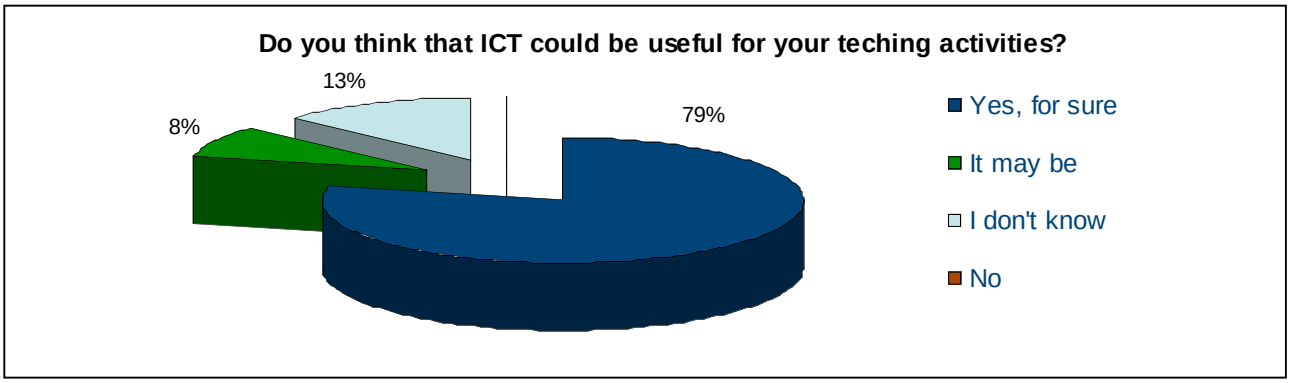
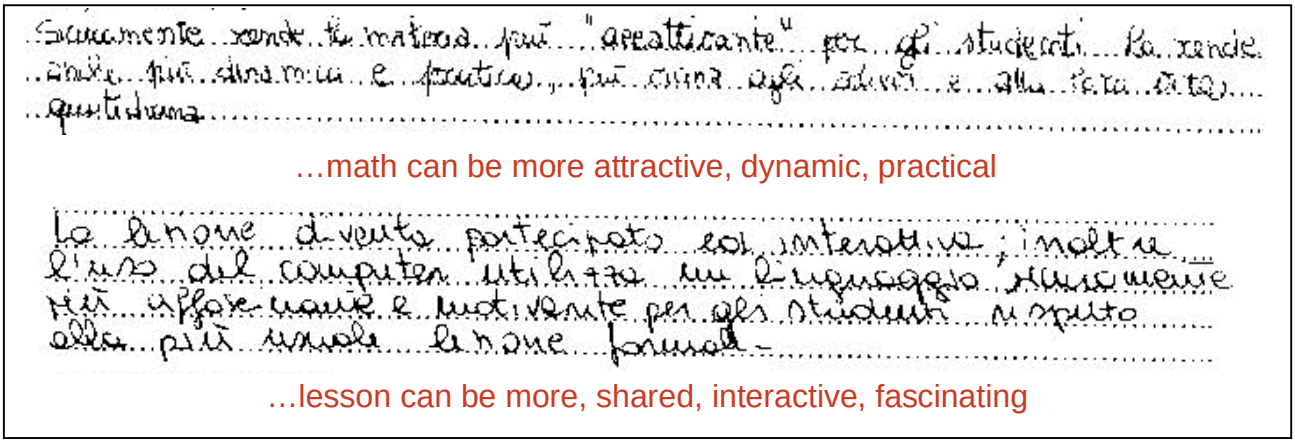


Figure1: The 79% of the in-service student teachers gave a positive ("Yes, for sure") answer to question 1.

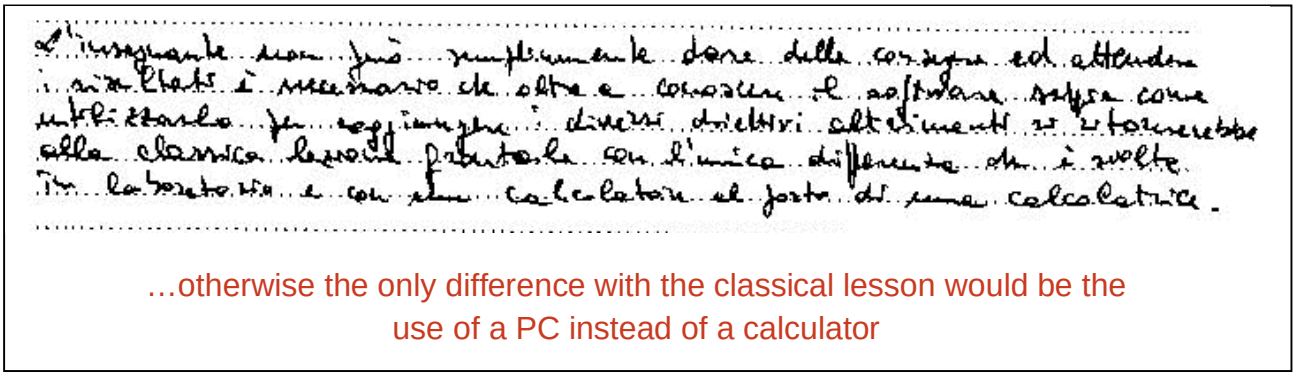


…math can be more attractive, dynamic, practical

…lesson can be more, shared, interactive, fascinating

Figure2: Some in-service student teachers' answers to question 1: Do you think ICT could be useful for your teaching activities? Why?

Answers given by the pre-service teachers were, instead, a little bit more didactically oriented: some of them recognise that, if nothing else, the knowledge of the instrument functionality is probably not enough for a teacher to use it in an effective way in terms of construction of meanings by the students (see Fig. 3).



…otherwise the only difference with the classical lesson would be the use of a PC instead of a calculator

Figure3: A pre-service student teacher's answer to question 1.

None of the in-service teachers recognised that technology could bring a great support in creating new interesting and attractive learning environments. While, at least some interesting observation could be revealed among answers given (to question 2) by the pre-service teachers: some of them suggested the use of technological tools to allow students "collaboratively solve intriguing problems".

Be aware of the opportunity to create a new "milieu" and change the "economy" of the solving process was, however, extremely far from their perception of the use of technology in mathematics teaching/learning activities, both for in-service and for pre-service teachers.

About the question 3, concerning the difficulties they think can be encountered when designing and developing a math lessons using somehow ICT, they mostly ascribed possible difficulties to the lack of an adequate number of PC and the technical problems that might occur, but also to the natural students' bent for distraction and relaxation, especially when facing a PC (see Fig. 4).

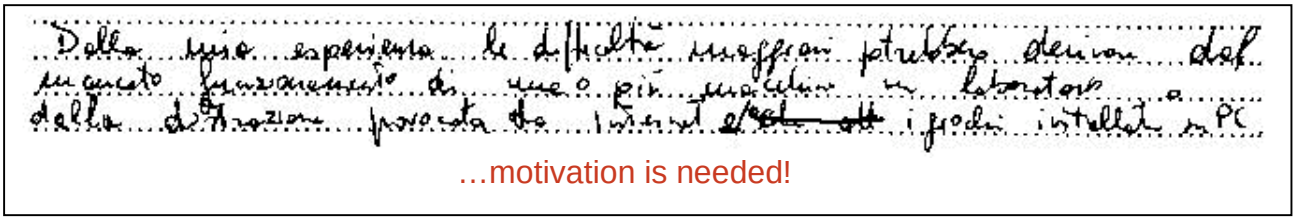


Figure4: Some student teachers consider new technology as a motivating tool that requires motivation.

As a consequence they did not feel the need to be skilled in using technology for their teaching and did not usually consider that their lack of skills presents them with any difficulties. And, although the 75% of the student teachers recognised (answering to question 4) the need to have some didactical competences in order to use new technology, what they asked to know about was, in most of the cases, just software functionalities (not potential, nor constrains): only some of the pre-service teachers also asked to know how to effectively integrate their use in the teaching practice.

Even tough some of the activities that in-service teachers prepared at the end of the course revealed the willingness to attempt a new approach to the use of ICT, answers to the second anonymous questionnaire shown they still continued to find difficulty to be aware of the potential offered by ICT (see Fig. 5).

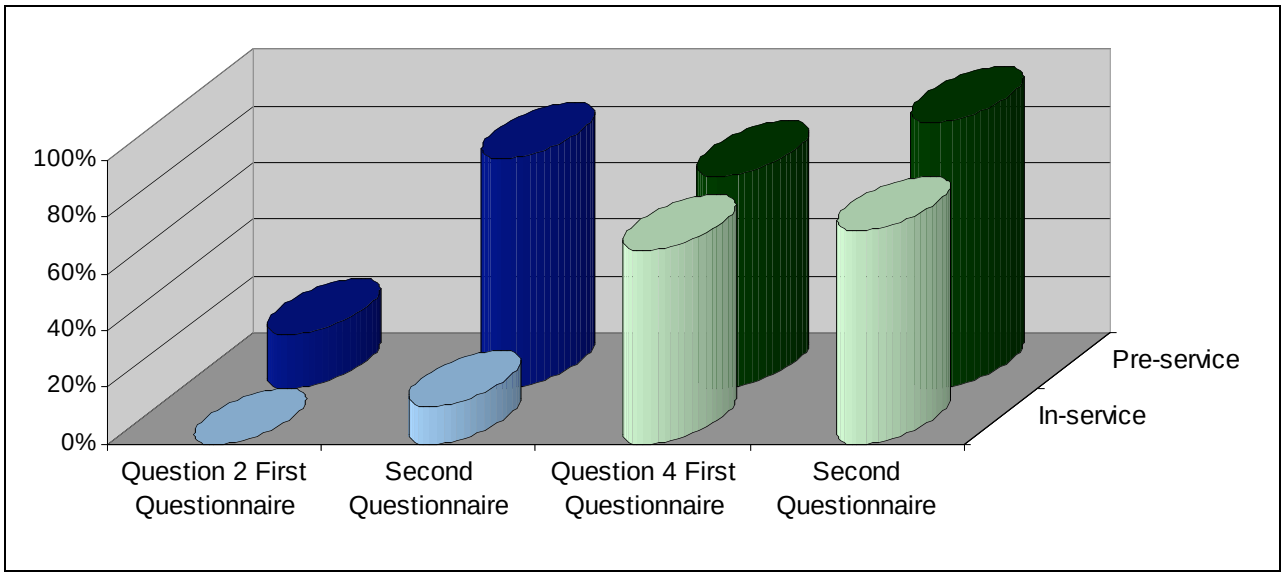


Figure5: Percentage of positive ("Yes, for sure") answers given by both in-service and pre-service teachers respectively to the first and the second questionnaire to questions 2 and 4.

For this reasons, for the second phase of the project I planned to pay particular attention to promote teachers' reflections on the opportunities offered by appropriate uses of technological tools in order to create new learning environment and, according to the idea of "mathematics laboratory", to foster the construction of mathematical meanings.

Student teachers were invited not only to design a possible teaching/learning activity involving somehow the use of technology, but they were also involved in a "mise en situation" (as in the known Chevallard's approach) during which they had the opportunity to assume the roles of the student, the teacher and a researcher/observer.

In this way, they faced with the complexity of the integration of technologies in classroom practice. Their comments at the end of the experience shown that they have developed an awareness of how the students' instrumental genesis can take shape (psychological level). Moreover, answers to the second anonymous questionnaire revealed that they felt the need to understand the constraint and the potential of technologies (technological level) and to look for new mathematical problems (mathematical level).

EARLY CONCLUSIONS AND FUTURE WORKS

Discussion suggested by the researches in this field and by the analysis of this on-going experience led me to reflect on and to underline that an adequate preparation is essential for teachers to cope with technology-rich classrooms. In particular I believe that, only if teachers become aware of the potential usefulness and effectiveness of technologies as methodological resources (enable to foster the constructions of meaningful learning environment) they would recognise the need of an effective integration of them in the classroom activities and view new technologies as cultural tools that radically transform teaching and learning.

At the actual stage of this on-going research I can claim that, in my opinion, most of the teachers have difficulty to acquire the awareness of the potential of technology as a methodological resource. Hence, as educators, we also have to deal with the need to lead teachers to develop a more suitable and effective awareness of the usage of new technologies. Furthermore, I believe that the difficulty teachers have to acquire this awareness could be overcome giving teachers the opportunity to be subject of a "mise en situation". In this way teachers can experience by themselves the difficulties students can encounter and have to overcome, the cognitive processes they can put in action and the attainment they can achieve. They also have the opportunity to understand and manage with the students' instrumental genesis and to become more skilful and self-confident when deciding to exploit the potentials of technologies in mathematics education.

For future works I think in particular to go on with this idea, promoting further experiences of "mise en situation" according to the following stages:

- let teachers experience the importance of the relationship between the specific knowledge to be acquired by the students and the knowledge teacher possesses of it;
- let teachers experience the importance of the relationship between the specific knowledge to be acquired by the students and whatever students already know;
- let teachers experience the importance of the relationship between their knowledge and the students' ones.

I suppose, indeed, that through these stages, teachers could experience by themselves the processes that come into play bringing technology in a teaching/learning situations. In particular, according to the early results of this study, I believe that in this way teachers do tackle with the obstacles encountered, the difficulties to be overcome, the cognitive and metacognitive processes carried out and the attainment that can be achieved.

To conclude, in the next future I aim to verify that, thanks to this methodology, not only they can cope with changes they could meet in a technology-rich learning situation but, reflecting on them, they can also become aware of how to better make use of technology as a resource to create an effective and meaningful learning environment.

Finally (also considering the explicit suggestions of the WG7 call for papers), I suppose that an interesting help to foster the development of teacher's instrumental genesis can be given by the use of Geoboards (Bradford, 1987). A Geoboard is a physical board (often used to explore basic concepts in plane geometry) with a certain number of nails half driven in, in a symmetrical square, (for example five-by-five array): stretching rubber bands around pegs, provide a context for a variety of mathematical investigation about concepts and objects such as area, perimeter, fractions, geometric properties of shapes and coordinate graphing.

Thus, I would like to let high school teachers operate with an unusual (at that level) context/tool like a Geoboard, and try to understand if, in this way, they can perceive teaching resources, both digital or not, as methodological resources: when teachers become aware that some resources can be effectively used for the construction of mathematical meanings they can start to successfully design and experiment new interesting learning activities.

REFERENCES

Bottino, R.M. (2000), Advanced Learning Environments: Changed views and future perspectives, in M.Ortega & J. Bravo (Eds.), *Computers and Education: towards an interconnected society*, The Netherlands, Dordrecht: Kluwer Academic Publishers, pp11-27.

Bradford, John (1987). *Geoboard Teacher's Manual*. Ft. Collins, CO: Scott Resources, Inc.

Brousseau G. (1997), *Theory of Didactical Situations in Mathematics*. Dordrecht: Kluwer Academic Publishers

Fasano M. & Casella F., (2001), The didactic laboratory as a place to experiment models for the interdisciplinary research, in M. Michelini (Ed.), *Proceedings of the International Conference Developing formal thinking in physics*, Udine, Italy, pp. 399-403.

Hölzl R. (2001), Using dynamic geometry software to add constrast to geometric situations – A case study. *International Journal of Computers for Mathematical Learning* 6(1), Springer Netherlands, pp. 63-86.

Hoyles C., Lagrange J-B., Noss R. (2006) Developing and evaluating alternative technological infrastructures for learning mathematics. In Jürgen Maasz and Wolfgang Schloeglmann (eds), *New Mathematics Education Research and Practice*. Sense publishers, pp. 263-312.

Laborde C. (2002), Integration of Technology in the Design of Geometry tasks with Cabri-Geometry, International Journal of Computers for Mathematical Learning 6(3), Springer Netherlands, pp. 283-317.

Lagrange J-B., Artigue M., Laborde C. and Trouche L. (2003), Technology and Mathematics Education, in A. Bishop et al (Eds.), *Second International Handbook of Mathematics Education*: Part two, Dordrecht: Kluwer, pp. 237-269.

Midoro V. (Ed.) (2005), European teachers towards the knowledge society, Cortona, Italy: Menabò.

Mously J., Lambidin D. and Koc Y. (2003), Mathematics Teacher Education and Technology, in A. Bishop et al (Eds.), *Second International Handbook of Mathematics Education*: Part two, Dordrecht: Kluwer, pp. 395-432.

Noss R. & Hoyles C. (1996), *Windows on Mathematical Meanings: Learning Cultures and Computers*, Dordrecht: Kluwer.

Trouche L. (2000), La parabole du gaucher et de la casserole à bec verseur: Étude des processus d'apprentissage dans un environnement de calculatrices symboliques, *Educational Studies in Mathematics* 41, pp.239–264.

Trouche L. (2003), From artifact to instrument: mathematics teaching mediated by symbolic calculators, Interacting with computers, Elsevier, Volume 15, Issue 6, pp. 783-800.

UMI-CIIM MIUR (2004), New mathematical standards for the school from 5 through 18 years, Ed. Anichini G., Arzarello F., Ciarrapico L., Robutti O.

Vérillon P. & Rabardel, P. (1995), Cognition and artifacts: a contribution to the study of thought in relation to instrumented activity. *European Journal of Psychology of Education*, 10(1), pp.77-101.