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The roles and needs of mathematics teachers using IT

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ABSTRACT

Teacher education stands as critical among the various issues pertaining to the integration of information technology into secondary mathematics education. Remarkable improvements have indeed taken place recently both with respect to the material aspects of IT (hardware, management, accessibility, maintenance) and the availability of high quality educational software. Successful use of the computer depends essentially on the quality of the teachers and of their pedagogical agenda. Renewed and diversified roles confront teachers in an IT educational environment. Pre-service and in-service teacher education must help all of them to modify their attitudes and develop the new competencies in mathematics, informatics and the didactics essential for them to fulfil their pedagogical mission.

Keywords: information technology, teacher education, integration, pedagogy, attitudes

INTRODUCTION

The last two decades have witnessed a wealth of attempts aiming at integrating information technology (IT) into secondary mathematics education. The advent of microcomputer technology, and subsequent

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progress both in hardware and software development, have given rise to very high expectations about the impact of informatics on the teaching and learning of mathematics in the secondary school.

The pedagogical potentialities of the computer in mathematics have evolved considerably since the days when it was used strictly in the context of numerically oriented languages. For instance, the availability of the programming language Logo with its underlying philosophy of exploring mathematics in specially designed microworlds, the development of symbolic mathematical systems like Maple or Mathematica capable of carrying out symbolic computations previously considered to exemplify a genuinely "human" ability, or the recent advent of geometry exploration software such as Cabri-géomètre allowing users to manipulate and transform geometrical objects, have drastically modified the perception of the influence computers might have on the teaching and learning process in mathematics. Moreover, the computer capability of handling multiple representations of information - numerical, graphical and symbolic - and of moving from one form of representation to another has opened up the way to unprecedented applications in mathematics education (see [1, p 255-260]).

Nevertheless IT, more precisely microcomputer technology, is probably not as extensively used as an instructional tool as all these developments might suggest, even in mathematics as seen for instance in the recent findings of the IEA Study [2, p 70]. A wide range of explanations have been put forward in connection with this situation: restricted number of computers available in school and their limited power, lack of software of sufficient quality, complexity of user interface, difficulty for the average teacher to use the computer in the typical classroom on a sustained basis [3, p 517]. This paper aims to support the idea that, although all these facts are related to important issues, none are as critical as those pertaining to the teacher's capacity and ability to cope with this new pedagogical environment.

IT IN THE SECONDARY MATHEMATICS CLASSROOM

The successful integration of IT requires a wide range of actions concerning numerous issues (see [2, pp 103-105] or the guideline paper [4, p 22]): general aims of secondary education, expectations of society, curricular reform, material infrastructure (availability and maintenance of hardware, development of software, adequate funding policies), human resources. The public debates that took place in the early years in many

countries around the introduction of computers in schools - very often more of a political than of a truly pedagogical nature and held in a nearly feverish climate that could but hinder sensible decision-making (see [5, p 48-55]) - were essentially concerned with material aspects such as: which type of machines should be installed in the schools, and in what quantity? While the numerous difficulties related to the material organization of the IT classroom or to the availability of high quality educational software are certainly crucial, these are not the main impediments to a widespread use of computers in teaching. To a certain extent, remarkable improvements have indeed taken place in recent years in both these respects; for instance a "more than decent" computer environment can now be found in a number of schools in many countries - although on a general scale the actual availability of the computer to the pupil is still rather low. Kaput states that availability "is at best an hour per week per student for mathematics" [3, p 517], while Anderson asserts that a large part of the equipment is becoming obsolete - "50% of the computers used in (American) schools by teachers or students are 8-bit computers" [2, p 21].

Material considerations are not the last word to a successful integration of IT in education, an assertion supported by the main conclusion of the IEA Study:

> "improving education with computers requires more than hardware and software. Students also need to work with skilled people including teachers, parents, co-workers, and friends." [2, p xx]

This paper concentrates on the teachers themselves, their competencies, their attitudes, their perception of their multiple roles. Teacher education (both in a pre-service and an in-service context) is a channel of the utmost importance through which IT can create an impact in the secondary mathematics classroom. This stand-point matches the conclusions of the recent ImpacT Study to the effect that the three main resource-related factors influencing concrete use of IT are:

> "access to computers, the organization of IT in the class, and the teacher's skills and enthusiasm for using IT in the curriculum" [6, p 28];

the teacher's contribution being identified as "the most important" factor [6, p 159]; note should also be made of the remark about the importance of a "sympathetic and positive Head" in developing teacher's confidence in using IT (p 91).

While it is true that modern technology is affecting educational aims in general, the influence is particularly strong in the case of mathematics

education, as reported in the Study of the International Commission on Mathematical Instruction (ICMI) [7, p 2, 68]). This study states that mathematics itself and the way in which mathematicians work are being directly modified; the demands, expectations and employment patterns within society with respect to mathematics are changing, the educational goals and structure of entire curricula must be reappraised, and new pedagogical possibilities for teaching and learning mathematics are being opened up. Still Anderson states that, even in the mathematics classes, the use of computers is "decidedly lower than many might have expected it to be" [2, p 68]. It has been claimed about current school mathematics that:

> "our children are taught to do mathematics in ways that are very largely outmoded, with at least 80% of the curriculum time wasted on trying, more or less successfully, to develop fluency in skills of now-limited value." [8], p 9

Extraordinary demands are thus being made on the teacher towards a deeper use of IT in his mathematics classroom.

THE EVOLUTION OF TEACHING

One of the effects of IT integration is to reinforce the "professional" dimension of teaching. While the specificity of teachers' multifaceted tasks has always been such that they should be fully considered as professionals - the "professionals of the pedagogical act" - and trained as such, this professionalism is now stronger than ever in connection with the modified and diversified roles they play in an IT educational environment. It must be stressed however that some of these modifications in teachers' roles are not specific to the IT situation and are of value with or without the computer. For instance, Graf considers that

> "coordination of students' work, conduct of group dynamics, development of problem solving, creativity and reflective thinking by students are examples of roles not always fulfilled in teaching, but not directly related to computer use." [9, p 32]

But the computer environment introduces a renewed perspective inducing a change in both students' attitude towards mathematical content and expectations towards the teacher.

Various roles can be mentioned with respect to the teacher's pedagogical implication in the IT classroom (see for instance [8, pp 27, 88, 97] or [10, p 84]): acting in turn as manager, task-setter, guide,

accompanist, coordinator, explainer, counsellor, leader, resource, and even as a fellow pupil (working on a task alongside the school students). Not any more the sole nor the main source of information, teachers are confronted with their genuine pedagogical mission, that of "facilitators" able to create a context appropriate for a fruitful interaction, via the machine, between pupils and mathematical concepts.

Being no longer those who transmit truth and knowledge to the learner in a more or less dogmatic and unidirectional way, teachers must consequently accept a lessening of the degree of control they exert over the pedagogical activities. They must also accept the resulting shrinkage of their sense of security, in comparison to a traditional management of the classroom - for instance when expected to make sense of a "strange" mathematical object generated on the screen by pupils during an exploration. Teachers must in addition be able to cope with the heterogeneity of pupils' reactions to the various learning situations being offered, the computer making possible a greater diversity of potential ways of reacting than a traditional environment.

The contribution of teachers to the organization of the educational environment has aptly been described by Cornu [8, p 28, 90] and Artigue [11, p 29] as that of a "didactical engineer", in the sense that their work, while being based on a body of scientific knowledge, is concerned with more complex objects than the refined ones of science: their central task is thus to transform theory into usable products. In the case of IT integration, this requires teachers to be able, for instance, to elaborate a sound pedagogical strategy, to design a coherent teaching program, to choose appropriate tools and products to be used. But above all teachers must be in a position to assess the educational value of the technological import so to ensure that pupils are "engaged in a good learning experience" [6, p 76] in keeping with their pedagogical aims and objectives: use of IT in the mathematics classroom is not an end in itself but a way to better understanding by the pupils, as well as a preparation for work force and literate citizens of an information-oriented society [2], p 99].

> "The decision to implement a new technology ... is fundamentally an educational decision, to be guided by educational objectives. ... The question to be answered is, 'Will the technology help us do better what we have been trying to do?' " [3, p 548].

In order to make such judgments, teachers must have developed a wide range of new competencies related to various aspects of the teaching and learning of mathematics.

THE COMPETENCIES OF TEACHERS

At least three types of competencies are necessary for teachers in order to adequately fulfil the new roles which confront them in an IT environment; competencies related to mathematics, to informatics and to didactics.

The influence of computers on *mathematics* has aptly been described elsewhere, for instance [8] or [12]. Not only can mathematics be taught differently, but in a very deep sense it is different, a much greater emphasis being placed on numerical and algorithmic processes and on an experimental approach involving exploratory investigations. The evolution of mathematics teaching related to an evolution of mathematics itself, of the way it is being practiced. Secondary mathematics teacher must thus develop a deep epistemological view of the subject, enabling an understanding of its origins, its history, its changing role in the society and its growing applicability.

Teachers must also be comfortable with distinguishing those mathematical skills of decreasing importance, (because they correspond to tasks better accomplished by the machine, from mere arithmetical skills like calculations of square roots to more advanced techniques for algebraic computations or graphical study of functions), from those skills becoming more important. These skills of growing importance include the choice of an appropriate mathematical model, identification of significant parameters, discernment between those tasks which should be ascribed to the computer and those which require insight and human decision, interpretation and critical appraisal of the "answer". Such skills involve conceptual thinking and planning rather than execution of routine calculations. The impact on teachers' responsibilities is outstanding. Dörfler and McLone state:

> "This shift ... will not make school mathematics less demanding. On the contrary, according to every known taxonomy of intellectual activities, the abilities needed to make adequate use of computers (and of calculators) are on a higher level than those for executing calculations." [13, p 79].

The overall effect of such an evolution in mathematics is well-summarized by Mascarello and Winkelmann in the following terms:

> "In total, there can be observed a specific shift in the spectrum of abilities, from precise algorithmic abilities to more complex interpretations, so to speak from calculation to meaning ... In this process the mathematics to be mastered tends to become intellectually more challenging, but technically simpler." [8, p 109].

Proper integration of IT also means that teachers must know about *informatics* in general and that they must be familiar with the computer itself, both in connection with hardware and software considerations. While this does not mean that teachers need to be fully-fledged programmers, it certainly suggests that they should aim at becoming competent enough to "reach beyond the constraints of packaged tool software." [1, p 261]. In fact, teachers should have developed enough autonomy so as not to rely upon external help each time something goes wrong: teachers unable to cope with the basic technical aspects of computers are at great danger of losing credibility among their pupils, often much less inhibited by the "machine". But this level of expertise should not be interpreted as denying the importance of support either by technical staff, peers or IT coordinators in the school. More comments on this can be found in Anderson [2, p 50-52, 104] and Ruiz [4, pp 22, 28, 40]; Anderson remarks that "in most instances, coordinators spend more time helping students ... than they do helping teachers", p.51.

Finally teachers must be proficient with the *didactical theory* underlying their work, so to be able to clearly define their pedagogical projects: what should the pupil learn? can the computer be used fruitfully? and how? Didactics of mathematics has clearly been emerging recently as a branch of science with its own body of knowledge (see [11]). It thus behoves the teacher to gain familiarity with its progress in a range of issues, including the relation between pupil and knowledge, the various obstacles (psychological, didactical, epistemological) that can intervene, the types of errors made by pupils and the information thus revealed on their appropriation of knowledge, and the didactical role of assessment. This didactical background is really crucial, as no machine, as powerful as it can be, can make up for a poor pedagogical program. Cornu affirms that "In no case can the technology replace the pedagogy." [8, p 92]. All this results in a complex situation where the teacher is the one first and foremost responsible for elaborating a coherent teaching and learning context within which integration of IT can become effective.

EDUCATING ALL TEACHERS

While many successful teaching experiments have been reported involving the computer, these are often associated with enthusiastic teacher-pioneers and are very difficult to generalize or even to reproduce. Cornu considers that "Un logiciel ne transporte pas avec lui tous les paramètres didactiques, tout l'environnement pédagogique nécessaire." [12, p 55].

One of the major difficulties in the integration of information technology in secondary classrooms is thus to have all teachers become competent with this new environment, and not only those naturally inclined. This represents an outstanding challenge for both pre-service and in-service teacher education.

Many of the early programs aiming at introducing computers in school rested on a core of highly motivated teachers, so-called "multiplicative agents", expected to pass their knowledge and pedagogical agenda on to their colleagues through a "cascade" effect. But this model has limitations and in many cases the anticipated effect has not materialized, see the remarks by Watson [6], pp 96, 162 and Cornu [12], pp 29-30. What is now needed is a more global approach to the concerns of the teacher in relation to integration of IT in the mathematics classroom. The problem does not concern mainly the necessary familiarity with new technology, but more profoundly the teaching and learning issues being raised. Teachers need to gain the capacity to confront those, to evolve and adapt.

It has been suggested that successful integration of IT in schools requires a new generation of teachers, that Yokochi et al describes as technology oriented teachers [14], p 71. It is clear that we can perceive the emergence of a "new teacher", more open-minded with respect to technology and having more diverse competencies, both from a disciplinary and a pedagogical point of view [12], p 63. But we cannot wait for today's teachers to have all been replaced by a future generation nor can we hope for such an evolution to happen by itself. Concrete actions thus need to be taken simultaneously both at the in-service level, because some of the teachers actually in place will still be in their classrooms in years from now, and at the pre-service level, to allow future teachers a meaningful contact with the IT environment. Integration of new technologies in schools amounts first of all to integration in teacher education. It is insufficient to inform teachers about "how to use" IT, they must actually work with it. It is only through such an effective use of IT in their own learning that teachers can go through the required change of attitudes that will lead them to perceive the computer as a natural pedagogical tool. But this in turn raises the crucial problem of educating teacher educators.

CONCLUSION

Watson has reported that integration of IT can have "in particular circumstances ... a highly positive impact on children's achievements." [6], p 4. But Anderson and Watson both show that the actual degree of penetration of computers in schools, in particular with respect to mathematics education, is still rather low, with teachers using IT being the exception and not the norm ([2], p 70, [6], p 83). It is thus no surprise that these two recent IEA and ImpacT Studies identify teacher education as a key issue for the coming years. Adequate preparation of human resources being a long-term process, teachers should not delay their personal involvement until a time when some widely accepted "best" solutions to the various pedagogical issues raised by IT might emerge. Fey considers that the actual situation already "offers impressive opportunities for progress." [1], p 266.

Teachers should nevertheless keep in mind that as important as it may be, IT is a resource among other resources, although maybe of a special type. Ruiz reminds us that "... still a large part of their teaching does not involve direct use of computers." [4], p 31. Teaching and learning are first and foremost human activities, involving the teacher and the pupils as well as the interactions between them and with knowledge. IT comes into play to facilitate these interactions.

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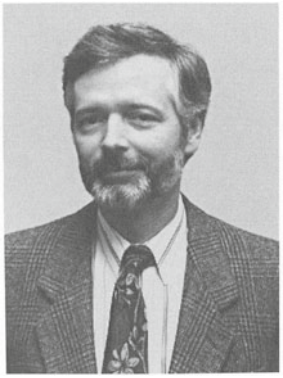

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