The influence of information technology in the daily work of mathematics teachers

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Abstract: In this paper, I discuss the profound changes in the global work of a mathematics teacher when information technology is presented as an everyday tool. I discuss the communication changes among students and colleagues, the changes in mathematics in and of itself, and the possible way to see and feel mathematics when a computer is presented. I argue about the influence that these new visions have on the construction of a different image of mathematics in the students. The present work is due to a two different backgrounds: several years of intensive experience using different mathematics software in freshman college level; and an interesting experience training and updating high school teachers. I take several examples from these experiences that are lead to build a better integration of information technology to teach and learn mathematics; and to point out some problems that emerge when the use of software is intense in such integration. Finally, I support the importance of continuing the exploration of such integration.

INTRODUCTION

In the last decade, we have been witnesses of a gradual, growing, fast, and complex process of integration of information technology in the different sectors of our societies. Information technology goes from the financial sector to the commercial one, from the educative sector to the cultural one. This process seems irreversible. Everything makes us predict that computers, and computer networks will not be foreigners in homes, schools, universities, or work centers. Instead, computer, and computer networks will be considered as a natural part of the environment in which we are born and grow, and they follow the same way of other well strengthened technologies that already exist in the every-day-life of people.

In fact, we have seen in the past how every new technology (from cars to airplanes, from films to cell phones) requires a dialectic process of adaptation because of society. Such adaptation process can last even for several generations. Finally, the new technologies become in a way almost a natural part of the environment in which we live. Seeing and using radios and phones has been natural for us. In the same way, using computers will be natural too.

Information technology cannot be reduced just to the concept of machines because it includes diverse dimensions. However, the computer has been for many years the only visible sign of the existence of information technology for people. Unfortunately, even today, that is the predominant vision that exists in different sectors of societies. Information technology cannot be even reduced to a fashion because its roots appeared in remote times.

In fact, modern information technology has its roots in the convergence of three important tendencies (Breton, 1987): the development of calculator machines, the processes of automation, and the elaboration of information. Each one of these sectors has had its own evolution characterized by different stages. Many of these stages are directly linked with the development of mathematics.

From the mid 60's to the late 70's, information technology went through deep transformations (Breton, 1987):

- On one hand, there is a considerable extension of the information technology applications. Many people consider this stage as a true revolution, and later on it was going to impact on all the economic and social structures.
- On the other hand, the apparition of personal computers. In this stage exists the will to fight against the centralization of data by very few privileged people.

These two transformations contribute in a determinant way to the great diffusion of modern information technology. Such effect brings new problems linked to the multiplication of different forms of applications. The necessity of a better control of these new applications implies knowing in a deep way the limits and potentialities of information technology. This is a global necessity of contemporary societies that interests all sectors, from the scientific to the industrial, from the commercial to the educative, and so on.

Each sector has to study and resolve the specific problems related to the integration of the deep values of information technology. This activity implies the necessity of incorporation of a new element in our culture. Such incorporation requires a process of adaptation and learning of this "new" sector of knowledge in order to incorporate information technology as another element of our culture. The development of a *"computer-science culture"* allows us to understand and influence the information technology transformations on the social organization, in every-day life, in different work forms, in the way of being of each one of us, and in the way in which we relate with everyone else and with our objects of study.

I want to mention a few words about the relationship between information technology and mathematics, before I approach the issues related to teaching from the perspective of the new technologies.

MATHEMATICS AND INFORMATION TECHNOLOGY

Information technology has made deep changes in mathematics at not elementary levels since several years ago. It is good to remember what some authors say: "Computers are transforming the way mathematicians discover, prove and communicate ideas" (Horgan, 93). "Computers and computation have changed the entire modern world, but their effects in the fields of sciences and engineering have been especially deep" (Aragón, 96). Many of the problems related with the application of mathematics to other fields have changed because of the use of information technology as an instrument. "The perennial debate over whether mathematics should be taught by mathematicians or by engineers looks increasingly anachronistic in the light of technological change" (Kent & Noss, 98). This process seems irreversible like in other fields. "Applied mathematics is and will become more and more computational" (Bricio, 92). These quotes and many others make us predict that the next century the mathematical work will change radically on the matters of what has been done in past centuries.

There are other signs that go beyond personal opinions. For example, a guide of the National Institute of Standards and Technology in the USA (12/25/1998) lists a total of 110 math programs for mathematical modeling and statistic analysis (GAMS) that are accessible to scientists and engineers. In a list of 120 math journals (RM), we found 24 of them (almost 20 %) that mention information technology as an important issue. By 7/12/1999 we found (FSU) 79 electronic journals of math. The web sites of research centers, service centers, and math departments grow in quantity and quality.

Mathematics was a resource for information technology for a long time. Now, likewise information technology is a resource for mathematics, consequently new mathematics branches appeared or some branches were modified. Today is studied: Discrete Math, Dynamical Systems, Chaos Theory, Fractal Geometry, Computational Geometry, Numerical Analysis, Experimental Math, Visual Math, and so on.

Everything mentioned before testifies to the fact that we are witnesses of the raising of new methodologies and new forms of communication in mathematical work.

MATHEMATICAL EDUCATION AND INFORMATION TECHNOLOGY

We must not miss the use of mathematical software out of the scholar world. Mathematical software is being used in physics, chemistry, and different branches of engineering. If we consider that the mathematical work in schools shows the real work that mathematicians do, we have to take into account that today a considerable and always growing

number of people have the computer as something indispensable. The future is leading us to a process in which the use of computer in mathematics is becoming every day more intense. So, mathematical educators mainly at university level would do wrong if they do not consider the use of computers to create mathematics.
Recent recommendations empower us to analyze this problematical issue at such a level.

> "It would be good to collect examples of the use of information technology and software which enrich students experience of mathematics and result in better understanding and learning" (ICMI, 98).

Effectively, the educative sector is another sector that has been strongly influenced by information technology, particularly mathematical education. Such effect has not been only at university level, but also all the school levels even in kindergarten. Information technology has influenced in a sensible way each of the elements of the famous Chevallard triangle. Information technology can transform radically the traditional relationships teacher-student, teacher-knowledge, and student-knowledge.

Just to point out some situations, I would like to give some examples. Teachers have to make an extra effort in classrooms where there are computers because the computers "steal" the student attention. New mathematical problems and situations are raised that were not expected by the teachers, and the students require an explanation. Computing problems and situations appear and the decent stuff might not be prepared (for example, networking problems, missing files, insufficient computer memory to cover some tasks, and so on). Students can experiment on their own without waiting for the teacher. Using computer networks the possibilities of long distance communication become bigger since the contemporaneity of space and time is not required.

The sector of mathematics education is studying widely the information technology phenomenon. The new specific magazines that have started to circulate are proof of this phenomenon. Some of these magazines are The Journal of Computers in Mathematics and Science Teaching, The International Journal of Computers Algebra in Mathematics Education, and The Journal of Computers for Mathematical learning (appeared only in 1996). These magazines have published different investigations, experimentation, proposals, and so on.

Recently, there have appeared different centers that offer a great diversity of information. This information can be computing resources for teachers and students, investigation and circulation about projects, Web site lists, software, publications, organizations, congresses, mailing lists, exams, and so on. Just to mention some examples, we can find The Geometry Center (GC) from Minnesota University; Centre for Teaching Mathematics (CTM) from Plymouth University; CTI Mathematics (set up to support and promote the use of computers in teaching Mathematics at degree level throughout the UK); T^3 *Teachers Teaching with Technology* (T^3) (developed in the USA, and presently used in UK too. Now, it tries to increase the teacher's trust in the application of technology); The Computer Algebra in Mathematics Education (CAME) (international organization founded in the ICME-8 from Sevilla in 1996 and open to all those who are interested in the use of computing algebra software in math education); Mathematics Resources on the Internet, managed by the CTI Mathematics from Birmingham University; Teacher's links managed by the Center of Research in Math Education (CRIME) from Southampton University; S.O.S. Math (SOS) from The Department of Mathematics of Texas University at El Paso, USA; Computer Based Assessment Project (CBAP) from Wolverhampton, University; all these among others.

THE NEW WORK OF MATHEMATICS TEACHERS

Now, in the brief picture already described, What does the every-day work of math teachers change when they integrate information technology in their classes or while they are integrating it? What are the consequences of such activity?

On one hand, as I mentioned before the relationship between the teacher and his object of study is changed by the use of a new tool. A math teacher can discover new issues that he never thought when he uses mathematical software to solve a problem, to design an exercise, to verify a solution, and to elaborate a graphic among other computer applications. For example, a math teacher can discover that the result of a book is wrong, he can intuit the properties of a complex function from a graphic that he never built, he can discover new interesting edges in the formulation of a problem and the usual solution strategies.

The use of computerized instruments not only allows teachers to improve their professional activities (Meyer, 1996, Beilby & Bishop, 1994), but also to communicate with their students in a new way. Teachers can use electronic mail to communicate with their students, therefore teachers are adding writing communication to the traditional verbal communication. Teachers can interchange math files with their students. Teachers can design a web site to file their course material; as a consequence their students can access it at all times. Teachers can use a browser to find information in any part of the world and different languages about research articles, book information, software bookstores, experimentation practices from different schools, course information, convocations, and congresses among others.

The math teachers have to be prepared in order to take advantage of all these possibilities. Several places have emphasized staff training as Zehavi, 1996; Monaghan, 1997; and French, 1998. However, Who is going to train the math teachers in this area? Where and when are they going to be trained?

In order to use computerized instruments it is required to have "experts" in the field. Experts that know the specific work instead of experts in general. On the contrary, not only do we take the risk of having teachers involved in a set of courses that will be used in a mediocre way, but also teachers will divulge a misrepresented way the use of information technology in a specific field of work.

On one hand, there is the problem of the formation of new teachers. On the other hand, there is the training and actualization of teachers already working in their field. We have to take into consideration that most of the teachers presently working are part of a generation that did not grow with an intensive use of computers. As a result, there is a rejection by large groups of teachers about computers because their vision about information technology is incomplete or even erroneous; they have the typical false statement "the computer does everything". In either way, teachers in formation, or teachers already working in their field, the problem still remains. From where are we going to bring the experts in the field? What characteristics should they have? Who and how were they trained? How should we know if they are really experts? What should they know about information technology?

When an article or part of a book about an experiment with software is read, there are so many things that are not mentioned or isolated. This issue can be a strong obstacle for many teachers; consequently, it will be in the field a kind of hidden curriculum in information technology training.

For example, when we talk about the use of electronic mail, we refer to teachers and students that should have access and know how to use a program that manages the electronic mail. It implies not only the minimum knowledge of an operative system and the ways to get connected to a network, but also its optimum use implies at least the use of anti-virus and compression programs.

In a similar way, the use of a browser not only requires us to have access and know how to use a program of this kind, but also it requires the use of an operative system and its forms of getting connected to a network. The optimum use not only implies at least knowing the use of anti-virus and compression programs, but also it requires the use of programs of the kinds Teleport, Go!Zilla, and Adobe. Teleport program is used to download entire web sites. It reduces the cost and time of connection in the network besides eliminating the rush to consult a site. Go!Zilla program is used to download big files avoiding the problem of losing the connection when the file is almost completely downloaded. Adobe program is used to read files with PDF format.

The simple use of a word processor not only requires us to have access and to know how to use a program of this kind, but also it requires the minimum use of an operative system. In the case of math teachers, they have to know the skills and strategies to edit the mathematical formulas, the elaboration of graphics that requires the knowledge and use of mathematical software, and the elaboration of images through software.

It is necessary to add to what has been described before, the software that impacts the most in mathematics education: The Mathematical Software.

Mathematics Education Research requires expert teachers in the use of software in their regular classes. The use of software in regular classes requires a certain level of competence that is acquired only with the intensive experience in such situations. From my point of view, the effects of information technology integration on the student work can be measured only after long time of continuous use. For instance, How can we measure the effect of information technology on mathematics education when there are not well prepared teachers to create a good integration, or when there are teachers with a misinterpreted vision of information technology in and of itself?

In the last years, the math programs not only have increased in number, but also they have increased their capacities, variety, goals, and characteristics to the point that it was already necessary a classification for it. For instance, Zhao (1998) made a classification of mathematical software in two big categories: direct products, and indirect products. Some of the programs that indirect products include are math text editors, math web sites, Internet links, and communications protocol for mathematics computer networks. The category that Zhao proposes in direct products is:

1. On line mathematical formula tables
2. *CAS*, Computer algebra systems
3. *NCS*, Numerical computation systems
4. *APS*, Automatic or Assistant proving systems
5. *GDAS*, Graphics and data analysis systems
6. *MES*, Mathematics education systems
7. *SC*, Symbolic calculators

The fact of having a classification of mathematical software reflects the complexity of knowing, analyzing, and using it, mainly for a teacher.

Consequently, according to the level in which teachers work, they have at their disposition two math software groups: programs that were designed to solve mathematical problems without didactic purposes such as CAS, APS, OR GDAS; and programs for mathematics education such as MES, and math tables on line. In the first group it is essential for teachers to establish didactic strategies in software training, and the use of mathematical concepts introduced with the aid of software as well. There is not enough yet of the aid material that we might find of this kind, but many magazines and web sites have already started to present concrete experiences of using this software in regular courses.

Another central problem is the change of bibliography. Many mathematics books do not take into consideration information technology in their arguments because they were written before the information technology era. New mathematics books have started to be published with the proposal of using specific programs; or using information technology without mentioning the specific software, allowing teachers the freedom to make their own elections. This kind of material is essential to reach a good integration of information technology in mathematics education, also who uses this software knows that the manual reference is not enough.

The use of information technology allows us to "feel" mathematics in a different way, to see and almost "touch" mathematical objects, which vision was prohibited for all past generations (for example the fractals). The liberation of large and annoying calculations allow us to concentrate in other parts of the problem. For example, instead of getting distracted making operations, we can be more focused on setting out and analyzing a problem, and we can be discussing the results. Naturally, the higher level that we reach, the higher the utility of math software will be.

It is very important to take into account the students vision when they have integrated information technology in their math courses. To a certain point the students fear for knowing math disappeared, this consequence in and of itself is a progress about the traditional courses; this is not only my personal experience but also the point of view of many people, for example (Böhm, 1994) or (Soto-Johnson, 1998). It is mainly caused since students can experiment and make mistakes, they can make conjectures, they can work by themselves without the presence of a teacher (the one who they ignored many times when he or she is present). It happens many times that at the end of a class they do not want to stop not because they are playing video games, but because they are working on mathematics.

In addition, I have observed as many teachers have observed too, bigger group collaboration. For example, when several students are seated in front of the same monitor there is an interesting negotiation in the keyboard; they proved solutions together; and they help each other to interpret the software feedback (Edwards, 1997). Such collaboration is also extended to the work between teachers and students as some people as pointed (Bennett, 1995; Biryukov 1995).

The same characteristics mentioned before can be extended in the cases in which teachers have the student's role in training math software courses.

AN EXAMPLE OF A BRIEF METHODOLOGY FOR SOFTWARE INTRODUCTION

My methodological proposal for math software introduction in a regular course starts from the elaboration of a set of materials that allow the gradual introduction. This process always starts from the mathematical concepts, and using the software according to how it is going to be needed. Mathematical software must not be taught in an isolated way, as many times the manuals do. Alternatively, some of the following materials can be elaborated:

1. **Quick particularized user guides** According to their use.- It will not be introduced derivations in the same way for high school students in their calculus class than the students of differential equations. According to the teacher.- Basically, I am talking about the level in which the teacher handles the program, to his particular ways of introducing the topics, to his language, to the kind of problem that he faces, and so on. According to the kind of students.- This issue is about the previous software knowledge, the experience of using software, and general experiences with information technology. I have observed that this kind of quick guides is used for my fellow workers, and for students of other courses.
2. **Re-design logbook** The re-design logbook must allow us to individualize problems in the mathematical concepts and the use of software, and to re-design the strategies of software introduction as well besides socializing this kind of experiences.

3. **Design of laboratory sessions** The design of laboratory sessions must allow the adequate use of the available time for computer equipment, and the recollection of valuable materials for educative research as well.
4. **Design of individual work sheets** The design of individual work papers must allow the students to practice by their own, and to have a feedback. These papers are designed in such a way that teachers can include their answers and comments.

SOME WORDS ABOUT THE COMMUNICATION AND THE THIRD WORLD

Computer networks offer us possibilities to make wider our communication capacity with our fellow workers. For example, without being in the same physical space we can communicate with fellow workers in other parts of the world to be able to discuss a particular problem; we can plan activities in common with fellow workers who are in other cities; we can elaborate "four hand" documents; we can revise, ask, and receive articles in an electronic way; we can translate; and so on. Obviously, it sets the problem of having a common language which allows us to communicate among people in different countries (sometimes the necessity of learning English!).

The use of computer networks allows students to communicate without being lead by their teacher; allows also economic savings to students who live far away from their study centers because they do not have to go there to consult their teachers. On the other hand, students have the necessity to write their doubts, therefore it is required other kind of skills compared with the classical verbal ones that occurred in a classroom.

In the particular case of Mexico, which can be extended to other cases in other countries, there is the additional problem that most of the software is found in English, and such language is not handled by most of the teachers and students. There is the necessity of creating strategies to work with low resources because of the high equipment and software cost. For example, the use of free electronic mail; the use of mail boxes with students that have internet at home; the good administration of time in computer centers and special classrooms; the use of special equipment as networks and projectors; and the lack of comprehension of school administrators as well. However, such limitations must not be the reason for a teacher to remain inactive, instead this kind of obstacles must be a creativity well for teachers, administrators, and students. As I pointed out before in different occasions, it is evident that a more advance technology corresponds to a more elitist people (Bates, 1995). Furthermore, to leave a great part of the population out of the use of computers will make wider the social differences in such society, and among societies.

In conclusion, it is extremely important to continue with the exploration of the information technology introduction in mathematics education.

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