DIGITAL TECHNOLOGIES IN MEXICAN HIGH-SCHOOLS

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In this paper we present some of the issues in Mexican public high-schools related to the incorporation of digital technologies in mathematics classrooms; noting that the inclusion of technologies is very isolated, and that schools still lack proper facilities. We also present some of the didactical approaches of teachers in using digital technologies during their lessons; we observe lack of preparation of these lessons and conflictive situations for the learning processes arising from difficulties in the implementation of technologies and generated by deficient technical content and pedagogical knowledge.

Keywords: Technology; Didactical Approaches; High School Education; Educational Changes

Introduction

The use of digital technologies (DT) in schools has become increasingly important in today's societies, due to its inherence in all areas of daily life. But in education, changes have been slow. In fact, research on the impact of computers in classrooms on students' academic performance has shown that the effect has been moderate if any at all (e.g., Papert, 1993; Kilpatrick & Cuban, 1998; Chadwick, 2001; Battista, 2007). The incorporation of DT in classrooms, is a particular challenge for teachers. The importance of teachers' professional development, that strengthen their competencies and knowledge for helping students address the needs of the 21st century, has been a theme of several international educational conferences (e.g., at the International Conference on Education—ICE, and the International Congress on Mathematical Education—ICME), in particular with regard to the need of incorporation of digital technologies. Over a decade ago, the National Council of Teachers of Mathematics (NCTM, 2000) stated that technologies had to be used widely and responsibly in order to achieve a complete mathematical training, and to facilitate visualization of mathematical ideas. However, as Chadwick (2001) cautions, when teachers use technology they should ensure that the means do not cause straying from the educational aims. Technology can be a didactical tool only insofar as it helps in the construction of meanings of the objects of study; we also believe that a responsible use of DT should be supported in results from educational research in order to be successfully implemented. Sacristán, Sandoval and Gil (2009) concluded, from a research conducted on Mexican primary and middle-school teachers, that if teachers are to successfully incorporate DT in their practice, they need to understand how to use these tools in order to create meaningful learning in students.

Research Objectives and Theoretical Framework

Our general research aims to analyze elements of teachers' didactical practices in Mexico, and their relationship with curricular contents and recommendations; one particular aspect that is the focus of this paper, is teachers' didactical practices related to the use of digital technologies in mathematics classrooms.

In our study, we use as framework the categories proposed by Shulman (2001) related to the knowledge base that teachers should have in their professional development; thus we consider pedagogical content knowledge (PCK), curricular knowledge, technological pedagogical and content knowledge (TPACK, that provides understanding on the technological tools that the teacher uses in her/his practice) (Mishra & Koehler, 2006), among others. Llinares (2000) recognizes that a fundamental part of a teacher's practice lies in the choice of the instruments s/he uses (spoken language, modes of symbolic representation, didactical materials, use of technologies in daily practice, etc.) and he emphasizes the importance of her/his understanding of which and how they will be used, and for which aims. On their part, Ponte and Chapman (2006) state that a teacher's knowledge and her/his didactical approach, are mutually dependent in the teacher's activity; this relationship is representative of the organization of the

elements for teaching. We have used the above ideas to design our survey questions and to observe characteristics in teachers' development of knowledge, not only taking into account what they know (content knowledge), but what they *do* with what they know (knowledge use), in a twofold way: their mathematical content knowledge (Ball, 1988) and the technology use during their classroom practice. In this way we attempt to assess how meaningful is a teacher's use of DT in her/his classroom.

Methodology and Data Collection

In studying teachers' didactical approaches, we also consider their knowledge in terms of the educational changes and curricular reforms that have occurred in the last decades both at international and at national levels; in particular we consider those related to teaching methodologies (recommended classrooms strategies and dynamics, didactic materials, etc., often based on specific epistemological theories—e.g., constructivism) and the use of DT in the classroom (computers, videos, Internet, specialized software for mathematics, etc.).

In a first research phase, we carried out a documental type of research where we reviewed the diverse programs of study and curricular recommendations for high-school mathematics in Mexico, in order to establish what is considered essential for the teachers' practice. In a second research phase, we carried out a survey of 159 high-school mathematics teachers in different regions of Mexico; through this survey we had some panoramic insights of the ways in which high-school teachers have perceived the educational changes and needs in the 21st century world. In a third research phase, we carried in-classroom observations, as well as pre- and post- interviews, of a subset of the surveyed teachers: 13 teachers in Mexico City, who claimed in the survey to have changed, in the past decade, the way they teach and incorporated DT to their practice, and 3 other teachers, not originally surveyed, who where reputed in their schools to use DT in their lessons. Thus, we observed (and interviewed) a total of 16 teachers, in 5 different public high-schools in Mexico City, for up to two classroom sessions of 60 to 120 minutes, in which they were meant to use DT. It is worth noting that the 5 schools we visited are considered amongst the best public high-schools in the country.

For the analysis of the results, we carried out a correlation of the results, through a methodological triangulation to structurally relate the cualitative, quantitative and documental data (Denzin, 1990; Bryman, 2007). In this way we could analyze the relationships between a teacher's didactical beliefs (including her/his beliefs on educational needs and changes, and on DT tools as didactical instruments; teaching methodologies used in her/his practice; her/his changes in the last decades), what s/he claims to have changed due to educational reforms in Mexico, and her/his actual didactical approaches in the classroom.

Some Results and Sample Data

In this section we present some results derived mainly from the second and third phase, related to the use that the teachers in our study make of DT in their practice. Other results are beyond the scope of this paper.

Some General Results on the Use of DT by the Study's Teachers

The great majority of the 159 teachers surveyed, 91%, agreed that there have been significant educational changes in the last two decades in the world; however only 38% mentioned the use of technology as one of the most significant changes. Nevertheless, the surveyed teachers coincided in that the use of DT has become an essential part of students' development and that it is important to include them in teaching for didactic support. A large majority of them, 73.8%, claimed to use DT to support their mathematics teaching practice. And 65% said they used Internet to search for theoretical information related to the topics studied in their classes, to search for formulae, or to send homework to their students.

In terms of the observed and interviewed teachers, all 16 of them mentioned that they had taken professional development workshops on the use of digital tools, mainly on the use of graphing tools, such as Winplot—which was also the most common use mentioned; and on the use of information and

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communication tools (i.e., Internet) or office suites; and ten of them had had a short course on some dynamic geometry software (i.e., Cabri, SketchPad or Geogebra).

However, from the interviews, we realized that the way in which these third-phase teachers used DT, was mostly as checking and comparison tools, or to save time by using tools (e.g., Winplot) that would facilitate the construction of graphics. A surprising response was that of a teacher who said he only used DT because it was a requirement of his school.

Furthermore, although, when we interviewed them, all 16 teachers claimed to use DT for their lessons, at the time we visited them only four of them actually used them with their students in our observation sessions. Some of explanations that were given for the lack of use of DT when we observed, were the following:

- they only used DT in class once per school term (e.g., to show students how to use a graphing software) and afterwards students are supposed to use it for homework;
- they use Internet (e.g., email) for sending and receiving students' homework;
- they ask students to research how to use a graphi ng software at hom e and turn in com puter-plotted graphs as homework;
- the school doesn't have the necessary equipment;
- they don't have access to the school's computer room;
- they only use DT for class preparation.

Therefore, though all these teachers claimed to use DT in their practice, it was clearly a very limited use, if any at all.

Sample Data from the Four Teachers Observed Using Technology

Here we summarize the way in which the four teachers used DT when we first visited them:

Three teachers, whom we will name teachers A, B and C took their own laptops and beamers to their respective classrooms. However, teacher A could only connect his equipment to the ceiling lamp, due to the lack of electrical outlets in his classroom.

Teacher A showed his students a video downloaded from the Internet on the theme of geometrical congruence and similitude that was the theme under study; however the video had no sound, had Portuguese subtitles and was blurry, so that it was difficult to follow and see.

Teacher B had no problems in connecting his equipment. He used a plotting software (Graphmatica) to show his students the domain and range of polynomial functions. Though he did allow a couple of students to play with the software, the DT tool was used only for visualization and the main activity was carried out in paper-and-pencil.

Teacher C also used Graphmatica, but she faced many problems in projecting the images (taking over 20 minutes of a two-hour session). She was teaching the theme of irrational functions and asked the students to type a function in Graphmatica. She began with $y=\sqrt{x}$ typing it on the whiteboard (Figure 1) and asking a student to do it with Graphmatica (Figure 2).
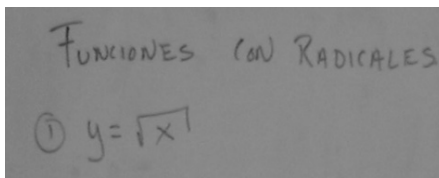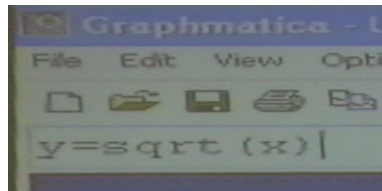

Figure 1: Teacher C writes function on board

Figure 2: Graphmatica input

She wrote other functions on the board, that students took turns graphing in Graphmatica: $y = -\sqrt{x}$, $y = \sqrt{-x}$, $y = \sqrt{x} + 3$, $y = \sqrt{x} - 3$. But when she moved on to more complicated functions: $a)\ y = \sqrt{x^2 + 9}$, $b)\ y = \sqrt{x^2 - 9}$, $c)\ y = \sqrt{-x^2 + 9}$, $d)\ y = \sqrt{-x^2 - 9}$, the way of inputting these functions became more complicated: whereas before they had been using the SQRT command, they now had problems and the teacher changed to using the ½ power instead. But this created further problems; such was the case of function c) which was incorrectly inputted (Figure 3) and produced an incorrect graph (Figure 4).
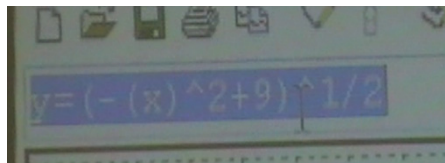

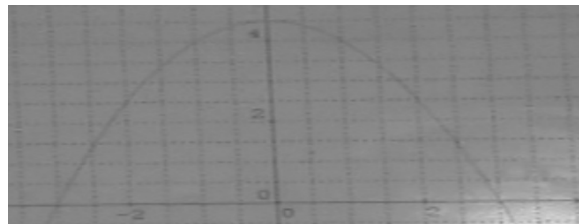**Figure 3: Input in Graphmatica for function c)**

Figure 4: Graph produced by Graphmatica to an incorrect input

The problem with the input of this function was that the ½ power was not placed between parentheses. Therefore the plotted function was actually $y = \dfrac{(-x^2 + 9)^1}{2}$, which for x=0, gives y=9/2=4.5. However, the teacher did not notice this; even when a student pointed out that the graph was wrong, that the curve should have cut the y-axis in 3, she replied by saying that the root of the function, where the graph cut the x-axis, was 3, so the student's comment was not correctly taken into account. All the other functions were also incorrectly inputted and thus incorrectly graphed; the teacher, however, did not acknowledge that there was any problem. Another four students also doubted the accuracy of the graphs, but the teacher just said that those were the behaviors of the functions, never correcting the situation.

Teacher D took her students to the school's co   mputer room, where each student could use Graphmatica. The topic was the same as Teacher C's, but in this case there were no problems.

Discussion and Concluding Remarks

Though curricular reforms and society's changes are pushing for the inclusion of digital technologies in schools, our results show that is not straightforward. Though the majority of the surveyed teachers are conscious of the changes brought about by digital technologies in the world and how these have permeated daily life, and 73.8% claimed to use computers as teaching aids, when we went to visit the schools we observed a different reality. In our study we observed that the incorporation of DT in Mexican public high-schools is extremely limited, if not nil.

One of the categories that were established in our study, derived from the work of Shulman (2001) and others (as discussed in the theoretical framework section above), is that related to curriculum knowledge: in our study, we wanted to see if and how teachers took into account and used the methodologies, strategies and other recommendations stated in the official programs and curricula, in their practice. But in our study, most teachers observed and interviewed were unable to explain what those recommendations from the curriculum were (let alone put them into practice), even though they had previously claimed explicitly to be using them, including the use of technology.

Another observation is the lack of equipment and facilities for using DT that is seen even at some of the best public high-schools in the country (which were the ones we visited). Most public high-schools are not equipped with computer rooms, and in those that do have them, teachers tend to not use them (in fact, we were able to observe only one teacher using it), arguing problems in accessing those rooms, or lack of training in their use.

When teachers do use DT, the use that is done, tends to be limited to presentation (as in the case of Teacher A), visualization or computing uses (e.g., using graphing software), for checking results produced in paper-and-pencil, or simply for communication (e.g. using email or Internet for sending homework's). It is thus more of a mechanical use (or, simply, for accuracy and saving time, as in the case of the use of plotters) rather than having educational aims, and much less a meaningful harnessing of the potential of DT for enhancing learning. Furthermore, we observed that teachers did not design any activities using DT (other than plotting a graph, or checking a result with the use of DT)

Those few teachers who mentioned to be up-to-date in the use of DT, underestimate their potential as educational aids and lack technical pedagogical and content knowledge (TPACK). They are not conscious of the difficulties that may arise during the implementation of DT in the classroom (such as in the cases of Teachers A and C), and lack the technical knowledge and mathematical content knowledge to deal responsibility with situations such as the one observed with Teacher C. Another deficiency noted, is that two of them had not prepared their lessons, which is an important aspect mentioned by Llinares (2000) that should be part of the professional teaching practice.

It is important to note that although some teachers have tried to adapt to the changes in education, attempting to change their teaching methodologies and attempting to incorporate DT into their practice, the lack of training and support can lead to confusions, misinformation, or even loss of interest or commitment. In fact, during the interviews, some of the high-school teachers complained that the only type of training they had received were on the basic use of office software suite packages, and not in more specific tools for mathematics education (such as dynamic geometry or CAS).

The above results coincide with those reported by Julie et al. (2010) from a survey conducted in Latin America in 2006. We would have expected changes since 2006, but as was noted ten years ago by Cuban, Kilpatrick, and Peck (2001) the incorporation of technology into classrooms has been a very slow process, and this seems to be particularly true in developing countries like Mexico, where the incorporation of technologies in teaching practices is limited. In Sacristán, Parada, and Miranda (2011) we discussed this problem, observing two types of limitations and obstacles: one related to digital divides (illustrated here by the lack of equipment and facilities); the second related to professional development of teachers and the educational system itself.

Hennessy, Ruthven, and Brindley (2005) point to the importance of teacher involvement (rather than a technologically-driven model of technology integration) in effecting classroom change; but they also point that this involvement is undoubtedly influenced by the teachers' working contexts. The little use of technologies we observed in our study, is partly due to lack of proper conditions, but also because teachers

have not experienced other uses. Hitt (1998) pointed out that teachers will only feel the need to incorporate technologies to their practice when they experience the effectiveness of a tool or resource in dealing with a problem. Thus, rather than focus on the delivery of technical skills (which are the type of courses the teachers in our study had received), it might be helpful if teachers can participate in professional development models that immerse them—and support them—in the experience of dealing with mathematical situations through technology. However, taking into account the reality of countries such as ours, this may not be so easy.

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