In this paper, we report data from six primary and middle-school in-service teachers in Mexico, who have been reflecting on the changes in their practice, and that of their colleagues, when incorporating digital technologies (DT) to their mathematics classrooms. The changes documented take into account different aspects: the teacher, didactical materials, classroom interactions, students’ learning and motivation, technical aspects and the broader school community context.

Introduction: Digital Technologies in Mexican Schools

The inclusion of new digital technologies in classrooms is inevitable, and teachers need to adapt to the changes brought about by these technologies, as well as harness their potential; but this is not straightforward. In our paper we will present data from case-studies of six Mexican teachers who have been reflecting on their changing practice, and the changes in the classroom and school culture, when incorporating digital technologies (DT).

Since 1997, the Mexican Ministry of Education has been making intense continuing efforts for incorporating digital technologies into Mathematics classrooms of the basic education system (primary and middle-school levels). The largest projects in this effort are known as the Teaching Mathematics with Technology (EMAT) Program for middle-schools, and Enciclomedia for primary schools. The EMAT program provides activities and a pedagogical model for incorporating the use of technological tools in mathematics classrooms, in a constructionist way, aimed to enrich the teaching and improve learning (Ursini & Rojano, 2000). The pedagogical model emphasizes changes in the classroom structure such as the requirement of a different teaching approach and the way the classroom needs to be set up. In particular, the pedagogical model emphasizes a collaborative model of learning, and a role of the teacher’s as guide, mediator and promoter of the exchange of ideas and collective discussion. The main tools currently used in EMAT are Spreadsheets, Dynamic Geometry, Logo and CAS activities with the TI-92, and. On the other hand, Enciclomedia, which has been massively implemented in all primary schools in Mexico, aims to help teachers by providing resources, computer interactive activities and strategies (mainly designed to be used on electronic whiteboards), through links in an enhanced electronic version of the mandatory textbooks (Lozano et al., 2006).

Theoretical Framework

We consider digital technologies (DT) catalysts for change, since they have a great potential for revolutionizing school practices. In fact, there have been conflicts reported between the autonomy that students gain from the use of DT, versus the restrictions of conservative curricula (Facer et al., 2000). This is one of the “forced” changes that educators need to face.

Mexican schools tend to be extremely traditional; one of the aims of EMAT was to use the DT as a means to transform the school culture. But, even though a decade has passed since the initial EMAT efforts, the benefits of the inclusion of DT in schools are not yet perceived and the difficulties in changing a school culture (including teachers’ difficulties in adapting to the proposed pedagogical model) are more evident than ever (Sacristán et al.,
2006); it is clear that the role of the teacher is critical for a successful implementation of DT in the classroom and for fostering meaningful learning in students.

Research results (e.g. Ertmer, 1999; Goldenberg, 2000) indicate that DT can help students learn in a more significant way, only through an adequate use; they also indicate that teachers with little experience in the use of DT, have difficulties in harnessing the power of these technologies as tools for learning, having as consequence a lack of significant influence of the DT in the school culture (McFarlane, 2001). Teachers not only need to be trained in the use of the new technologies but also need to understand how to use these tools, and change their practice in order to promote significant learning in their students. However, changing teaching practices is not straightforward: teachers can face struggles when attempting to modify their practices (e.g. Wilson & Goldenberg, 1998).

In order to provide strategies to help in the educational transformation and to overcome what Ertmer (1999) calls “second-order barriers”, more understanding is needed of all the variables, difficulties and changes that teachers’ face when attempting to incorporate new technologies into their practice. And what we believe can provide further insights is to document those changes from the perspective of the teachers themselves (as opposed to exclusively that of the researchers). We therefore want teachers to reflect on their own practice. That is the purpose of our study.

**A three-year development and research project with in-service teachers**

We are involved in a development and research project that is linked to a three-year master’s degree program in education. The project seeks to: a) train teachers in the use of DT tools (specifically those linked with the EMAT and Enciclomedia projects) for mathematics teaching and b) research and understand how changes in school practice and culture are brought about by the implementation of those tools into the classroom. More specifically, the project seeks to document the methods, techniques, resources and strategies that teachers use and develop when incorporating new technologies into their practice, and understand the influence and impact of, and on, the broader school community (since we consider teachers part of a symbiotic system that is the school community).

**Methodology**

In this project we have been working (to date, for almost two years) with six in-service mathematics teachers, all of them students of the aforementioned master’s program. Their ages are between 35 and 45 yrs. old, with a minimum of eight years of in-service practice. Two of these teachers (Sarah and Jane), both female, are primary school teachers in fifth- and sixth-grade (children 10-12 yrs. old); the other four (Mary, Michael, Adrian, and Raymond) – one female, the other three male— are teachers of the three grades of the Mexican middle-school (children 12-15). Four of these participants (Sarah, Jane, Adrian and Raymond) are also involved in training programs for their colleagues. Although all of them had taken some workshops on the use, for mathematics teaching, of some technological tools (such as the Enciclomedia or EMAT tools), the use they had carried out of these tools in their practice, before being part of the project, was very limited (if any).

During our development and research project, the teachers have been involved in three, almost simultaneous, activities: a) in the training, and development of abilities, for the use of digital technologies (DT) in the classroom; b) the design and planning of teaching strategies and activities that integrate DT; and c) engaging in observation and reflection-on-action (Bjuland, 2004) of the changes in their own teaching practice with the new tools. In addition, the four teachers who are involved in training programs for other teachers, have also engaged in observation, or training-and-observation, of some of their colleagues (not involved in the development project) when incorporating DTs. As part of the master’s degree courses, the participants have also analyzed and discussed research papers and results.
As a theoretical and methodological framework for integrating these attempts of educational innovation with teacher learning research we follow the work of García et al. (2006), as well as that of Artzt & Armour-Thomas (1999) which provides a model for enabling teachers to reflect on their instructional practice.

The participants have been analyzing and reflecting upon the potentials, limitations and changes brought forth by the incorporation of DT into their practice, and that of their colleagues, from various perspectives:

(a) The perspective of the teacher and the didactical use of DT:
- changes in the role of the teacher (e.g. changes of the teacher as lecturer, to that of mediator) and the difficulties in those changes;
- changes in teaching methodologies;
- changes in their beliefs and conceptions;
- use and design of activities with DT;
- articulation of the DT activities with the curricular requirements;
- design of assessment techniques for DT activities;
- complementarity’s of different DT tools among themselves, and with non-DT activities (such as those with paper and pencil);
- new mathematical knowledge and perspectives through DT.

(b) The perspective of the classroom interactions:
- changes in classroom structure;
- changes in teacher-student relationships;
- changes in student-student relationships (collaborative work);
- changes in the physical setup of the classroom, etc.

(c) The possible impact on students:
- in their learning;
- in their motivation (affect), beliefs, and classroom participation.

(d) The technical perspective:
- technical knowledge for the use of the DT tools and equipment;
- technical difficulties.

(e) The social context:
- changes in the school community;
- the role of school authorities;
- impact and collaboration with colleagues;
- the interaction with parents.

The participants have been collecting data by using video recording of their and their colleagues’ classrooms; taking field notes when possible; designing questionnaires for colleagues, authorities and/or students; collecting their activities and assessment designs and sometimes students’ work, and most importantly, writing weekly reports. In addition to that, we designed an initial questionnaire for evaluating the participants conceptions on the use of DT and we have held bi-weekly meetings with the participants where they present oral
reports, are informally interviewed, and engage in reflections and discussions with the other participants. Finally, a year after the beginning of the project, “independent” researchers (not involved in the development project) have carried out some observations of the participants during their practice. In this way we are able to carry out case-studies of each of the participants, combining data from both their own reflections and reports, and from researchers observations and interviews. Below, we present some of the findings.

**Some Interesting Results and Discussion**

*Initial Conceptions of the Participants on the Use of Digital Technologies*  
(Data from the initial questionnaire and from the participants’ work during the first trimester).

The main beliefs that the participants had on the use of the DT was that they are a useful tool for teaching because DT facilitate the construction of graphical representations (“it is easier to create graphs”); and that they can save time for some activities in comparison those with paper and pencil. In the questionnaires, none of them mentioned any disadvantages nor seemed aware of the different knowledge or practices that DT can bring. However, many expressed a lack of confidence and concern in the pedagogical and technical knowledge that DT demand from the teacher, and some of them felt uncomfortable in using some of the tools with students; and one of the participants did not believe that the DT tools could help create significant learning in students.

*Results of the Participants Self-Observations and from Observations of Their Colleagues*

Since the beginning of the project, the participant teachers’ beliefs, attitudes and practices have been in constant and profound transformation, and enriched by their long-term exposure and use of the DT in their classrooms, by their sharing of experiences and by their observations of other colleagues.

**General changes in teachers’ practices and beliefs.**

In terms of *confidence with the use of technology*, despite their initial reluctance, in retrospective most participants have realized that the only way they could build confidence was by gaining experience through the direct use of the DT in their practice. One of the participants expressed that although adequate training and continuous support helped her to change her practice, ultimately it is up to the teacher to make the changes.

In terms of *how their practices, and the classroom dynamics, have changed*, most of them recognize that with DT, they need to change the way they teach. Most participants have expressed how they have now taken a back-seat role in their classrooms, becoming more of observers and guides than lecturers. Mary and Michael, in particular, continue to emphasize this at every meeting. As Michael expressed it recently, they have learned more and more, and come to accept, that students can learn on their own, or from collaborative work, with the support of DT, and that they request less and less assistance from the teacher; Michael adds that he has learned to be patient and “open to what he can learn from his students”. On the other hand, Janet, Sarah and Adrian have noted, that although their colleagues –which they observe— make attempts to allow students to collaborate and to have group discussions, these attempts are short-lived and they quickly revert to traditional forms of teaching as they feel uncomfortable letting students talk or hearing them laugh. The participants feel that it takes time for teachers to get used to this change in the classroom structure.

In fact, as the participants reflect more on their practice, they have become increasingly aware of the resistance to change and difficulties of their colleagues (as partly illustrated above). Janet and Sarah remark that although many of their colleagues use DT in their personal lives, most do not consider these tools, including calculators and spreadsheets, as adequate for didactic use. In fact, they have noted that many fellow primary school teachers only use the Encicolmedia tools for projecting the digitalized textbook, and not for exploratory mathematical activities. Also, in general, Sarah, Janet and Adrian have observed
that many of their colleagues attempt to teach with DT in the same way as they did before (i.e. without DT) such as resorting to teaching algorithmic memorization, and are unable to recognize their own mistakes or the value of making mistakes. These participants have even expressed their frustrations in being unable to help their colleagues change or realize the potentials of DT. Interestingly, Raymond, who was initially unenthusiastic about the use of DT, has now made it an aim, to motivate fellow teachers for the use of DT in their mathematics teaching.

Most of the project’s participants have become aware that the use of technology “is a tool and not an end” (Mary’s words). Janet feels that some of the teachers she has observed, are not successful in the implementation of DT into their practices, because they are not clear why they are using it (i.e. they do not have a broader educational goal or plan) and just give students some DT activity for the sake of using the technology.

Awareness of teacher’s own mathematical knowledge limitations and changes in the conception of the type of mathematical learning developed.

Another aspect is that the DT use have made the participants, and their colleagues, aware of their own limitations in their mathematical knowledge. Sarah and Janet have noticed that often the teachers they have observed, refrain from certain DT activities, because they lack mathematical confidence and feel their deficiencies can be exposed by the DT activities.

But, in general, all the participants have realized that the knowledge developed with the DT can be of a more conceptual nature. Mary explains that she has learned to look more at what abilities her students are developing rather than looking for correct answers to problems.

DT tool use and design of DT activities.

At the beginning of the project, all of the participants began with the use of pre-designed DT activities (either from EMAT or from Enciclomedia). Only recently, Mary and Michael began designing their own activities. In one of his first activities (word problem explorations with spreadsheets), Michael made some mistakes in the values of a problem: this led to unforeseen investigations on the part of the students; although these were interesting, the experience also made Michael realize the design difficulties and the importance of being more careful in trying out the activities himself before giving them to students.

Another aspect of the use of the DT tools, has been the complementarity between tools. Most participants began considering that using a single tool was enough to provide students with a rich opportunity for explorations with technology. Only Mary thought otherwise, and early on she began analyzing which tools were suitable for teaching which subjects, and how different tools could complement each other. Only recently, other participants, such as Adrian, have begun to realize that a diversity of approaches and tools can be useful.

Development of assessment techniques for the DT activities.

A concern that has become more and more prominent as we end the second year of the project, has to do with the assessment of the DT activities and of students’ work with DT. This has been one of Mary’s main interests: she has realized that traditional assessment doesn’t adequately evaluate the learning that takes place when using DT; she has asked herself how to assess students’ work with DT and has realized that she is more observant now of students work with DT than at the beginning of the project; she is also investigating how to design problems in a test, which, in order to solve them, would require the use of DT tools.

Other participants are beginning to be concerned about assessment as well, not only of students’ work but also assessment of the activities and strategies used. Adrian recently became concerned, and wrote, that there is a need to change the broader school assessment culture in authorities and parents (both of which should be aware that assessment with DT is different to traditional evaluations), teachers (who have to develop assessment strategies) and students (in particular, he feels that students need to see DT activities as more than just play).

Michael has also changed the way he assesses his students and his own work when using DT; in the beginning he looked for correct responses to problems; later he said: “after learning [the use of] the computer, now I assess not only the answers but also the abilities, the
questions that my students pose; [I also evaluate] my new teaching strategies”. We are not altogether clear exactly how he can assess students’ abilities, but he does take into account the participation and collaborative work of his students.

Implementation difficulties.

The difficulties are of two types: (i) pedagogical and of classroom management, and (ii) technical and administrative. In the first category, some participants, such as Raymond, found it initially difficult to cope with their students progressing at different paces and the need for the teacher to do more individual guidance work, which can be difficult due to time limitations. Another common concern is the need to properly prepare their classes in order to harness the potential of the DT tools; but also in this case, time limitations can make it difficult. With respect to this point, both Michael and Mary have now developed a work methodology that gives much more importance to class preparation involving DT activities.

In the second category, all the participants have expressed frustration with a multitude of technical and administrative issues. One difficulty is often the lack of school support. The teachers frequently have difficulties in gaining access to the technology-equipped rooms, and there are many technical problems with the equipment such as too few computers, lack of maintenance or restricted access that prevents children from saving their work. All the participants also express frustration with the amount of administrative cancellations of many of their programmed technology-based sessions.

Another difficulty relates to training. The participants observe that there is too little training available in schools, and often the trainers themselves are not proficient enough in what they teach, due in part to a cascading model of training. They also comment that other teachers, particularly the primary school ones, want more training in the use of the equipment (computers, beamers and electronic whiteboards) because they are afraid to damage it.

Observed changes in students behavior and learning.

In terms of the impact on students’ behaviour, attitudes and learning, all of the participants note an increase in motivation and interest in their students when using DT (Mary wrote that her students consider the work with DT, a game). The exception to this has been when they have observed other teachers “presenting” DT activities without allowing students to actively engage, collaborate, explore and/or discuss amongst themselves. In one of Michael’s first experiences, he also failed to engage students and felt that the classroom atmosphere was one of total apathy; but now he has learned to let students collaborate and explore and he feels that sometimes the classes run almost by themselves; he has also been surprised recently that his students are beginning to use the DT tools (such as spreadsheets) for solving problems in other school subjects (such as in carpentry workshops).

In terms of mathematical learning, both Mary (middle-school) and Sarah (primary school) comment that their students have improved in traditional departmental mathematics tests since using the DT tools. However, although Mary has noticed a general improvement in conceptual understanding, she had also noted the emergence of new difficulties in the formal math performance of some of her students. This has made her realize the epistemological difference of DT-based learning versus traditional learning and now views them as complementary. Adrian also noted that although students can solve the work (e.g. using spreadsheets) they have difficulties explaining their results. Michael also noticed this and it led him to ask his students to explain all their work with DT in written form; since then, he has noted that students increasingly write and describe their work better.

Concluding remarks

What we have observed, is that through the training and “forced” involvement (in the masters program) with the DT tools, these teachers’ perceptions of their use has been enriched. Second, the classroom experiences of implementing DT has led them to reflect on the potentialities and limitations of the tools. More importantly, the opportunity to reflect upon, share their personal experiences with the other participants, and observe fellow
teachers, has led them to develop a critical and reflective attitude, as well as enabled them to construct didactic strategies for the use of DT that are in accordance with the specific needs of their students. However, even these teachers have experienced difficulties in changing their practices; we keep in mind the words of Goldenberg (2000, p.8): “Provide instruction and time for teachers to become creative users of the technology they have.” We will continue the follow-up of these teachers and the analysis of their changes which may provide insights for strategies for more successful integration of DT in the classroom and in the curriculum.

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