Integration of Interactive Resources into the Teaching of Mathematics in Primary Education in Mexico

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Abstract: *This article reviews an interactive resource used in a national project in Mexico. The intention of its design is analyzed, as is the use to which teachers put it in math class. International research has shown that learning opportunities offered by Digital Technologies (DT) depend on the teacher's mediation supported by knowledge of the content to be taught and its technique which, together with the characteristics of the students, permit generation of new knowledge and mathematically useful learning activities, rather than mere adaptations of paper and pencil situations. We understand technological tools as an active part of the construction of mathematical knowledge. Instruments are not mere auxiliary components or neutral elements to the teaching of mathematics; they shape student actions. Every tool generates a space for action, while at the same time posing on users certain restrictions. Such limitations make it possible for of new kinds of action to emerge. The results of this study demonstrate that integration of technology into the classroom demands of the teacher not only knowledge of the tool, but also mathematical knowledge for teaching: pedagogical content knowledge, subject matter knowledge and the use of didactic teaching methods.*

1. Introduction

The presence of Digital Technologies (DT) in elementary education has generated new challenges for the management of school knowledge: contents, actors, resources, goals, and objectives. Several projects have been carried out in the last two decades that incorporate computers and digitalized resources into educational processes aimed at improving student learning [1]. Yet the results presented in research and in national and international evaluations (Enlace, Excale, and PISA, respectively) give evidence that what actually occurs is quite distinct from the proposals put forward by educational authorities, curriculum designers, and research groups. All of these perspectives have pointed up the demonstrative chasm between the normative ideal and reality [2] [3]. This is why it is necessary to immerse ourselves in educational and teaching reality to construct the theoretical knowledge closer to daily classroom practice. A more comprehensive view becomes fundamental to confronting the challenges generated by the selfsame innovations that are proposed and put in place. In the case of Mexico, we wished to know how teachers implement DT educational projects in primary education, such as Enciclomedia (*www.enciclomedia.edu.mx*) and Digital Skills for All (*www.hdt.gob.mx*).

The investigation which this paper discusses studies how the use of technologies adopts different forms through teacher practices, which have reconfigured the notion of DT-mediated learning. The uses DTs are put to in education, and specifically math learning and teaching, coincide with those reported by McFarlane [4]: each one of a range of tendencies has its own conceptualization for their inclusion in the classroom, for instance, as an object for teaching which extends the curricula; as an option to *technify* teaching strategies and existing contents; and as instruments that reconfigure curricular contents, classroom practices, and learning.

The analysis reported below, on the features of both the interactive resources generated for the Enciclomedia Program and the mediation teachers perform with these resources, forms part of this investigation. Enciclomedia is a large-scale Mexican project implemented in 2004 with the purpose of enriching primary school teaching and learning by working within an instructional model of a single computer in the classroom. An electronic version of the mandatory textbooks are used for all elementary schools throughout the country, and is being enhanced with links to computer tools designed to help teachers with the teaching of all subjects, including more than 300 resources multimedia only for mathematics. Mandatory education is now undergoing reform that implies modification of the free, obligatory textbooks and adjustment of the multimedia resources in Enciclomedia that are incorporated into a new project called Digital Skills for All (*Habilidades Digitales para Todos* or HDT).

Studies and evaluations of DTs in primary school [5] report that the Enciclomedia Program has indisputable potential benefits, yet a series of requisites are necessary for these to achieve fruition. Some recommend "promoting teacher-teacher, teacher-principal, teacher's mentor, etc. training in the use and exploitation of the tool." (*op cit.*, p. 60) Others have found that teachers use the technological resources subsumed into an entirely traditional manner of class explanation [6] or as a response to a need to unify and socialize student work [7][8]. All of these highlight the fact that the teacher must modify their own practice relative the planning, execution, and evaluation of the activities and their teaching role.

In consonance with these studies, experiences have been reported of math teachers using DT in class which note necessary modification of teaching practice and of the school culture [9][10][11][12]. Yet these changes are not immediate, but a product of a gradual, progressive process [5][8].

Investigations carried out in other countries [13][14][15] show that teachers select technological resources in a manner congruent with their class activity and their conceptions of the teaching and learning of math. They prefer resources which permit their students to learn math quicker and better, and which are adaptations of paper-and-pencil activities [16]. Pointed out by Patter [17] is the fact that teacher education in technology remains weak in certain aspects and that there is a need to detect, analyze, and justify what factors bar integration. One of the key research tasks becomes, as emphasized by Laborde *et al.* [15], to investigate teaching practices in daily classes relative the processes of technology integration.

Our interest resides in understanding how teachers mobilize professional knowledge in a technological dimension, as well as mathematical knowledge for teaching [18]. Thus the aim of our research is to analyze and categorize the Technological, Conceptual, and Didactic dimensions (TCD), those teaching competencies in primary education that incorporate digital technologies (DT) in math education. Investigation constitutes a window to better comprehend this phenomenon and to generate lines of research that allow construction of proposals for teacher professional development which improve student learning.

This article analyses an interactive resource, its potentials and restrictions, and the manner in which it is integrated into a math class. The analysis shows how the conceptual problems derived from the resource's restrictions may be transformed into opportunities for student learning. Therefore the teacher must integrate mathematical knowledge for teaching and knowledge of the tool in its varied dimensions: technical, conceptual, and didactic.

2. Teaching and Learning Mathematics with Computer Tools

This work sets out from the premise that learning is generated as a result of social participation and, therefore, of the interaction between the subjects involved — teacher and students. This participation must be active in the practices carried out within the group in which they are immersed. Tools, as material devices and/or symbolic systems, are considered to be mediators of human activity in this process. They constitute an important part of learning, because their use shapes the processes of knowledge construction and of conceptualization [19]. When tools are incorporated into student activities they become instruments which are mixed entities that include both tools and the ways these are used. Instruments are not merely auxiliary components or neutral elements in the teaching of mathematics; they shape student actions. Every tool generates a space for action, and at the same time it poses on users certain restrictions. This makes possible the emergence of new kinds of actions.

The teacher fulfills the crucial function of mediator in student learning, a role which encompasses selecting the programs to use; supporting students during the solution of their activities; motivating them to explore and learn from their own mistakes. This role requires that whole group discussions create explicit links between the knowledge generated by the exploration aided by technology and formal mathematical knowledge. In other words, the teacher assumes responsibility for organizing work, guiding, mediating, and advising. This new function can imply modification of the interaction, structure, and work in the classroom, changes which are undergoing formulation and are not presented here.

3. Methodology

The data reported here are the result of non-participant observations of nine teachers who participated in the study voluntarily during a school year. The criteria for selection were to be in-service elementary school teachers; to have incorporated DTs into their instructional activity, particularly Enciclomedia; and a disposition toward being observed and interviewed if necessary. Two of the subjects studied at teacher's college (or *normal school*, specializing in high school pedagogy); six of them have bachelor's degrees in elementary and junior high education with weak training in mathematics, and one of these B.A.s has a degree in Mathematics Education; the ninth subject has some study in Mathematics and Math Education. The latter is the case this study centers its analysis on, insofar as it is in her class where professional knowledge was deployed with greatest clarity.

The spaces of observation were classrooms in six Mexico City schools. While the type of equipment is not considered as a variable of analysis, we observed that some of the schools selected (three of the six) have media or computer labs, and only two of the schools were limited to the Enciclomedia equipment for 5^{th} and 6^{th} grades (which is one computer per classroom of one teacher with approximately 35 students).

The observations were performed by working with five resources for math lessons: *Balance*, *Dice*, *Animations*, *Dynamic Geometry for Primary*, and *Where Is the Number?* (*¿Dónde está el número?*) The classes were videorecorded and semi-structured interviews were held in some cases. The unit of analysis was the moment in the class when technology was used to implement a math activity and where the restrictions of resources facilitated reformulating the teacher's mediative actions to solve the conceptual problems the restrictions generated. Therefore this paper reports the results from use of the *Where Is the Number?* interactive.

Where Is the Number? An Interactive Game on the Number Line

The learning game is an interactive resource designed in Mexico for students to become familiar with the order of whole numbers, decimals and fractions, and number density. The interactive presents a numerical axis with two numbers displayed which indicate an interval. The user must find a number between the two shown. The user's score for correct answers is differentiated depending on type of number: a positive whole number scores one point, a decimal wins two points, and a mixed fraction is worth three points. The program registers four points for correct negative numbers. As many as four teams may play. The interactive includes a variety of modalities of play and levels of difficulty.

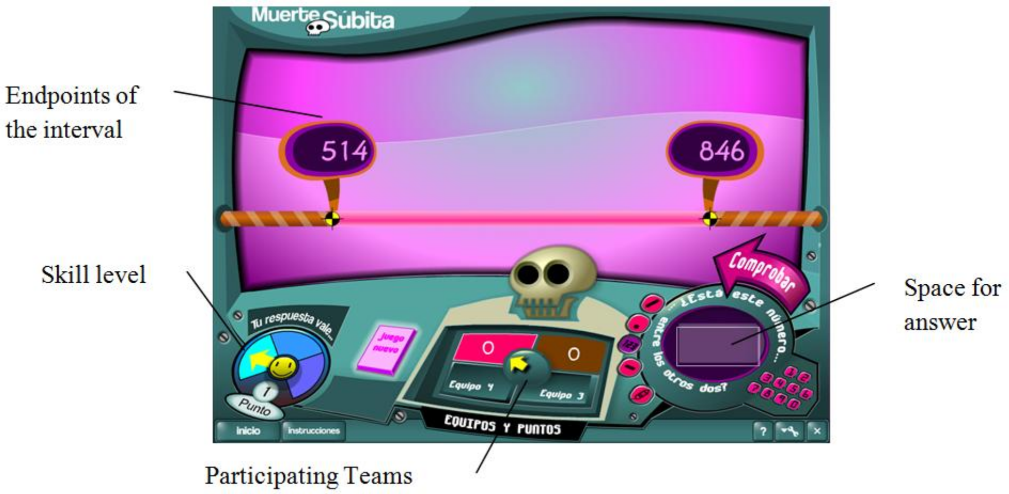

Figure 1 Description of interactive, buttons, and menus

Where Is the Number? gives immediate feedback to the user's actions, validating the response registered. Incorrect answers immediately give the turn to the next team. At the end, a winner is announced and, when more than two play, the participants are ranked.

The resource is designed so that when a number is given within the original interval, it is divided into two sub-intervals and the program selects the smaller of the two. This process naturally leads the user to manipulate decimals and fractions. Rational positive numbers are introduced in fifth and sixth grades.

The first of the limitations which this resource's programming has that impinge on this study's analysis is the random assignment of the numbers at the ends of the interval — the teacher has no control on their selection and mixed numbers even appear with proper and improper fractions (see

Figure 2a). Another limitation is that only mixed fractions can be typed in. The third limitation is that decimals can not go beyond the hundredths; for example, the interactive does not permit smaller increments between 105.05 and 105.06, see Figure 2b).

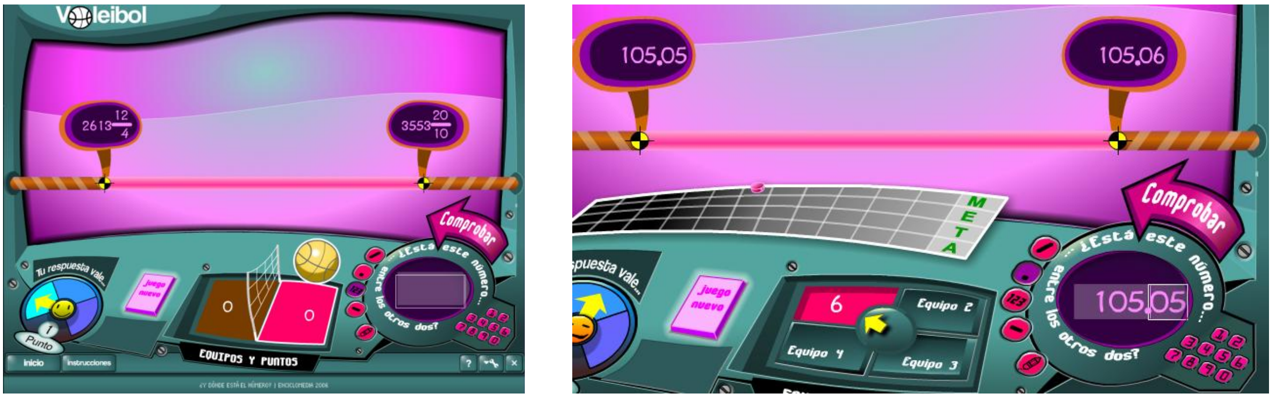

Figure 2 a) Improper fractions and b) restrictions on placing thousandths

This latter restriction signifies that the interactive does not allow for the discovery that a new number can always be found between any two rational numbers. Without mediation by the teacher, the resource could reaffirm the student conjecture — proven in the study — that, given two decimals with thousandths, no other number exists between them. The teacher's role is crucial in this process, since it will be his or her questioning that will enable student reflection on their actions and the search for the number even though the interactive does not permit writing or verifying it. Validation should not be sustained in the resource, but rather constructed from math itself.

4. Experiences in the Classroom: Results and Discussion

To achieve our goal, the analysis centers on how a teacher takes advantage of the restriction in *Where Is the Number?* to meet the didactic intent of the lesson: "To reflect on the arbitrary character of unit in a number line and to use this as a resource to compare fractions and decimals. To discover that between any two decimals there are other numbers (density)" [20].

The activity began when the teacher asks the students to get together into four teams of six people each. Then he/she inquires into previous knowledge.

> *Teacher*: How do we know when a decimal number is larger or smaller than another?
> *Student 1*: If we have the number 12.5 and the 11.5, we know that 12.5 is bigger than 11.5 because 12 is bigger than 11.
> *Teacher*: Any other strategy? What happens if we have 12.5 and 12.6? How do we know which one is bigger?
> *Student 2*. 12.6, because 6 is bigger than 5.
> *Teacher*: Can we find a number between 12.5 and 12.6?
> *Students*: There isn't any.
> *Teacher:* Which number is greater: 12.45 or 12.6?
> *Students*: 12.45, because 45 is greater than 6.

In this transcription, the students interpret the numbers to the right of the decimal sign as natural numbers. This is means that they decide which number is greater as the one with the greater number of decimals.

After this initial activity, the teacher opened the interactive and played collectively in the Race modality so that her students could become familiar with the number line. At first they played with whole numbers and then with fractions and simple decimals. The students' initial strategies were to use positive whole numbers. They moved progressively to decimals and fractions because they earn more points. We can appreciate in Figure 3 that every team is using mixed numbers regardless of whether the fraction is proper or improper. It should be noted that when using fractions the interactive divides the straight segment into three subintervals, and the user must select which of these intervals his number will be found in. Figure 3 shows a student choosing the number 250½ between $168\frac{11}{10}$ and $332\frac{5}{5}$.

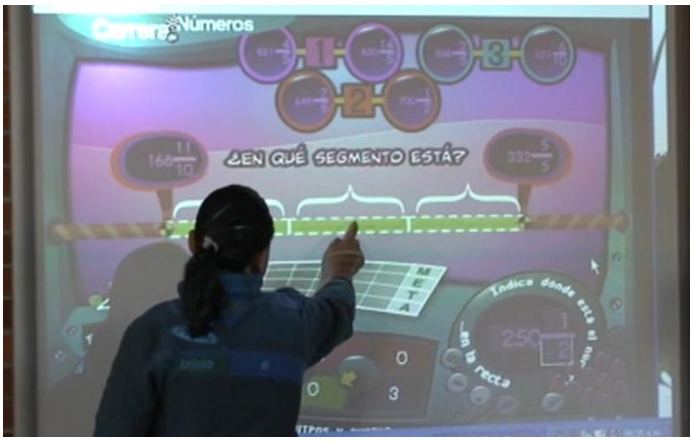

Figure 3 Student selects which of three segments her group's number falls into

Videorecordings of the class show that the teacher's interventions promoted students choosing a number as a result of team discussion; otherwise she insisted that they continue until they came to an agreement. These interventions favored mathematic dialogue among students and the use of other materials, such as a fraction chart (see Figure 4) to compare the fractions that they worked on in a previous class. This type of action demonstrates how different technologies can be complementary (digital/pencil and paper) in decision-making.

When they made mistakes where the hypothesized number did not fall into the given interval, or when the incorrect subinterval chosen, the teacher encouraged each team to argue why the interactive indicated that it to be a wrong answer. In this way the students themselves recognized their errors, reflected on them and, therefore, were able to suggest new responses. During this process, the teacher sometimes helped with focus questions such as, "Why isn't this number between these other two?" and "What number would this be?" If the team was unable to answer, then the other teams helped with the process. In cases like $831\frac{4}{5}$ and $831\frac{5}{6}$, the numbers give demanded of the students a comparison of the fraction, because the part with the whole number was the same. Again here the students made use of other materials to compare fractions.

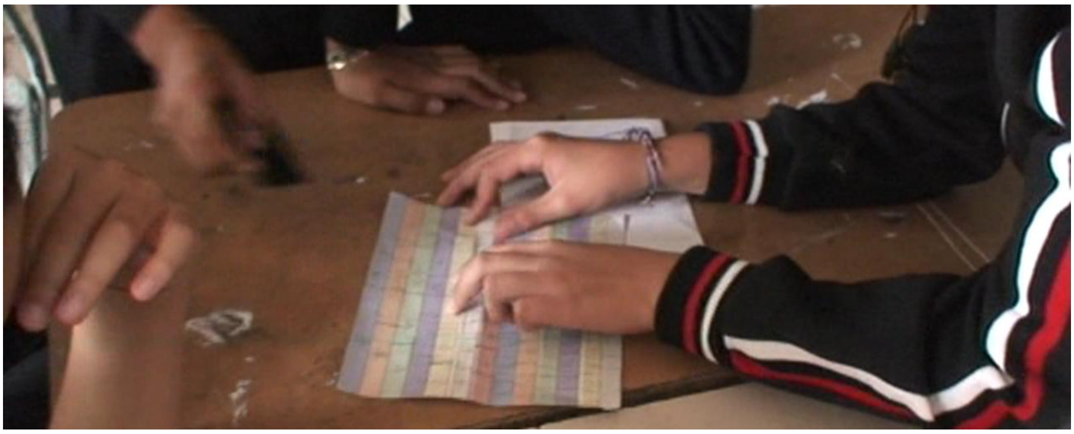

Figure 4 Complementary uses of technological resources (digital/pencil and paper)

To finish the activity, they reflected on the difficulties found in comparing the decimals and mixed fractions, and they discussed a new strategy to find a fraction between the two given — in other words, to add the two fractions and divide the result by two. This strategy which the teacher offered was well received by the students and proven in the exercises they had noted down in their notebooks.

The teacher was unable to use the resource in support of identifying that a number always exists between any two other numbers. As already mentioned, given that one of the interactive's limitations is an inability to attempt the numbers at the extreme ends of the initial interval, it was impossible to address cases like 12.45 and 12.5, or to transform 132.5 to 132.50. Nevertheless the discussion that was generated to result the conceptual conflict was based on the properties of numbers, that is, mathematics itself.

Thanks to the teacher's mediation, during the discussion the students noted that when comparing numbers like 132.45 and 132.5 they need for both to have the same quantity of decimals. This way they would be comparing 132.45 with 132.50, aligning the decimal points and noticing that the number in the tenths space in 132.45 is less than the tenths digit in 132.50, giving an answer that 132.45 is less than 132.5 — a most useful strategy, not only for comparing numbers. They particularly discussed how this strategy of adding a numeral was useful in finding a number between two other given ones; for example the numbers 12.5 and 12.6 can be transformed into their decimal equivalents 12.5=12.50 and 12.6=12.60, and in this manner, it is much easier to find the number sought.

Analysis of the various approximations the students made toward the order and "density" of the numbers by using this kind of technological artifact gives evidence that the process favors an expression, contrast, and passage from intuitive knowledge to comprehension and assignment of meaning to representations to construct the notion given adequate mediation by the teacher. The teacher's intention, based on mathematical knowledge for teaching and knowledge of the resource's restrictions and potentialities, procures a progressive transit from intuitive notions toward a formalization of the content, up to and including calculation with conventional procedures and symbologies. Mathematical actions likewise evolve gradually, that is, from strategies of trial and error to more formal procedures, as evidenced in the plenary activity to finalize the session. This type of action coincides with what was found by Sandoval *et al*. [10].

Resources like the *Where Is the Number?* promote questioning of the content, questions to which the teacher does not always have an answer. It is here where the centrality of mathematical knowledge implied in the resource itself. Moreover, such resources propitiate a debate that does not always arise, given the short time institutions allow for effective work.

5. Conclusions

The findings reported here reaffirm the consideration that numerous studies have reiterated: a need for teacher professionalization for students to be able to reach a certain level in the construction of knowledge with DTs. Transforming the math teacher's professional practice in the classroom will only be modified permanently if, in correlation, the disingenuous epistemological model is likewise modified, which is based on models of habitual teaching [21].

The teacher's mediation was a key element in transforming the limitations intrinsic to the resource into potentialities for learning built upon conceptual reflection during the process of the class. <for one consideration, she knew the topic of the lesson and the potential problems it presented for the students: comparing decimal numbers and fractions, which was evidenced in her opening questions. For another consideration, her organizational strategy of forming teams, together with the manner in which they participated during the course of the game and its established rules, promoted mathematical discussion and the appropriate use of the resource. In this case, the resource was employed in accordance with explicit didactic intention and not as an element for motivation.

As Laborde points out [22], the design of the program itself affects the construction of each and every one of the actions required for the use of that tool, including the mathematical knowledge also immersed in them. The user's mathematical knowledge, therefore, is crucial to exercising theoretical control over handling of the artifact, which in this case was instantiated in the number line.

The incorporation of DTs into teaching is conceived of by some teachers and educational authorities as the solution for avoiding certain difficulties for the students and thus freeing them to concentrate exclusively on conceptual problems. The situation is not as easy as this because the tools of learning introduce problems of manipulation and new queries for the solution of the tasks assigned [23]. As illustrated in the preceding passages, procedures for their solution within the context of a given problem depend on the tools available.

In summation, resolving a mathematical task within a technological environment requires two classes of knowledge: mathematical and instrumental. Yet the meanings a subject constructs are contextualized within a phenomenological experience and its process of decontextualization. Modification in significations requires social construction within the class, with the teacher's guidance [23]. This is why integration of technology into the classroom necessitates not only technological skills on the part of the teacher, but also mathematical knowledge for teaching: knowledge of the content to be taught and its teaching technique in a manner that propitiates the generation of new knowledge relative the assigned learning activities.

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References

[1] Secretaría de Educación Pública (2009). *Plan de estudios 2009*: SEP Available: http://basica.sep.gob.mx/reformaintegral/sitio/
[2] Ruthven, K. (2007). Teachers, technologies and the structures of schooling. *Proceedings of the Fifth Congress of the European Society for Research in Mathematics Education* [CERME 5], pp. 52-67
[3] English, L. (2008). Setting an agenda for international research in mathematics education. Lyn English (Ed.), *Handbook of the International Research in Mathematics Education*, Second edition, Lawrence Erlbaum, USA.
[4] McFarlane, A. (2001). *El aprendizaje y las tecnologías de la información*, Madrid, Santillana.
[5] Facultad Latinoamericana de Ciencias Sociales México (2008). *Informe de evaluación Proyecto Enciclomedia*. *Flacso*. Available: http://www.sep.gob.mx/wb/sep1/programa_enciclomedia
[6] Chávez, Y. (2007), *Enciclomedia en la clase de matemáticas*, Tesis de Maestría en Desarrollo Educativo en la Línea de Especialización en Educación Matemática, Universidad Pedagógica Nacional, México.
[7] Granados, S. (2010). *Uso de herramientas tecnológicas y Enciclomedia por profesores de primaria en sus clases de matemáticas*, Tesis de Maestría en Educación con Especialidad en Matemáticas, Cinvestav-IPN, México.
[8] González, J (2010). *La transformación de las formas de enseñanza en el aula de matemáticas en el nivel primaria, mediante la incorporación de herramientas tecnológicas digitales*, Tesis de Maestría en Educación con Especialidad en Matemáticas, Cinvestav-IPN, México.
[9] Lozano, M., Sandoval, I. & Trigueros, M. (2006). Investigating mathematics learning with the use of computer programmes in primary schools. *Proceedings of the 30th Conference of the International Group for the Psychology of Mathematics Education*, Prague, Czech Republic.
[10] Sandoval, I. Lozano, M.D. & Trigueros, M. (2006). Changes in the culture of the mathematics classrooms with the use of Enciclomedia, a national programme. *Proceedings of the 28th Conference of the North American Chapter of the Group for the Psychology of Mathematics Education (PME-NA*), Mérida, México.
[11] Sacristán, A. (2005) Teachers' difficulties in adapting to the use of new technologies in mathematics classrooms and the influence on students' learning and attitudes. *Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (PME-NA)*, Roanoke, VA. Digital version
[12] Sacristán, A.; Sandoval, I & Gil, N. (2007). Incorporating digital technologies to the mathematics classroom: in-service teachers reflect on the changes in their practice. *Proceedings of the 29th Annual International Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (PME-NA)*, Lake Tahoe, Nevada, USA. Digital version
[13] Drijvers, P.; Doorman, M.; Boon, P., Gisbergen, S. & Reed, H. (2009). Teachers using technology: Orchestrations and Profiles. *Proceedings of the 33rd Conference of the International Group for the Psychology of Mathematics Education*, Vol. 1, Thessaloniki, Grecia, pp. 481-488.
[14] Assude, T. ; Buteau, C. & Forgasz, H. (2010). Factors influencing implementation of technology-rich mathematics curriculum and practices. Hoyles, C. & J-B Lagrange (Eds.), *Mathematics education and technology*. *Rethinking the terrain*, New York, Springer, pp. 405-422.
[15] Laborde, C.; Kynigos, C.; Hollebrands, K. & Strässer, R. (2006). Teaching and learning geometry with technology. Gutierrez, A. & P. Boero (eds), *Handbook or Research on the Mathematics Education: Past, Present and Future*, Rotterdam, Sense Publishers, pp. 275-304

[16] Artigue, M. (2011). Tecnología y enseñanza de las matemáticas: desarrollo y aportes de la aproximación instrumental. *Cuadernos en Investigación y Formación en Educación Matemática: Medios e Hipermedios, 6(8)*, pp. 13-33
[17] Patter, R. (2009). Strategies to Enhance the likelihood that teachers will integrate technology into their classroom. *Master thesis Carlow University*.
[18] Ball, D; Thames,M. & Phelps, G. (2008). Content Knowledge for Teaching: What Makes It Special? *Journal of Teacher Education, 59 (5)*, pp. 389-407
[19] Rabardel, P. (1999). Eléments pour une approche instrumentale en didactique des mathématiques. *Actes de l'école d'été de didactique des mathématiques*, Houlgate 18-21 Août, IUFM de Caen, pp. 203–213.
[20] Secretaría de Educación Pública (1993). *Plan y programa de estudios*, México: SEP
[21] Brousseau, G. (1987). Représentation et didactique du sens de la division. G. Vergnaud, G., Brousseau et M. Hulin (Eds.), *Didactique et acquisión des connaissances scientifiques. Actes du colloque du Sèvres*, Grenoble, La pensé sauvage, pp. 47-64.
[22] Laborde, C. (2004). Instrument et processus d'instrumentation. *M2-EIAHD UE 3*. Université Joseph Fourier, Grenoble, pp. 1-8.
[23] Mariotti, M-A (2001). Introduction to Proof: The mediation of a Dynamic software environment. *Educational Studies in Mathematics 44*. Kluwer Academic Publishers. Printed in the Netherlands, pp. 25–53