# Teacher's practices and degree of ICT integration

Teresa Assude
UMR ADEF, Université de Provence

In the presentation of the working group 9 "Tools and technologies in mathematical didactics", we can see how deep is the gap between the research results on the use of technology in the mathematical learning ("richer opportunities to construct mathematical meanings", "explore and experiment with mathematical ideas") and the little use of these technologies in the real classroom ("actual use of these tools in real school environments is still very thin despite the abundance of governmental funding and interest at the European level"). This gap is problematic and "pose a real challenge to administrators, curriculum designers, teachers and students."

To take up this challenge, teachers have been coping with professional problems facing institutional injunctions for integrating ICT in classrooms. How do they implement these injunctions? What do they propose for pupils' activities? There are different ways of working out this professional problem. Some teachers simply put it apart and do nothing, others bring some minimal strategies into play, and others invest very much to achieve this integration. How can we distinguish these different practices? How do we characterize them? I have tried to answer these questions looking at the integration of a dynamic geometry software (Cabri-géomètre) in primary teaching.

My contribution in this study takes place within topic 2 "The role of the teacher in technology-rich mathematics education". My questions are connected with the question "how teachers can deal with the new pedagogical context of technology-rich learning?".

While approaching these questions, I carry on two purposes. First, I want to develop a theoretical tool to clarify how the teachers in their practice are "being aware of the constraints and affordances of the available technology". For this I define the "degree of ICT integration" using indicators such as "mode of instrumental integration" and "mode of praxeological integration" (I will explain these words in section 2). My second purpose is to describe how teachers without experience in using technology work out this complex problem and to define their needs about resources and training ("what pedagogical resources are available or should be developed?").

In this paper, I will essentially deal with my first purpose, i.e. a presentation of my theoretical tool. I will begin by succinctly presenting the context of the research work (without showing all the aspects of this research such as the role of Cabri in the teachers' professional development or the differences between several teachers' practices). Then I will make clear the theoretical tool and I will end by analyzing an example. This example is just to illustrate the possibilities of the theoretical tool for evaluating and characterizing teachers' practices in the use of technology.

## 1 – Context of the research work

The work was carried out in the frame of a national project (Technological Research Team in Education) entitled MAGI ("Mieux Apprendre la Géométrie avec l'Informatique", in English "Better Learning of Geometry with Computers"). The project is a development and research project involving twenty researchers, teacher educators and teachers divided into groups located in different places in France. The aim is to study the process of integration of dynamic geometry software, namely Cabri-geometry, into the ordinary teaching contexts of the primary and beginning secondary school. The project has two parts:

- design and implementation scenarios for the use of Cabri in several classes of primary and secondary schools (in about ten classes);
- study of the impact of teacher preparation sessions for the use of Cabri in their classroom practice.

Dynamic geometry is conceived in this project as a tool for helping students to move from a purely visual conception to the construction of geometrical theoretical concepts such as collinearity, perpendicular, parallel, congruence… That is why the primary and the beginning of secondary school, were chosen for study. In France, the entry to « theoretical geometry » begins in primary school and is achieved in the first years of secondary school. In addition, geometry is not a favoured subject for primary school teachers who view the teaching of geometry as essentially the teaching of a vocabulary and not as the construction of a coherent model of spatial phenomena and objects. Dynamic geometry can change their view of geometry and motivate them to change their teaching of geometry. This is why it seemed particularly interesting to investigate the integration of dynamic geometry at these school levels.

In this context, the subgroup in Toulon worked with primary school teachers who had no knowledge of dynamic geometry before the project. They were introduced to dynamic geometry in a short training session (half a day). We worked with three teachers (Ingrid, Françoise, Robert), in charge of 10 year-old pupils. The agreement was made with the teachers that they would integrate the use of the software in relation to the whole work of their class, that they were completely free to choose activities with the software and that the role of researchers was restricted to observing teachers without intervening in the choice and the design of the activities nor the management of the class. We wanted to bring out the conditions and constraints of integration of the software by ordinary teachers who had to construct « everything » including a relationship with Cabri. Analyses are done by means of observation notes, videos, students' notebooks, and interviews with teachers. The teachers in Toulon were observed over one year.

The number of sessions devoted to the use of Cabri varied according to the teachers. Françoise proposed 5 sessions : two for introducing students to Cabri and three sessions of reflection. Ingrid proposed 4 sessions : two for introducing students to Cabri (the same ones as Françoise) and two sessions, one on square and one on

triangles. Robert proposed a weekly session from December onwards (altogether about 15 sessions). These sessions dealt with triangles, squares, circles.

## 2 – Theoretical framework: mode and degree of integration

My analysis of technology integration into teaching is based on a multidimensional approach (Artigue & Lagrange 1998, Artigue 2001, Guin & Trouche 2004, Lagrange 2001, Trouche 2005) that takes into account several dimensions: epistemological, cognitive as well as instrumental, institutional and anthropological. This multidimensional approach shows the complexity of the integration and anticipates the actors' difficulties in using technology: we take into account the instrumental genesis (Vérillon & Rabardel 1995), the institutional constraints, the epistemological changes in mathematical learning and teaching, the interplay between technical and conceptual work. The study made by Lagrange et alii (2003) has shown that there has not been much research about this problematique of integration. The process of integration is not easy because there are too many variables to manage in the classroom: one of these variables is the dialectic between old and new practices (Assude & Gélis 2002). In our case, the work with Cabri implies to know some principles: difference between drawing and figure (Fischbein 1983, Laborde & Capponi 1994, Laborde 1998), the role of dragging, etc.

My work follows all those studies but I use these different dimensions to define some indicators and the theoretical tool "degree of integration". What do I mean by "degree of integration"? This measures the organization by the teacher of the instrumental dimension and the mathematical dimension, and their relations. However it is difficult in the moment to assign a very precise degree to a teacher's practice and I prefer to define modes of integration, characterizing a teacher practice over a period of time, a session or part of a session, or a sequence of teaching sessions. These modes are:

- the mode of instrumental integration pointing to how instrumental integration is taken into account. I am interested in the teacher's "orchestration" (Trouche 2005), and I'm particularly looking at the types of tasks (Cabri or mathematics), the instrumental knowledge (IK), the mathematical knowledge (MK), the relations (IK/MK);
- the mode of praxeological integration (Chevallard 1997, 1999) pointing to how the pupil's mathematical work is organized: I am particularly looking at the relationship between paper-pencil tasks and techniques and Cabri tasks and techniques;

These modes are associated with three variables: the dialectic between old and new, the didactical contract and the quantity of work. Furthermore, these modes are not independent (instrumental and mathematical dimensions are overlapping one another). I would like to stress here that, as technology involved in mathematics education embodies mathematics, the technical and the conceptual parts are intrinsically intertwined (Artigue *ibid*.): the use of technology shapes the knowledge

constructed by students (Hoyles et al. 2004). But I distinguish these modes for bringing out the different dimensions of integration.

### *2.1 - Mode and degree of instrumental integration*

Until now I have identified four modes of instrumental integration:

- instrumental initiation
- instrumental exploration
- instrumental reinforcement
- instrumental symbiosis.

To determine these different modes, I use several indicators: types of tasks (mathematics (TAM) or Cabri (TAC)), instrumental knowledge (IK), mathematical knowledge (MK), relations between these two indicators (IK/MK). We distinguish between two cases of instrumental knowledge: either pupils are beginners or novice in using the artifact (low IK or no IK) or they already have knowledge of the artifact but they have not yet a good knowledge of how to handle all the facilities (average IK).

Pupils are beginners:

In the *instrumental initiation*, pupils don't know the software and are initiated into Cabri tasks. The teacher's aim is mainly that the pupils learn how to use the software (pupils must learn some IK). The relation between IK and MK is minimal.

In the *instrumental exploration*, pupils do not know the software and are going to explore it through mathematical tasks. The teacher aims at improving both IK and MK. The relation between IK and MK can vary from the minimum to the maximum according to the mathematical task. This mode can evolve to the instrumental symbiosis.

Pupils are not beginners

In the *instrumental reinforcement*, pupils are already used to the software but they are confronted with instrumental difficulties while dealing with a mathematical task. The teacher will give them instrumental information. The teacher's aim is improving mathematical knowledge. The relation between MK and IK is maximal because IK is required to achieve the mathematical task.

In the *instrumental symbiosis*, pupils have already used the software and they are confronted with mathematical tasks which allow them to improve both their IK and MK because they are connected. The relation between IK and MK is maximal:

each one allows the other to increase and the connection between paper-pencil work and Cabri work is strong.

| | Initiation | Exploration | Reinforcement | Symbiosis |
|---|---|---|---|---|
| TAC | x | | | |
| TAM | | x | x | x |
| IK | x | x | | x |
| MK | | | x | x |
| IK/MK | | | IK tool to MK | Max |

These different modes of instrumental integration lead to classifying the integration practices from the lowest level (where the only integration taken into account is instrumental initiation) to the highest level (where the different modes are taken into account according to the appropriate moment).

### *2.2 - Modes and degree of praxeological integration*

The pupil's mathematical work can be described by mathematical praxeologies (Chevallard 1999). These mathematical praxeologies are quadruplets made up by tasks, techniques, technologies, theories. Technologies here mean a justification of techniques. Our indicators are now praxeologies associated with two other variables: variable "paper-and-pencil/cabri" and variable "old/new":

- types of tasks cabri (TAC) (old/new)
- types of tasks paper-and-pencil (TAPP)(old/new)
- techniques cabri (TEC)(old/new)
- techniques paper-and-pencil (TEPP)(old/new)
- relations between tasks cabri and tasks paper-and-pencil (TAC/TAPP)
- relations between techniques cabri and techniques paper-and-pencil (TEC/TEPP)
- "weak techniques" (meaning techniques without technological and/or theoretical justifications)(WTE)
- "strong techniques" (meaning techniques with technological and/or theoretical justifications)(STE)

Until now I have identified five modes of praxeological integration. A mode is *void* if there are no TAC and TEC in the pupil's mathematical activities. A mode is *minimal* if there are TAC and TEC, and there are no TAPP and TEPP. A mode is *juxtaposed* if there are TAC, TEC, TAPP, TEPP and no relationships between these tasks and these techniques. A mode is *intertwined* if there are TAC, TEC, TAPP, TEPP and there are some relationships between these tasks and techniques and all techniques are weak. A mode is *maximal* if there are all types of tasks and techniques and strong relationships between these tasks and techniques and if there are STE and new rules of didactic contract taking into account the specificity of dynamical geometry software.

| | Void | Minimal | Juxtaposed | Intertwined | Maximal |
|---|---|---|---|---|---|
| TAC | | x | x | x | x |
| TAPP | | | x | x | x |
| TEC | | x | x | x | x |
| TEPP | | | x | x | x |
| TAC/TAPP | | | | some relations | x |
| TEC/TEPP | | | | some relations | x |
| WTE | | | | x | |
| STE | | | | | x |

These instrumental and praxeological modes associated with other variables like as « old and new dialectic », « rules of didactic contract » and the « number of sessions », are a means to define a degree of ICT integration. At this moment, I define four degree: *zero*, *low*, *medium* and *strong*.

A degree of ICT integration is *low* if the instrumental mode is initiation, if the praxeological mode is minimal or juxtaposed and if there is no dialectic between old and new tasks and techniques and no changes in didactic contract. A degree of ICT integration is *medium* if the instrumental mode is initiation and reinforcement, if the praxeological mode is juxtaposed or intertwined, and if there are some relations between old and new and some changes in didactic contract. A degree of ICT integration is *strong* if all those dimensions are implemented in classroom.

## 3 – A low level of instrumental integration: an example

In this section, I use the different modes and indicators to analyze an example of teacher's practice. A teacher - Françoise - has proposed two initiation sessions to the pupils. During these sessions pupils learn some IK: creating and moving a point, creating and moving a straight line, creating and moving a circle, creating a segment, naming points. They must read a form indicating all the actions they need to do and there is no collective institutionalization of these IK. The status of points is not identified, and though there are moves, the teacher does not insist on moving to verify the constructions.

In these sessions, the type of task is a Cabri task whose aim is to build and move some mathematical objects. The relation between IK and MK is minimal and so is the connection between Cabri tasks and paper-pencil tasks. We have here an instrumental initiation. Besides, that initiation does not insist on changes in the didactical contract: the function of moving the constructions and the contribution of Cabri to an experimental approach of geometry are not told. That initiation is aimed at building mathematical objects instead of emphasizing the kind of work the software allows with those objects. In the following sessions the teacher is reluctant to use both the instrumental reinforcement (although it sometimes appears) and the instrumental symbiosis.

The mode of instrumental integration is limited to an instrumental initiation and that fact leads us to make the hypothesis that during the first year in which that

teacher tries to integrate Cabri software, she does not pay enough attention to the instrumental dimension (although there are initiation sessions). From this point of view the degree of instrumental integration is low.

## 4 – A low level of praxeological integration : an example

Françoise proposed two initiation sessions and three sessions about reflection (two sessions in technology classroom and one session in traditional classroom) to the pupils. The first session began by remembering some IK, followed by activities about reflection with the title "Go to play". An example of these activities follows:

*1) Create a point A and create a straight line (MN)*
*For this, select the tool "point" in the box "creation"*
*Don't forget to name it A*
*Start again and create the points M and N (naming them immediately)*
*Select the tool "line" in the box "creation"*
*Approach the cursor to M: press when the message "through this point" appears*
*Approach the cursor to N: press when the message "through this point" appears*
*2) Construct the image B of the point A by reflection with respect to the line (MN)*
*For this, select the tool "reflection" in the box "construction"*
*Approach the cursor to A: press when the message "reflect this point" appears. The point A is winking.*
*Approach the cursor to the line (MN): press when the message "with respect to this line" appears.*
*Name this new point B*
*Move the point A*

*Question 1: What's happened to the point B?*
*Question 2: Where must you put the point A so that A and B are the same?*

The aim of these sessions is the exploration with the software of the notion "reflection". The pupils are working in pairs and each has a paper with the instructions. The type of tasks are the following:
T1: construct the image of a point by reflection
T2: identify some properties about reflection

For these pupils, T1 is an old task and T2 is a new task. In the paper they have, construction techniques are described in a lot of detail and controlled: all actions are indicated as in the example above. Pupils just need to follow the instructions. To identify some properties, pupils must observe drawings and complete some sentences like this: "*Complete: the image of a segment by reflection is a …… with the same ……*"

Pupils used the techniques proposed by the teacher but they did not understand why these techniques were relevant. They had many difficulties in identifying and completing the sentences because they followed the indications step by step, and they

did not have a global activity vision. This strong control prevents pupils from facing some instrumental difficulties and acquiring mathematical knowledge but it is also how the teacher manages the integration of Cabri (she is working for the first time with the software). She is strongly controlling the pupils' work to avoid any questions she could not answer.

There are not any relations between PAC and PATT, and so there are not any relations between PEC and PETT: the work with the software is isolated, all the techniques are WTE, and there is not any reflection about the specificity of dynamic geometry software.

In this classroom, the mode of praxeological integration is minimal and the degree of praxeological integration is low. Françoise wanted to integrate Cabri but she controlled the pupils' work by close activities and "technique algorithms".

## 5 – Conclusion

My work allowed me to characterize some integration practices from a set of indicators. I used these indicators to analyze three teachers' practices and we presented here an example using Françoise's classroom[1]. It can seem limited but it permits me to develop a theoretical tool and to make an hypothesis.

For next works, my hypothesis is the following : a low degree of integration means that the instrumental dimension is not sufficiently taken into account ; there is not a good interaction between the paper-and-pencil activities and the software activities, and no dialectic between old and new. A medium degree of integration means that one of these dimensions is taken into account but not the others. A strong degree of integration means that all those dimensions are implemented in the classroom. The number of sessions is also an important variable – few sessions with software do not allow a good integration - but a justifiable number of sessions is not a sufficient condition for a strong degree of integration if the other indicators are not verified.

In the future, I will use these indicators to evaluate and characterize the practices of teachers well trained in the use of technology. I will compare the degree of ICT integration and I will verify if the low degree is specific of inexperienced teachers. In any case, the work with these teachers has shown me that teachers training and resources must insist on all the dimensions and particularly the instrumental one, and the relationship between instrumental and mathematical dimensions.

## *References*

Artigue M. & Lagrange J.-B. (1999), 'Instrumentation et écologie didactique de calculatrices complexes: éléments d'analyse à partir d'une expérimentation en classe de Première S', *in D. Guin (ed) Actes du congrès " Calculatrices*

[1] Other teachers' practices analyses can be seen in Assude 2006, Assude, Grugeon, Laborde & Soury-Lavergne 2006, Assude & Grugeon 2006.

*symboliques et géométriques dans l'enseignement des mathématiques "*, IREM de Montpellier, pp. 15-38.

Artigue, M. (2002) Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between technical and conceptual work *International Journal of Computers for Mathematical Learning* 7(3), 245-274

Assude T. & Gélis J.M. (2002), Dialectique ancien-nouveau dans l'intégration de Cabri-géomètre à l'école primaire, *Educational Studies in Mathematics*, 50, 259-287.

Assude T (2006), Degré d'intégration de Cabri-géomètre à l'école primaire, Colloque "Espace mathématique francophone", Sherbrooke, CD-Rom.

Assude, T., Grugeon B. (2006). Développement d'ingénieries de formation des enseignants pour l'intégration des TICE. *Revue Quadrante*, volume XIII, n°2, 2004, pp.31-50.

Assude T, Grugeon B, Laborde C, Soury-Lavergne S (2006), *Study of a teacher professional problem: how to take into account the instrumental dimension when using Cabri-geometry ?*, Etude ICMI 17 « Digital Technologies : Rethinking the terrain », Hanoi, Vietnam

Chevallard Y (1997), 'Familière et problématique, la figure du professeur', *Recherches en didactique des mathématiques*, 17.3, pp.17-54.

Chevallard Y (1999), 'L'analyse des pratiques enseignantes en théorie anthropologique du didactique', *Recherches en didactique des mathématiques*, 19.2, pp.221-266.

Fischbein E. (1993), 'The theory of figural concepts', *Educational Studies in Mathematics*, 24.2, 139-162.

Guin D & Trouche L (2002) (sous la dir), *Calculatrices symboliques, transformer un outil en un instrument du travail informatique : un problème didactique*, La Pensée Sauvage, Grenoble.

Jones K. (2000), 'Providing a foundation for deductive reasoning : students' interpretations when using dynamic geometry software and their evolving mathematical explanations', *Educational Studies in Mathematics*, 44 (1-3), 55-85.

Lagrange J.B. (2001), L'intégration d'instruments informatiques dans l'enseignement : une approche par les techniques. *Educational Studies in Mathematics*, 43, 1-30.

Lagrange J.-B., Artigue M., Laborde C. and Trouche L. (2003), 'Technology and Mathematics Education: A Multidimensional Study of the Evolution of Research and Innovation', in A. Bishop and alii (eds), *Second International Handbook of Research in Mathematics Education*, Kluwer Academic Publishers, Dordrecht, pp.239-271.

Laborde C., Capponi B. (1994), 'Cabri-géomètre constituant d'un milieu pour l'apprentissage de la notion de figure géométrique', *Recherches en Didactique des Mathématiques, 14-1.2*, 165-210.

Laborde C. (1998), 'Visual phenomena in the teaching/learning of geometry in a computer-based environment', in C. Mammana and V. Villani (eds), *Perspectives*

*on the teaching of geometry for the 21st century*, Kluwer Academic Publishers, Dordrecht, pp.113-121

Hoyles, C., Noss, R., Kent, P. (2004) On the Integration of Digital Technologies into Mathematics Classrooms, *International Journal of Computers for Mathematical Learning*, 9(3), 309-326

Trouche L (2005), Construction et conduite des instruments dans les apprentissages mathématiques : nécessité des orchestrations, *Recherches en Didactique des Mathématiques*, 25.1, 91-138.

Vérillon P. & Rabardel P. (1995) Cognition and artifacts. A contribution to the study of thought in relation to instrumented activity. *European Journal of Psychology of Education* 10(1), 77-101.