Teachers practices and professional geneses with ICT

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Teachers practices and professional geneses with ICT

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Abstract

This paper shares presents some theoretical issues concerning teachers' professionnal genesis with spreadsheets by bringing closer the results abtained in different research. It aims at gaining insight into the teachers practices with technology and how these practices evolve in time. Comparing the evolution of an ordinary teacher integrating spreadsheet in her practices with the practices of teachers expert with spreadsheet, we find some similarities in the way of using this tool, and make some hypotheses on the importance of these common elements as key issues in ICT integration.
Keywords: ICT, spreadsheet, double instrumental (professional/ personal) geneses, instrumental distance.

1. Introduction and theoretical notions

How does technology influence mathematics teaching and learning? After an enthusiastic period where pioneers claimed ICT benefits for learning, many reports stress a phenomenon of "disappointment": as Michèle Artigue notes it (Artigue, 2008), twenty-five years after the first ICMI study on this theme (Cornu & Ralston, 1992), if our knowledge certainly increased, the situation did not much evolve. Deploring the poor integration of ICT in mathematics teaching, researchers advance the "teacher barrier" (Ruthven, 2007, Balanskat & al, 2006). Teachers' practices are seen as a key issue and it seems crucial to advance in the comprehension of how these practies change and integrate technology.

To contribute to this issue, we are bringing together the observations that we made within different research (Haspekian 2011, 2006, 2005b) which were addressing ICT practices at different levels of expertise: teachers expert with ICT, preservice teachers and an ordinary teacher neither novice nore expert in teaching with ICT. The similarities between the results of these different research lead to stress some theoretical hypotheses about the genesis of teachers' practices with ICT, the way these practices develop and the encountered difficulties for teachers.

In the following, we present first the theoretical frames and notions underpinning our analyses: on one hand the didactic and ergonomic aproach (Robert & Rogalski 2002), which describes teacher's activity through five components: personal, mediative, cognitive institutional and social one, on the other hand the instrumental approach (Artigue 2002, Guin, Ruthven & Trouche, 2004) from which we use the concept of instrumental genesis and instrumental distance. Then, we present the observations of teaching practices with ICT at different skill levels and the links that can be reached between them.

1. Didactic and ergonomic approach

The issue of ICT integration in mathematics teaching can not be studied from the only lens of ICT benefits for students' mathematics learning. In a research led on the integration of calculators, Trouche (2005, p. 307) had already noticed the importance of two other factors relative to the teachers: their degree of mastering the tool and the conception (more or less negative) which they had of this very integration. In the same way, the numerous works analyzing ordinary practices underline that teachers' activity is not determined only by contents reasons (about mathematical knowledge) or learning reasons (on students's side) but also by arguments linked to the teachers seen as subjects, practicing a job with its own constraints and liberties. According to the didactic and ergonomic approach (Robert & Rogalski 2002), the *cognitive* and *mediative* components relate to the choices made by the teacher in the spatial, temporal and mathematical organisation of the lessons. These choices are made according teachers' *personnal* component. But teachers are not totally free in these choices. They are more or less constrained by *institutional* and *social* dimensions. The personal component relates to the teacher as a singular subject, with his own history, practices, vision of mathematics learning... The institutional and social dimensions relate to curricula, lessons duration, school social habits, mathematics teachers habits etc. In the case of ICT practices, instrumental aspects seem to interfere with each of these components, particularly the personnal one plays a crucial role in the integration or not of ICT in mathematics. In order to analyse more locally some phenomena observed with ICT practices,this lead us to use the instrumental approach and particularly two notions that the results rely on: the idea of *instrumental distance*, and the *professionnal intrumental genesis* with the tool.

2. Instrumental Distance

In French curricula, dynamic geometry software are prescribed as much as spreadsheets. But the previous is better integrated in mathematics classroom than the second. We introduced then the notion of *distance* to the referential environment (Haspekian 2005a) to contribute to the explanation of this phenomenon.

The idea of *distance* takes into account, beyond the "computer transposition" (Balacheff, 1994), the set of changes (as cultural, epistemological or institutional) introduced by the use of a specific tool into mathematics "praxis". For a given tool, a too big distance to the "current school habits" is a constraint on its integration (Haspekian, 2005a). On the other hand, didactical potentialities of technology rely on the distance it introduces as regard to paper-pencil environment (as for instance providing new representations, new problems, increasing calculation possibilities...). We have brought out 4 types of elements that can generate some distance (Haspekian, 2005a). Some are directly linked to the *computer transposition*: as the representations and the associated symbolism. But some can also be of an *institutional nature*[1], or *didactical nature* (vocabulary, field of problems they allow to solve…), or, at last, *epistemological* one (what gives tool an epistemological legitimacy). This is linked to teacher's personal component (her representations of mathematics, of mathematics teaching, of the role this tool plays in the development of mathematics).

3. Double instrumental genesis on teacher's side

The way teachers orchestrate and support pupils' instrumental geneses evolves year after year. Considering spreadsheet as an instrument for the teacher, allowing her to achieve some teaching goals, we consider a process of instrumental genesis ***on teacher's side*** (Haspekian 2006). This is based on the idea that, from the *same artefact spreadsheet,* the instrument developed by the pupils *or by the teacher in a personal context* is not the same than the one developed by the teacher in the *professional teaching context*. The same artefact, the spreadsheet, becomes an instrument for some mathematical activity (for both pupils and teacher in their personal usage of the tool) and *another* instrument for teacher's didactical activity (Haspekian 2006). Indeed, the didactical functionalities of this tool are not pre-defined; the teacher must develop and integrate them in her usual teaching practices and habits along a *(professional)* instrumental genesis. Splitting thus the instrumental

[1] Beyond the computer transposition that modifies the mathematical objects, the modification, from an institutional point of view, concerns actually the whole ecology of these objects (tasks, techniques, theories can be modified). The idea of "distance" reflects this gap between the praxeologies associated to two different environment (considering paper pencil as a peculiar environment of the mathematical work)

analyses lead us to consider a professional instrumental genesis different from a personal one. The *personal instrumental genesis* leads (as for pupils) to the construction and appropriation of a tool into an instrument for mathematical work, and differs from the *professional instrumental genesis*, which leads to the construction and the appropriation of the previous instrument into a didactical instrument for mathematics teaching activity.

We have shown in Haspekian (2008, 2011) that these two geneses are not independent (in some cases -as here- this *double instrumental* genesis may happen simultaneously), neither are they independent of pupils' instrumental geneses. Applying the instrumental approach to the spreadsheet seen as a *teaching* instrument built by the teacher, let's precise the two processes of this professional genesis:

- An **instrumentalization process**: the tool is instrumentalized by teacher in order to serve her didactic objectives. It is distorted from its initial functions and its didactical potentialities are progressively created (or "discovered" and appropriated in the case of an educational tool).
- An **instrumentation process**: teacher, as a subject, will have to incorporate in her teaching schemes that were relatively stable some new ones integrating the tool use. Teacher will progressively specify the tool use to a particular class of situations (as "take advantage of spreadsheet for algebra learning") and organise her activity in a way progressively invariant for this class of situation (Dan's case already shows some regularities from year 1 to year 2).

2. Different research on practices with ICT in mathematics teaching

In the following of this paper, we are bringing together the results of two different research. The first one concerns the practices of what we have called "experts" teachers: they are teachers who have been integrating ICT for a long time and who are also "ICT trainers" in mathematics teachers training. By comparing their practices between them and also with the practices of preservice teachers, we have highlightened some characteristics of the practices with ICT.

The second research is a two-years case study of a teacher, named Dan in the following. She is a long experienced teacher but integrating the spreadsheet for the first time in her practices. The case of the spreadsheet is a good revealing of the phenomena that come into play in the development of practices integrating ICT for at least two reasons. First, the spreadsheet is a professional tool without any didactical functionnality given *a priori*. The instrumental distance in this case is not negligible and plays a considerable role in the difficulties of the spreadsheet integration. Second, the teacher has to turn this non educational tool into a didactical instrument through a professional genesis, which is here again rather complex, partly because of this instrumental distance. The study observed the way Dan integrates spreadsheet in her practices and the evolution of this integration over her first two years.

By bringing together these research, interesting similarities emerge. Dan evolves with the spreadsheet towards the characteristics of experts' practices. The next section gives some of the results obtained with experts teachers, the last one describes Dan's case study and shows how her evolution goes towards expert practices.

1. First research: some characteristics of experts practices with ICT

Are there regularities in the practices among the teachers who successfully integrated the spreadsheet? We looked for regularities at the following levels: in teachers conceptions, in the evolution of their practices and in the changes this evolution led to. These questions can be first enlightened by the notions of "coherence" and "stability" as Robert & Rogalski quoted it:

> "the coherence of the system of the practices of a teacher (…) would prevent the introduction of inconsistent elements with this system" (Robert & Rogalski, 2002). Similarly -but with another theoretical framework, Lagrange (2000) underlines that the introduction of a tool in mathematics

lessons generates an upheaval of the “praxéologies” which is a factor of non integration of the tool.

How do experts deal with these obstacles? We carried out questionnaires and interviews with trainees and “experts” (teachers who are integrating spreadsheet in their class and are teacher-educators on ICT)[2]. The results stressed on one hand some common lines among the **novices** (as their obvious difficulties to perceive the **potentialities of the tool**, to conceive organizations which they have never seen), on the other hand some convergences among experts practices that can be connected to their success to integrate spreadsheets. We present below two results obtained by comparing experts/ beginners’ practices.

The first result concerns the tasks given with spreadsheet. A common part of the questionaries adressed to experts and novices was constituted by a set of tasks, from a basic use of the spreadsheet, as a mere calculator, to a more interesting use of the spreadsheet potentialities (based on research situations mentioned in Capponi, 2000, Arzarello, Bazzini, & Chiappini 2001, or Rojano &, Sutherland, 1997, and analysed by their authors as being positive for mathematics learning). Teachers had to choose which of these different ways of using spreadsheet were interesting for mathematics teaching and learning. The results obtained join those mentioned already in other research (Laborde, 2001, Monaghan, 2004): novices, nonexpert of spreadsheet, hardly identify tool’s potentialities and interesting situations. Moreover, the choices of the beginners, and their arguments, were systematically opposed to those of the experts (which corresponded to the interesting situations). Teachers’ first approach of spreadsheet use is not the best way of benefitting from technology potentialities. As Artigue (2002) recalls it, the observed (and quite understandable) tendency consists in using technological tools not for their epistemic value (helpful mean of understanding mathematical objects) but just for their pragmatic value (produce results quickly and easily) in some tasks very similar of those traditionally given in paper-pencil environment.

The second result concerns some common characteristics in experts’ practices as the importance of taking into account not a single tool but a system of instruments. Two characteristics appear to contribute fundamentally to their success in integrating spreadsheets: **a game "ancient / new "** playing both at the level of the mathematical contents and at the level of the instruments, and a certain **art/skill** to know how to mix these levers. These characteristics provide an economic functioning both on the management of the class in ICT sessions, and on the management of pupils’ instrumental geneses. For example, at the level of the contents, one expert says having “*a way of making revisions by bringing something more*”. Another says he has “*the same notions presented in two different environments*”. For another one, she systematically works again by hand after ICT session and combines paper-calculator-spreadsheet: “*I make links non-stop, again and again…*”

For all of the experts, it is this orchestration of a whole system of instruments that becomes a base to support spreadsheet integration: this tool being perceived as more complex, they make their pupils meet it after other software. This allows **a gain of time** on the management of class in ICT session (discover the class, organize the contract, etc.) and **a gain of time** on the instrumental geneses with spreadsheet, a part of it being taken through other tools (physical manipulation of the material, the computer, virtual manipulation of files,…).

In the common characteristics, we also found an increased attention paid to the questions of “mutualisation” and “socialisation”. Two elements are used for that: first, the experts are all organising their sessions with pupils working in pairs, second, they have the habit to use the videoprojector in order to mututalise here again the scattered knowledge and make the contents more homogeneous (mathematical knowledge but also instrumental knowledge).

[2] In the case of trainees, we had group discussions so that teachers exchange, discuss, which emphasizes their opinions. With the experts we had individual interviews whith an additional part concerning their practices.

2. Second research: a two years case study

Dan is not a trainee[3], but she is not an expert with ICT in mathematics teaching. She has experienced dynamic geometry software and integrates now spreadsheet for the first time. We collected data that very first year and the year after. The observations show some evolutions from a year to the next one. As we said, we will see that this evolution with the spreadsheet converges towards the characteristics of experts' practices described above.

During the first year, Dan was motivated by her participation in a research project focusing on spreadsheet use for *algebra* learning (Haspekian, 2005b). At the end of the research, an interview collected her thoughts and feelings about this experience. The following year, she uses the spreadsheet by her own choice, without any research protocol. On that occasion, we recorded her first spreadsheet session and the following session in a paper and pencil environment. Some phenomena during this observation and the way Dan evolved in her practice with spreadsheet as a didactical tool provide interesting data. Let us first present the evolutions at stake and then describe the theoretical frames to analyse these data.

During the second year, Dan introduced spreadsheet not with algebra but with statistics (headcounts, frequencies and cumulative frequencies after having seen these notions in paper pencil environment). In this context, some of the observed elements are surprising: the lesson shows very little statistics, is mostly centred on the tool functionalities, and reveals unexpected mathematics (notions of variable, formula, distinction "numeric/algebraic" function...). These latter reflect the influence of year 1 experience, centred on algebra, but this does not explain all the evolution year 2 (variations and regularities) summarized in Table 1:

Use of spreadsheet	Year 1	Year 2
VARIATIONS		
Class level	7^{th} Grade (12 year old)	8^{th} Grade (13 year old)
Old/new content	New	Old
Mathematical Domain	Algebra	Statistics
Spreadsheet location	Limited to computer lab	Computer lab +ordinary classroom
Synthesis	No	Yes
Interactions Teacher-Students	Mostly individual	Individual and collective
Use of the video and collective presentation	Piloted by teacher, limited role	Teacher and student. Important role
Students Configuration	Work by pairs	Work by pairs + collective work: one student at the board
REGULARITES		
Maths objectives, teacher aims	Algebra	
Additional material	Worksheet for pupils and pre-organised spreadsheet file	
Institutionalisation	In an ulterior lesson, in ordinary classroom	

Table 1. Comparison Year 1- Year 2

Table 1 shows an evolution of 3 components: the mediative and cognitive components (mathematical domain chosen, way of introducing spreadsheet, class level, etc.) have evolved along the two years. This indicates (and is confirmed by the phenomena observed during the lesson) that the personal component of Dan evolved too. What can we say about this evolution and why? Using both the notions of distance and double instrumental genesis, the next sections aim at comparing

[3] she's been teaching for more than 10 years

Dan's evolution with the experts' practices, showing why and how Dan evolves towards experts' practices.

3. Bringing together the results

Spreadsheet is not given as a didactical tool to serve mathematics education. It may progressively become such an instrument along a professional genesis. As we said, the way teachers orchestrate and support pupils' instrumental geneses evolves year after year. The way Dan evolved from a year to another concerns the beginning of such a professional instrumental genesis and shows the complexity that comes along with. In this evolution one main tendency emerge: Dan is reducing the instrumental distance in her way of using the spreadsheet, and this goes in the direction of expert teachers!

1. An essential tendency in Dan's evolutions

Dan builds up some *schemes of instrumented action*[4] with the goal of using spreadsheet to teach algebraic concepts (variables, formulae, for instance through the use of the recopy, or by taking benefits of the numerical feedback to infer the equivalence of two formulae etc.). This brings into play some usage schemes concerning material aspects as the tool integration in a larger set of instruments (with the video projector), or the organisation of the lessons: (a) using a video projector at the beginning of each session to make collective explanations, (b) making pupils communicate and work by pairs, (c) giving pupils a sheet of instructions and a pre-built computer file to gain time, (d) regularly "clicking" on cell to check whether pupil have edited a formula or numerical operation, or even directly the numerical result...

The next year, some of the different elements that are part of her orchestrations have been modifyed by including the following evolutions: **(a) Higher level of class :** she uses spreadsheet with 8th graders instead of 7th graders, (**b) Lower quantity of « new » concepts:** not mix the introduction of the spreadsheet with the introduction of new mathematical notions, (**c) Domain change:** introduce the tool with statistics which seemed to Dan more appropriate than algebra, (**d) Deeper articulation between social and individual schemes,** the importance of the articulation in instrumental geneses has been mentioned by Trouche (2005) (in the interview, Dan says she did not organise moments of mutualisation enough and she explicitly wished to take care of this point the 2nd year).

Observing deeper these evolutions, they all appear to converge in the direction of *reducing* the instrumental distance. Indeed, as we will see, at different levels, Dan's modifications year 2 tend to decrease the spreadsheet's too big instrumental distance:

2. Reducing distance... Towards experts' practices

Changing the class level: Higher level of class

This modification comes with the change of the domain (c): in French curricula, spreadsheet is explicitly mentioned with statistics for 8th Grade pupils, whereas it. In appears in a more general and vague way for 7th Grade curriculum, requiring from teachers a deeper work to define its potentialities for learning mathematics. These latter appear more distant from spreadsheet mathematics than in the 8th Grade, where spreadsheet appears clearly in relation with precise notions. Thus, choosing this level allows Dan to reduce the distance and match more easily with the official prescriptions. Besides, year 1, Dan found pupils'instrumentalisation not easy in 7th Grade (difficulty to use the "recopy", to select a single cell, to edit a formula). Older pupils seem to be more skilful and problems linked to instrumentalisation should be less interfering with the

[4] Rabardel (2002) distinguishes two types of schemes: *usage schemes* (related to the *material* dimension of the tool) and the *schemes of instrumented action* (related to the global achievement of the task, with goals and intentions).

mathematical work. With 7 Graders, manipulations of the tool seemed more difficult and the tool appeared less transparent.

The "old/new" game in the mathematical and in the instrumental contents

Year 1, Dan introduced both a new tool and new mathematical contents (algebraic notions). The ratio old/new is different in year 2 and also goes towards reducing the distance by reducing the part of "new": all the mathematical notions at stake in the spreadsheet session (headcounts, frequency, cumulative frequency) had previously been seen in paper pencil environment. This work (new environment with "already-seen" concepts) will then serve Dan as a base to work algebraic notions (new concepts in an "already-seen" instrument).

Domain changing

The mathematical domain chosen by Dan year 2 also reduces the distance for at least three reasons. Statistics are usually seen to be more in conformity with spreadsheet work than algebra. Furthermore institutional pressure is less important in statistics than algebra, a more classic and traditional domain strongly linked to paper pencil mathematics. On the contrary, statistics are nowadays seen as more fitted to technologies. At last, in the spreadsheet language, one can find more common terms with statistics whereas the distance to the traditional algebraic vocabulary is important (Haspekian, 2005a).

Moments of mutualisation and articulation with paper-pencil mathematics

Dan introduced year 2 some moments of mutualisation in spreadsheet sessions. In the interview, she affirmed her will to increase the similarity with the traditional sessions. She said having the feeling that it is necessary to multiply the links with the paper pencil mathematics (for instance, she started the sequence by a paper- pencil session, then worked the same notions in a spreadsheet session, then she came back on the work done with spreadsheet in a paper pencil session, etc.).

All these actions contribute to reduce the distance with paper-pencil, to mix these two environments in a greater proximity. But if we go back now to the results obtained in the research with expert teachers, Dan's evolution tends to join experts practices.

Indeed, we have seen that in their practices, this "mixing" of different environment appeared as a key point to integrate spreadsheet. Teachers who used to integrate spreadsheet had precisely these characteristics. It is thus interesting to notice that Dan's professional genesis follows the same line. For instance, the moments of mutualisation and articulation with paper-pencil mathematics are better thought the second year by Dan, whereas she did not pay much attention on it the first year. This has been seen as we mentioned it in §.2 as an important characteristics of expert teachers.

The "old/new" game mentioned above is another characteristic found in the expert practices. They manage ICT integration by adjusting and adaptating the degree of novelty to to degree of complexity of the tool: to introduce a complex artefact such as the spreadsheet, they choose ancient contents (already seen in paper pencil environment), once spreadsheet is seen on ancient contents, they can use it next time to introduce new mathematical knowledge.

We can note that here again Dan's evolution goes in that direction. First year she introduce both spreadsheet and a new mathematical domain (algebra), whereas the year 2, she chooses for that a domain (statistics) previously studied in paper-pencil; pupils meet the new instrument on an old content. Dan's long term intention, as she said in the interview, is to use spreadsheet to work algebra, but now she will do it after pupils having seen the spreadsheet on another content (an old one) in order not to intruduce both new artefact and new contents.

Of course, the year 2, Dan had not all the characteristics of the experts as evoked in §.2, but this is not surprising. She is at a stage on her professional genesis with the spreadsheet, integrating it for the second time. It is predictable that this stage is not yet stabilized and that she is evolving. For instance, for the experts, the game old/new concerns also the instruments, not only the mathematical contents. We have seen in §.2 that experts make pupils meet computers with *another* software than spreadsheet, such as dynamic geometry, which present a lesser distance than the spreadsheet. In that way, pupils meet ICT classroom, instructions about the use of computers, files, opening and closing sessions, articulation with paper-pencil, work in pair and so on, within a software that seems easier to integrate. Once they are used to these bases and orchestrations on an old instrument, they are ready to meet a new one, less easy, such as the spsreadsheet. In Dan's evolution, we do not see yet this exploitation of different instruments to facilitate spreadsheet introduction, but it seems reasonable to think that one does not gain all the experts' characteristics in one year practice. This instrumental professional genesis is a long process, as for any instrumental genesis.

4. Conclusion and perspectives

As we saw, we can explain Dan's evolutions in terms of a *reduction* of the distance (either by making this distance more explicit or by alternating work in the environments enriching both of them). Integrating spreadsheet constitutes a significant creative task for teachers as the tool is not given with any didactical functionalities. It requires a professional instrumental genesis on teacher's side different from the personal genesis with the tool (even if they interfere, see Haspekian, 2011) and also different from that on pupils' side.

These combined considerations helped us to analyse Dan evolution and to note that in her evolution she tends to acquire some of the characteristics found as a common line among expert teachers: articulation with paper-pencil mathematics, moments of mutualisation and socialisation, and the game ancient/new playing on the contents (not yet on the instruments).

We suggested that these elements are good candidates for being key issues in ICT integration. To confirm these hypothesis, we need a larger panel. Our first research with experts concerns 6 teachers. The fact that Dan's evolution tends towards some of their common charactéristics is an indication that these elements may reprensent important characteristics of ICT practices, but this needs research at a larger scale.

Finally, several questions remain. Understanding better characteristics of experts' pratices and of course the way to acquire them for teacher, are important in a training perspective and this still remais an open research field. We also made the hypothesis that in the questions of ICT integration but also in these questions of practices evolutions, a criteria which seems important is this notion of intrumental distance. If it is a source of difficulty for teachers, it is also necessary to determine which elements may counterbalance the distance and play in favor of the tool integration, such as institutional injunctions, or tool's epistemic value, didactical design...

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