GENESES OF TECHNOLOGY USES: A THEORETICAL MODEL TO STUDY THE DEVELOPMENT OF TEACHERS' PRACTICES IN TECHNOLOGY ENVIRONMENTS

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This paper introduces and discusses a new frame aiming to describe and characterize the evolutions of teachers' practices related to technology uses. Articulating several theoretical developments of Activity Theory enables us to conceive a model to interpret the evolutions in terms of "geneses of technology uses". We consider these geneses as movements which articulate three levels of organization of practices related to the temporality of actions and to the goals/motives of the activity: a micro level, a local level and a macro level.

Research studying mathematics teachers' practices when using technology were very fruitful in the two last decades. Authors investigated this field by using diverse theoretical frames. In the European sphere, Monaghan used the Saxe cultural model (Monaghan, 2004) to study the emergent goals of teachers in ordinary technology-based lessons. Ruthven (2007) introduced five key components structuring the classroom practices in the context of technology uses. Drijvers et al. (2010) develops Trouche's concept of instrumental orchestrations (2004), by defining several type of orchestrations in the technology-rich mathematics classroom. Even if these studies have considered some evolutions in teachers' practices, they have not adopted a theoretical perspective to investigate it.

We conducted two studies of teachers practices, carried out on the long term. The main common issue of these studies was to observe the teacher's activity in classroom and its impact on the students' learning. At a methodological level, we have particularly analyzed students' tasks, teachers' options regarding these tasks and the corresponding management of students' work on these tasks. The first research (Abboud-Blanchard, Cazes & Vandebrouck 2007, Abboud-Blanchard & Cazes 2012) dealt with specific tools, called here Electronic Exercises Bases (EEB). These are software applications that mainly consist of classified exercises with an associated environment. The research provided a set of data about thirty teachers over 3 years. The analysis was both qualitative and quantitative, and related to: lessons preparations, class observations and answers to questionnaires and interviews. The second research (Abboud-Blanchard & Lenfant-Courblin 2009, Abboud-Blanchard et al. 2008) investigated the first professional uses of technology by pre-service mathematics teachers in order to understand the conditions in which these uses take place. The data was of two types: professional dissertations about using technology in classroom and interviews carried out with them at the end of their first year of teaching practice. The analysis enabled an exploration of the uses of technology in two phases of the teacher's work, which are preparation work and classroom work.

The analysis carried out within these two research studies led us to question the evolutions of teachers' practices and to conceptualize them by constructing a *model of geneses of technology uses*. This construct articulates several theoretical frames deriving from Activity Theory, mainly the instrumental approach and the double approach of teachers' practices. The aim of this paper is not to provide a detailed presentation of our studies but rather to introduce our model and to show how it can give meaning to the observed evolutions.

In the first section, we present the fundaments of our frame starting from elements related to Activity Theory (AT). We introduce "geneses of technology uses" as movements which articulate three levels of organization of practices. In sections 2 and 3, we describe these movements between the levels and give examples to illustrate our purpose.

THEORETICAL CONSIDERATIONS

Activity Theory takes the object-oriented-artifact-mediated-collective activity system as its unit of analysis, thus bridging the gulf between the individual subject and the societal structure (Engestrom, 1999). In this paper, AT enables us to study mathematics teachers' technology uses, by considering the unit of the context of the teaching activity, while being particularly sensitive to the mediations between the subjects (teachers) and the object of their activity (the students and their mathematical work). However, we address AT from a cognitive individual perspective, taking into account the context surrounding the teacher's activity.

More precisely, we use the concepts of AT in the context of French research, as developed within the field of ergonomic psychology (*i.e.* cognitive ergonomics) (Leplat 1997). This development highlighted the fundamental distinctions between, on the one hand, subject and situation and on the other hand, task and activity. Within this French approach, the activity of the subject is indeed developed in situ. The task corresponds to the goal the subject must achieve, taking into account a double system of determinants which relate to the subject or the situation. The development of AT within cognitive ergonomics research brought Verillon and Rabardel (1995) to introduce the Instrumental Approach (IA) which distinguishes artifact and instrument, the artifact being on the situation's side and the instrument on the subject's side. IA consists, for a given subject, in a process (instrumental genesis) of appropriation and transformation of a given artifact, in order to accomplish a given task, within a variety of context uses and a same class of situations. IA was then developed in the field of French mathematics education by Artigue (2002), Guin and Trouche (2002) and Lagrange (2005).

In our work, we articulate the cognitive individual perspective of AT with the cognitive aspects of the ergonomic approach. This allows introducing a developmental approach not specifically highlighted in the AT, which enables us to characterize the evolutions of teachers' technology uses that we call *geneses of*

technology uses. In particular, we consider that geneses of technology uses *encompass* instrumental genesis of specific artifacts. Indeed, the instrumental approach, applied to the teacher, does not deal with the practices as a whole. It does not take into account the context surrounding the teaching activity, neither the connection between teachers' instrumental geneses and students' activities, which are key elements that we aim to investigate in our work. This fact leads us to articulate the above concepts of AT with the double didactic and ergonomic approach of the teaching practices (Robert and Rogalski 2005, Robert 2012).

The double approach adapts AT to the teaching of mathematics in school situation. It aims at the study of the teacher's practices starting from the study of various forms of his/her activity in class and for the class. It introduces five components of teaching practices. The didactical components, cognitive and mediative, translate recurring choices in the activity of teachers that are related to the activity of students. The cognitive component translates choices related to the design and organization of tasks for the students. The mediative component translates choices during sessions related to the management of students' work on the tasks and interactions through verbal communication. The ergonomic components complete the former and are related to the professional context of teaching. Personal, institutional and social components respectively translate the personal (beliefs, knowledge and experience) determinants and the determinants related to the teaching situation (social constraints, curricula…).

The double approach postulates the stability of practices. This stability is, at the same time, a postulate, in the double approach, and a result of a set of research work relating to the teaching practices, with or without technology (see for example Vandebrouck (ed.) 2008). In our study, we consider that AT takes into account, in a global way, for the study of the geneses of technology uses, the complex articulation between stability of practices and evolutions of the activity in situ.

To achieve a degree of stability concerning the evolutions of the activity, we introduce three levels of organization of practices (Abboud-Blanchard & Vandebrouck 2012). These levels are related on the one hand to the temporality of the action and on the other hand to the goal/motives of the activity:

- The micro level is about "automatisms", for example elementary gestures of the teacher for the preparation of lessons' management. One can bring this micro level closer to the short-term of the action and the level of the operations within the AT (Galperine 1966, Léontiev 1978). However, the construction of the micro level of teaching practices (constitution of the actions' schemes or the operations' schemes (Vergnaud, 1982) can be done only over the long-term of the action.

- The local level refers to everyday actions, where co-exist preparations and improvisations; the level of the adaptation of the teacher to the students' work. The goals of the teacher's activity are basically related here to management's issues and to teacher-students interactions. Studying this level allows to better

understand what precise activities the students could have developed, related to the task, the teacher's discourse and help and also the nature of the students' work.

- The global level refers to scenarios, preparations, assessments… It can be reached by studying the motives of the teacher's planning of his/her teaching project. Some of these motives may explicitly occur after a reflective view on the action already accomplished.

We consider that a teacher who begins using a technological tool does not have sufficient "automatisms" and routines related to this use, neither a holistic view on the organization of a coherent teaching approach that integrates this tool. In response to this unfamiliar "overload situation" at the local level, several phenomena would take place:
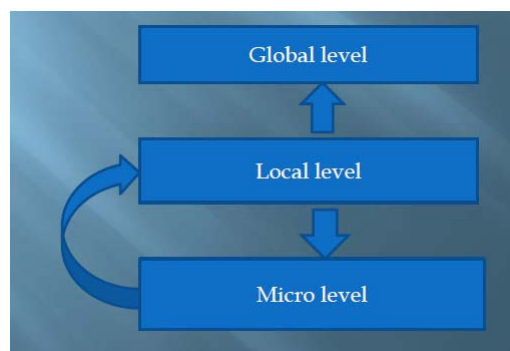

Figure 1: the three phenomena modelizing the geneses of technology uses

- a first phenomenon reflects the way that the teacher makes use of his/her 'traditional' paper-and-pencil practices for the context of technology uses: the micro level of practices supporting the local level. We describe this phenomenon in the second section;

- two other phenomena are involved in the geneses of technology uses . We interpret these as « *movements* » going from the local level of practices towards both the global level and the micro level. We describe in the third section theses movements and their articulation with the IA.

FROM THE MICRO LEVEL TO THE LOCAL LEVEL

A teacher's first session in the classroom using a new tool reveals phenomena that lead the teacher to manage his/her session at the local level within an « improvisation mode ». Even if the session is well-prepared, some difficulties occur that relate to classroom management. It seems that the teacher bases his/her management on his/her traditional practice, which allows him/her to better deal with the technology session at the local level. In other words, it seems that the automatic regulation of teaching practice at the micro level allows the teacher to cope with difficulties emerging during the technology based session at the local level.

For instance, a teacher using EEB provides different help to her students depending on whether they are more or less in difficulty. She gives more procedural help if the student is really in trouble (reinforcing one method) and she provides more constructive help (giving other possible methods…) if the student is more comfortable with the task - Robert (2012) distinguishes teachers' procedural and constructive help for the students: procedural help allows students to perform their mathematical tasks and a constructive help promotes more directly the students' constructive activity. However, during the interview post-observation, it appears that the teacher is not aware of this differentiated practice. This can be related to a characteristic of the mediative component of her practice.

Nevertheless, the use of such micro level of "automatisms" does not ensure efficiency at the local level. For instance, a teacher gives the same individual help to each student, as he does usually during traditional setting with the whole class group, considering that students may be at the same level of task resolution. Therefore some students do not succeed to overcome their difficulties even after the teacher's help. Indeed this help is not adapted to their personal resolution trajectory. For other students, the teacher answers questions they have not yet asked.

Thus, faced with difficulties at the local level, some teachers feel the need to build new specific practices with technology, while others tend to reduce the role of technology within their teaching. As an example of this last case, the students of a beginning teacher had not understood the task during a technology based session. The teacher realizes only at the end of the session that the students were really in trouble with the technological aspects of the task. This observation led her to give a posteriori explanation, during a traditional session, in order to be sure that the task is correctly understood by students, without although considering changes of the technological aspects of the task.

MOVEMENTS STARTING FROM THE LOCAL LEVEL

The phenomenon described in the previous section concerns teachers performing classroom activities in order to manage the classroom on the short term; whereas geneses of technology uses are mainly related to developments at the medium and long-term of the action. Our analysis reveals an evolution of the whole teaching project, including the uses of technologies, starting from their uses at the local level. We interpret this evolution as a movement from the local level of practices to the global level. In parallel, there is a development of technology uses at the micro level entailed by frequent uses at the local level.

Towards the global level

The main movement seems to be an evolution of scenarios. It concerns what we might call, referring to the double approach, the cognitive component of the geneses of use. There is a new balance between traditional sessions and technology sessions,

between collective work and individual phases of students' activity or between old and new mathematical knowledge in students' activity.

As an illustration of this type of evolutions, we note that all our studies mentioned above emphasize that teachers promote quickly the use of 'paper notes' within the students' activity involving technology. For instance, teachers using EEB insist that students use a sheet to keep notes and some of them promote use of a specific notebook devoted to technology sessions. This use of paper evidences is an aspect of the integration at the long-term of technology activity within ordinary activities of students.

Another aspect of this movement is the fact that some teachers evolve towards a systematic implementation of collective moments such as phases of institutionalization at the end of technology sessions. When observed, these collective phases are often based on the use by the teacher of students' written notes. This observation shows particularly the articulation with the above evolution and the relative complexity of the movement. However, the nature of the technological tool or the kind of technology session can lead in some cases to opposite phenomena. For instance, we observe the complete absence of such phases at the end of training sessions with EEB. These sessions seem to be too individualized and too heterogeneous to permit such collective moments.

This movement, from local to global level, explains some difficulties for the integration of technology within ordinary practices as a consequence of the stability of practices. Indeed, for some teachers, established practices at the global level are incompatible with such a development of practices.

Towards the micro level

In this paragraph, we deal with the development of technology uses at the micro level, starting from their uses at the local level of practices. This development is particularly related to teachers' instrumental genesis of specific artifacts. Indeed, the identification of schemes of uses which characterize instrumental geneses is related to both the micro level and the local level of practices, i.e. during the process, the teachers builds operations schemes of use of the artifact as well as actions schemes. However, in the model we provide, the identification of schemes is not a central issue. We rather examine the evolution of technology uses through the lens of teachers' practices dealing with students' activities. Moreover, Abboud-Blanchard and Lagrange (2006) have shown that there exist two dimensions in instrumental genesis of teachers: the personal dimension and the professional dimension. Understanding geneses of technology uses as a whole, needs to consider these two dimensions.

Personal instrumental genesis concerns teachers' activity with technology for their personal uses, as well as for teaching preparation. For instance, a beginning teacher was meeting dynamic geometry for the first time. Starting from a position of

apprehension ("*it is something that scared me*"), she firstly evolved with the development of some practices related to the preparation phase. She used dynamic geometry to draw geometric figures to be integrated in students' worksheets. Then, she developed some practices in which she feels confident without however really reflect on the educational aspects of practices with this technology: a whole class video projection, where students are simple spectators of "technological images".

Professional instrumental genesis concerns both the personal appropriation by the teacher of the software in order to be efficient when using it with students and the actual use in classroom. For instance, an experimented teacher using EEB for the second year, has felt the need to master all the functionalities of this technological tool in order to be able to better adapt his assistance to students for each given exercise. He developed three types of actions to manage the students' activity in computer room. When he arrives to help a student, he first tries to understand the path of the student by questioning him/her, secondly he provides the appropriate help and finally he gives advices enabling the student to pursue his work without the presence of the teacher.

In both these cases, what teachers experienced at the local level, led them to develop micro actions which might enrich their routines when using technologies. Moreover, such development sometimes goes further and impact traditional practices involving both mathematical tasks and classroom management. For instance, a teacher who uses spreadsheet in both private and professional sphere on regular bases has improved her way of introducing algebra. She built new tasks, not necessarily using spreadsheet but although inspired by her instrumentation of spreadsheet. In addition, when performing algebraic tasks, she authorizes students to have tinkering procedures as they would have done with the spreadsheet.

DISCUSSION

The frame that we presented in this paper aims to describe and characterize the evolutions of teachers' practices in their connections with students' activity. The instrumental approach, applied to the teacher, goes also in this direction but does not however deal with the practices as a whole (as we explained above).

We think that our model can better grasp the complexity of the emergence in situ and evolution at the middle and long term of teachers' practices related to technology-based mathematics lessons. It articulates three levels of the organization of practices, and it opens to new meaning for these complexity and evolution. The variety and multiplicity of uses at the local level leads to:

- developments at the global level, mainly evolutions of teaching projects and scenarios, which go beyond the instrumental geneses of specific artifacts;
- developments at the micro level, i.e. the teacher developing new "automatisms" related to the use of technology in the classroom. These

automatisms concern of course the schemes of uses of specific artifacts but can also concern other types of automatisms about mathematics tasks or class management.

Moreover, the model also leads to new meaning for the somehow observed stability of practices in technology based environments. Indeed, the stability of teaching practices seems to result in "automatisms" at the micro level scaffolding the local daily practices. It seems to prevent some teachers who have difficulties to manage technology sessions at a local level from creating new "automatisms" specific to technology at the micro level or seeking to change globally their practices. The micro level of ordinary practices (not involving technology) could thus act as a barrier to the integration of new tools.

In the double approach, the stability of practices is based theoretically on the consistency between the five components of practices: cognitive, mediative, personal, institutional and social. In our studies we have identified geneses of technology uses related mainly to cognitive (tasks and scenarios) and meditative components (class management) of teachers' practices. We also investigated the determinants of these geneses, related to personal, social and institutional components (Abboud-Blanchard & Vandebrouck, 2012). In this short paper, we chose only to consider the geneses of technology uses through the lens of the two didactical components, in order to better exemplify the dynamic phenomena between the three levels of practices, in the "real technology-classroom life".

Finally, the model draws originally on features of the double approach of practices, yet it enriches this general frame by adding a dynamic modeling of the practices' development. Hence, we wonder if it can be generalized to the evolution of any given practice (not specifically addressing technology uses).

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