A DIDACTIC ENGINEERING FOR TEACHERS EDUCATION COURSES IN MATHEMATICS USING ICT

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A first part of our research led us to define a theoretical framework to analyse teachers' education courses and to make hypotheses to explain the lack of efficiency of teachers training (Emprin, 2008). This paper presents the continuation of this work. We use the methodology of didactic engineering, adapted to teachers' education, and a theoretical framework previously built to test our hypothesis. In a first part of this paper we will describe our theoretical framework and hypothesis about teachers training. In a second part we will develop the didactic engineering and its results.

TEACHERS EDUCATION COURSES ANALYSIS

The general question guiding this work is the difficulty for mathematics teachers to use ICT in their classrooms. Our choice is to focus on a particular factor explaining this difficulty: teachers' professional education; without denying the existence of other factors such as material problems, resources available etc. Several studies in France or wider as Empirica study of European Commission, TIMSS & PIRL of the Boston College and BECTA's reports indicate this explanatory factor. French political choices since 1970[i] show that a quantitative effort was made, our research thus relates to a qualitative problem of teachers' training.

A theoretical framework

First we chose to use a framework designed for the analysis of teaching practices and to specify it with teacher educators' practices: the two-fold approach. This framework, defined by Robert (1999), does not take into account specifics of the use of technology. This leads us to use, jointly with the two-fold approach, a framework making it possible to take into account this dimension as described in (Emprin, 2008). The instrumental approach developed by Rabardel (1995) appears to be relevant. This approach, which was already developed in the didactic of Mathematics ,for example in Trouche (2005), leads us to analyse instrumental geneses.

One difficulty is that teacher educators' practices can not be reduced to a teaching activity. A teachers' educator, in France, was most of the time a secondary school teacher, in many instances they keep on teaching to pupils. For this reason, like Abboud Blanchard (1994) specifies, the teacher trainer's previous practices as a teacher intervene in his practices as a teachers' educator.

We borrow the definitions of "activity" and "practices" from Robert & Rogalski (2002) which we must specify on various levels met during a teachers' education course:

This definition of "activity" is nearly similar to Rabardel's notion of "productive activity" (Rabardel, 2005, p. 20). It contains actions but also statements, attitudes and unobservable aspects which influence actions.

The definition of "practices" we use is a reconstitution of the five components described in the two-fold approach. Robert & al. (2007) give the description we have translated here:

> "We developed, taking into account the complexity of the practices, analyses capable of giving an account of what can be observed in class, which results from teacher's homework and the unfolding, and factors which are external to the classroom but which weigh on practices, including those in the classroom, and eventually contribute to the teachers' choices before *and* during the lesson. Indeed, practices in classroom are forced, beyond goals in terms of pupils' acquisitions, by determinants related to teachers' trade: institutional, social… Let us quote programs, timetables, schools, colleagues, class and its composition. Moreover, the practices have a personal anchoring which refers to the teacher as a singular individual, in terms of knowledge, picturing, experiments, trade's idea and also conditions its choices. Our analyses start from class session in which we distinguish components, institutional, social, personal, meditative (related to the unfolding in the classroom and improvisations), cognitive (related to the prepared contents and expected unfolding), closely dependent for a given teacher, and having to be recomposed: it is necessary for us to think of the components together, and to estimate the compensation, balance, the compromises to include/understand and start to explain what is concerned. »

To build our framework of analysis we need to dissociate the various levels of activities and practice but also to see their interactions. Figure 1 makes it possible to describe these various levels.

The first level of activity is the one of the pupil. We note it A0 level. The pupil has a task to realize, and acts accordingly. He uses an instrument belonging to ICT. This level can thus be analyzed with the didactic of mathematics and the instrumental approach. The observation of the process of instrumentation/ instrumentalisation informs us about the instrumental geneses of the pupil and the instruments built.

The second level of activity is the one of the teacher whom we note at level A1. The tasks of the teacher consist of managing and organizing the activity of the pupils. He also organizes the instrumental geneses of the pupil. The two-fold approach enables us to analyze a first level of practices which we note P1 level.

The other two levels of activity are those which exist in teachers' education courses. The activities of the trainees (who are thus teachers) during the training course, are noted as A2. They are organized by those of the teachers' educator noted as A3. The Two-fold approach and the instrumental approach give us access to a second level of practices noted as P2, those of the teachers' educators.

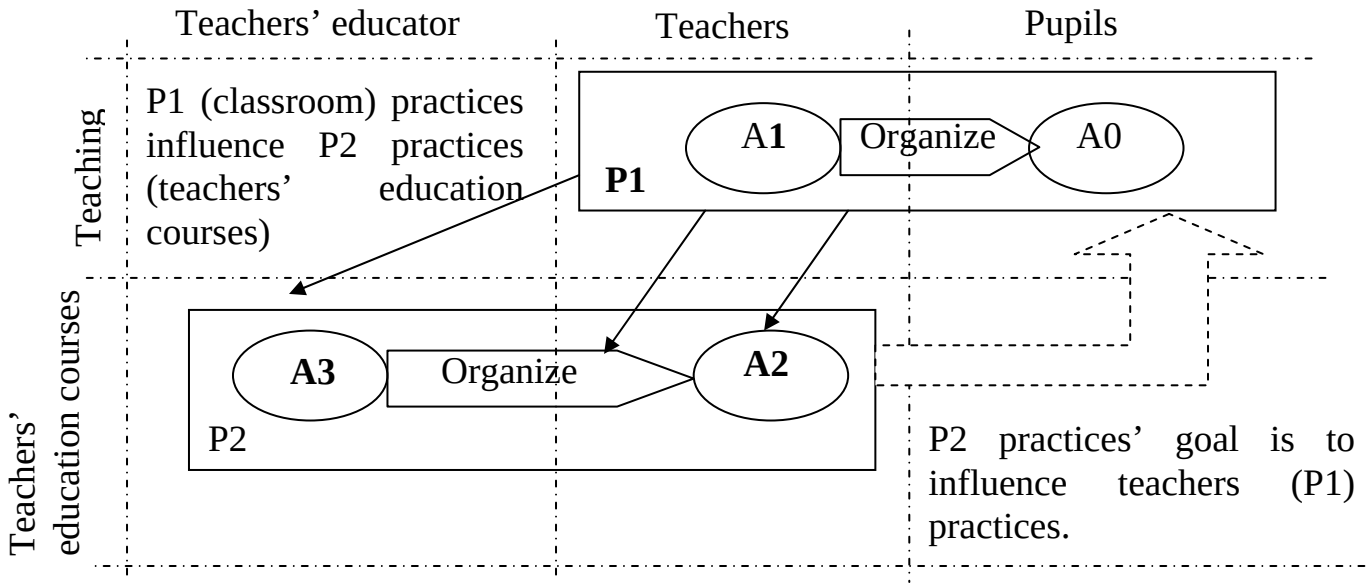

Figure 1: overlap of the four levels of activity and two levels of practices

Use of the theoretical framework

Our work is centred on the analysis of the teachers educators practice, thus we neither directly analyze the practices of P1 level, nor activities of A1 and A2 levels, nevertheless they appear during teachers' education courses as explanatory factors.

Teachers practices (P1) can be seen during teachers education courses in three main ways, through a video: practices are shown, when the teacher's educator narrates a classroom session: practices are narrated through what the teacher's educator asks the trainees to do: the practices are inherent. This last way is linked with a strategy of teachers training which is called homology. This strategy described by Houdement & Kuzniak (1996) shortly consists in doing with teachers (A3→A2) what they will be expected to do when they are back in their classrooms (A1→A0).

The two-fold approach is designed to analyze the real practices; it requires being able to observe the courses and to ask the teacher about the context in which he works. To analyse P1 practises which appear during teacher education session we use two-fold and instrumental approaches as a reading grid to see which part of practices teachers' educator focuses on.

Hypothesis resulting from the analysis of teachers education courses

We implemented this framework of analysis on a corpus of three teachers' education courses, of fourteen interviews of teachers' educators. The results obtained help us to build the first part of our hypothesis about the lack of effectiveness of teachers trainings.

First we notice that working time is mainly dedicated to a work on computers (more than 50% of the time). When trainees are not in front of computers, the time is

devoted to explanations (44 to 62%) and descriptions (35 to 52%) given by the teachers' educator, there is thus very few analysis or debate. In term of two-fold approach social, personal and institutional components of the practices are almost not approached. The mediative component of practices appears in the analysis of video or the narration of courses, but is not questioned. The cognitive dimension remains rather marginal. Our analysis also shows a possible drift of homology strategy: it is likely to introduce confusion between the various instrumental geneses, of pupil and teacher.

BUILDING OF A DIDACTIC ENGINEERING FOR TEACHERS EDUCATION COURSES

Hypothesis

We identify two complementary ideas explaining the lack of efficiency pointed previously. The first one results from the work of Ruthven & Hennessy (2002) and Lagrange & Dedeoglu (in press). Theses authors show a gap between teachers' needs and ICT potentialities presented by teachers' trainers. We also observe an absence. In France the "reflexive practitioner" of Schön (1994) and the "analysis of practices" developed by Altet (1994) or Perrenoud (2003) are two important models for teachers' education is thus remarkable that no allusion is made there in teachers' education courses to mathematics with ICT. That leads us to consider the introduction of a reflexive component in ordinary practices' analysis and to formulate four hypotheses taking into account the first part of our work:

- The analysis of real practices would make it possible to initiate a reflexive attitude in teachers (making it possible for the teacher to change their teaching practices)
- Leading trainees to analyze a real professional problem enables them to confront their representations, mobilize their knowledge (resulting from experience) and come to a consensus based on reasoning.
- An analysis of the professional practices taking into account several dimensions of practices (in terms of two-fold approach) and based on the analysis of the relationship between teaching practices and activity of the pupil, makes it possible for the trainees to mobilize their knowledge (resulting from experience and their theoretical knowledge).
- It is necessary to contribute, during teachers' training courses, to the professional instrumental geneses of teachers and to analyze the lessons in terms of instrumental needs and potential instrumental genesis of pupils.

In order to check these hypotheses we use the methodology of didactic engineering that we specify to teachers' education. This methodology defined in Artigue (2002) is based on the verifying of a priori hypothesis. Thus we need to define observable criteria linked to our hypothesis. We decline our four hypotheses in seven criteria:

- The trainees' ability to identify and define a problem.
- The formulation and the use, by the trainee, of knowledge coming from experience associated with theoretical knowledge to analyze the practice
- The implication of trainees' personal practices and of his own experience in the analysis.
- The trainees reach a consensus based on knowledge coming from experience and theory.
- During the session teachers' educator does not give any answers, any explanations. The knowledge is built by trainees and not given by the teachers' educator. We call that an a-didactical lesson referring to theory of didactical situations (Brousseau, 1998)
- The fact that the analysis makes it possible to take into account several dimensions of the practices
- It must then be possible to identify any trace of instrumental genesis making it possible for teachers to consider instrumented actions but also results on pupils' activity.

Our methodology leads us to conceive a scenario for teachers' education whose implementation will be analyzed by means of the theoretical framework built in the first part.

Scenario and analyzes

The scenario is inspired from Pouyanne & Robert (2004). It is based on the analysis of teaching practices by means of a video. Four periods are defined: an a priori analysis of the lesson (which has been recorded) where hypothesis about the effects of the teaching practices on pupils' activity are put forward; an analysis of the video and a comparison with the hypothesis; a search for alternatives based on the question "What would you do if you had to do such a lesson?"; and finally a debate around problems emerging during the first three period.

We implemented this scenario twice, in each one, videos show pupils using interactive geometry software (IGS): In the first training course eight grade pupils had to prove that perpendicular bisectors in a triangle converge. The second video show sixth grade pupils solving a problem (which is detailed below). We develop now this second session of teacher education.

In each teacher's education session, the scenario lasts about three hours. This part of the session has been recorded, transcribed and analysed. The analysis takes into account who is speaking, the type of speech (description, explanations, analysis) and its content.

An example of session

The lesson recorded for this teachers training is what we call in French “an open problem” referring to Arsac & Mante (2007). This type of problem is called “open” insofar as no specific solution is expected: what matters is pupils’ search.

Figure 2 gives the statement of the problem. Pupils are asked to say which one of [EG] or [AC] is longer.

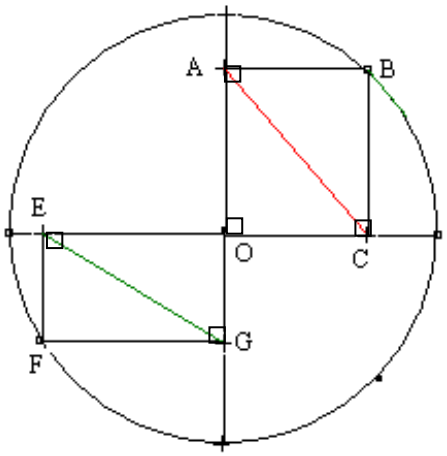

Figure 2 : an « open problem »

During the first part of the work with trainees, the a priori analysis, we had to let them use the IGS. It is a first change in the scenario. It seems to be very difficult for teachers to analyse the problem without having a working time on the computer. This time is not a time of homology even if the trainees do what is expected from pupils.

During the analysis the trainees have a transcription of the discussion with the teacher who is in the video. She specifies what is at stake in this lesson: she wants pupils to develop their critical thinking and to show them not to trust their perception. The trainees identify three stakes: the drawing with the software, the location of the rectangles in the whole geometrical drawing and the property of the diagonals of a rectangle. They specify that they think that the situation cannot be done by the pupils. They propose teaching aids to make the situation feasible. They propose to reveal the radius of the circle, the other two diagonals of the rectangle. Another solution considered is to cut out the problem or to make a preliminary recall of the useful properties. In this stage there is thus an implication of the trainees who adapt the lesson since they try, to some extent, to make it feasible in their classrooms. This implication can be seen in the following example.

> Trainee: that seems difficult to me in 6th grade also because I think that they will see that the diagonals have the same length but that they will not be able to justify it.

The viewing of the film reveals initially the need for dissociating the task of construction in the software from the remainder. Indeed the pupils encounter real difficulties to build the geometrical figure. The trainees realize that pupils need to build uses of the software. It is a part of the instrumental genesis. On the video, once geometrical construction has been carried out, the pupils try to conjecture. The trainees realize that pupils have the necessary knowledge to solve the problem but that they are not able to mobilize it.

In the film, the pooling of pupils' works take place at the end of the lesson, whereas the pupils are still in front of the computers. It is quickly carried out by the teacher. The conclusions of the trainees are that it is necessary to take more time, to move the pupils away from the computers and to let them talk. There is thus a clear evolution in the trainees' mind. In the first part of the analysis they have doubts about the ability of the pupils to solve the problem and in the last part they say it is necessary to devote more time to the pooling of what pupils have found.

The search for alternatives contains the essential components of the analysis. The trainees reaffirm that it is necessary to dissociate the drawing on IGS from conjecture. Some even propose to remove the drawings' work. This work also allows a long discussion about the place of this problem in pupils' training. Before pupils know the property of the diagonals of the rectangle, the problems is centred on research whereas afterwards it acts more as a consolidation of knowledge. This also leads to discuss the place of observations in the geometrical trainings. A trainee proposes to use this problem to introduce the property of equality of the diagonals which disturbs another trainee who believes that observing properties is conflicting with the idea of mathematics. This trainee finally realizes that she does not have tools to give proof of the property to pupils of this level while at the same time the property is in the official programme. During these discussions the teachers' educator scarcely intervenes. Trainees are personally involved in the analysis:

> Trainee: I do think that giving the instructions when the computers are "on" is always rather difficult; it is better to give instructions before turning the computers on.

In this example we can see that this trainee formulates a teaching knowledge, rather simple but which can now be used consciously by other trainees.

Most of the indicators can be observed for "many" trainees. Nevertheless, during a three hours session, a limited number of trainees can speak and consequently the internal evaluation of our methodology is only partial.

Finally, we noticed two changes in our scenario: the time of appropriation of the software was introduced during the analysis of the lesson and the final time of debates was removed. For the first change, the lack of acquaintance of the trainees with the artefact prevents them from making a real analysis. The second change is due to time devoted to debates during the session. The entire subject likely to be alluded to seems to have been discussed before. A last noticeable point is that trainees do not know other pieces of software which could be used in this lesson. The teachers' educator had to show different pieces of software as in the teachers' education courses we analysed in the first part of our work.

Conclusion on the didactic engineering of formation and continuation

The main results of this didactic engineering are linked with our criteria: it seems to be necessary to let the trainees use and try the artefact. It helps them to analyse the

lesson but it also seems to match with trainee expectations. It is possible to take into account several dimensions of the practices but in a smaller number than expected. The analysis of the video helps trainees to make cognitive and mediative components more explicit but the other components are more difficult to reach. The scenario built allows a reflexive analysis of the practices. Experience and theoretical knowledge is used to analyze the problem of introduction of the ICT. Instrumental geneses of the teachers and the pupils are really dissociated. The trainees considered what is necessary to pupil to use ICT in this lesson. They also found different options and they analysed the changes involved by these choices in term of learning or in lesson unfolding. For example ask pupils to draw the figure in the software helps them to use a proper vocabulary (because the software makes it compulsory) but it takes a long time and leads the teacher to reduce the time of conjecture.

Practices, in our didactic engineering, are shown in a video but it is possible to work on other types of practices such as real practices or simulated practices. Simulated practices make it possible for a whole group of trainees to work on the same teaching experience. The construction of such a simulator is the object of a work we initiated in 2007.

To conclude, the fact that teachers use experience knowledge to analyze practices with ICT makes it possible for us to consider the teachers' education course with ICT as a lever for teachers' education generally speaking. It seems to be easier to influence the way of teaching mathematics by influencing the way of teaching mathematics with ICT.

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i This very year the IPT plan began (Informatique Pour Tous) which could be translated in "data computing for everyone". For example in 1985, it allowed the purchase of computers for 33.000 schools and represented 5.500.000

hours of training for teachers. For more information see Archambault, J.-P. (2005), 1985, vingt ans après... Une histoire de l'introduction des TIC dans le système éducatif français. Médialog (54).