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How does an Activity Theory Model Help to Know Better about Teaching with Electronic-Exercise-Bases?

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The research presented in this paper relies on Activity Theory and particularly on Engeström's model, to better understand the use of Electronic-Exercise-Bases (EEB) by mathematics teachers. This theory provides a holistic approach to illustrate the complexity of the EEB integration. The results highlight reasons and ways of using EEB and show some dynamic aspects of this use. However, the general character of the model does not allow consideration of some specificities of the teaching mathematics context.

INTRODUCTION

This paper presents research related to the use, by secondary mathematics teachers of Electronic-Exercise-Bases (EEB). The general issues are: Why and how do teachers use EEB? What effect does this use have on their teaching activity?

In order to answer these questions, we observed voluntary mathematics secondary teachers using EEB over the period of 3 years (Abboud-Blanchard, Cazes & Vandebrouck, 2009, 2007). The data analysis is qualitative and relates to: lesson preparation, class observation and answers to questionnaires and interviews. The analysis provides a plurality of local results which are interpreted within an Activity Theory (AT) framework.

1. THEORETICAL FRAME

The study of the integration of a new tool, here EEB, in the teacher's activity requires taking into account a multiplicity of factors, particularly the institutional and social contexts in which the teacher practices her/his profession. Thus, the framework chosen for this study is AT which offers a holistic approach enabling better understanding of the complexity of EEB integration.

This theory developed by the Russian psychologists, Leont'ev (1981) and Vygotsky (1985), studies a **subject** acting on an **object** to produce a result. The activity of the subject is not "immediate" but "is mediated" by **tools**, both psychological and physical at her/his disposal. The system formed by these three poles, is called a "**production system**". Moreover, the subject does not act alone; her/his activity is socially anchored. Engeström (1993, 1999) modelled the social aspect of activity by adding to the "production system" three new poles: **community**, the set of subjects aiming for the same object; **rules**, which govern this community and **division of labour**, which refers to the hierarchical organisation as well as the horizontal division of tasks between individuals. Thus the activity of the subject is understood as a dynamic process, the result of interrelationships between these poles. Engeström describes tensions between the poles of the system as characterising system activity and driving system innovation.

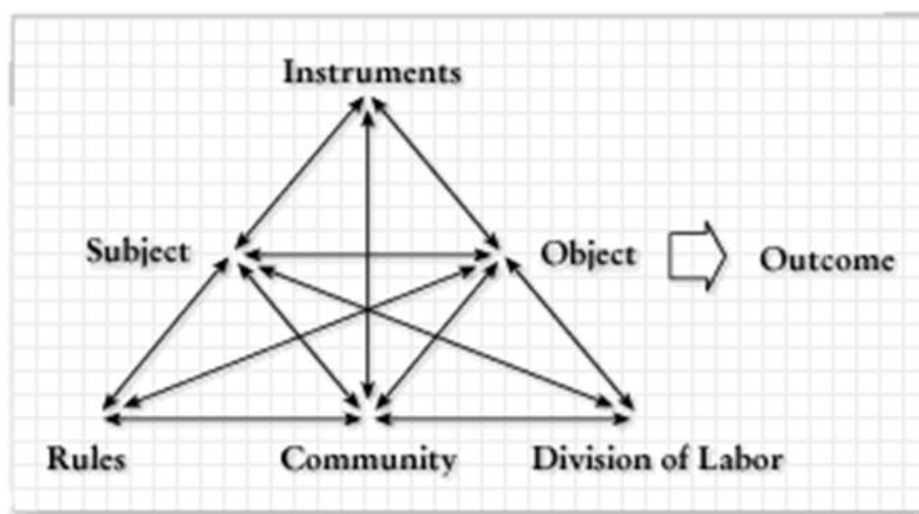


Figure 1 Model of the Activity Theory of Engeström

The study of the teacher's activity using this type of modelling permits us to consider several aspects which take into account the whole context of the activity, and not only the classic didactical triangle: students, teacher and mathematical knowledge, to which would be added EEB. However, the use of the Engeström's model requires specifying with precision the poles. Thus, when this model is used to study teaching practices, it's clear that the **subject** is the teacher observed. However, the object of her/his activity can be the whole mathematical learning of the students, but it could also be, the learning of a precise mathematical topic. Further, the community can be the mathematics teachers of a high school or more generally several subjects (teachers, curriculum's leaders, teacher educators...) taking part in the teaching of mathematics. So we first begin by briefly presenting how in our study we consider the poles of the system.

- **The object of the activity**, in Engeström's model, refers to the "raw material" or the "place where is situated the difficulty" which concerns the activity and which is modelled and transformed in the form of results. In our case, the object of the activity consists of the students and their mathematical work.
- **The tool** allows the subject to exercise her/his activity. It is a set of tools or of instruments. The essential instrument in our study is the EEB.
- **The community** concerns in Engeström's model, all the subjects who share the same object. The same subject, for a fixed object, can belong to several communities. Here, we consider different communities to which the teacher might belong, for example the community of the teachers of a high school or the community of the users of an EEB.
- **The division of labour** is about how members of the same community share the work. For example, several teachers may choose to prepare courses by team or to divide their students into joint workshop or to develop together educational resources (EEB or other ...).
- **Rules** are all the regulations, the constraints, the implicit or explicit standards which organise the system of activity. For example, in our case, it could be institutional rules concerning the curricula. Rules can also concern the explicit or implicit agreements which govern the community.

Therefore, modelling teaching activity by using Engeström's development of AT facilitates taking account of how the teacher uses different tools and deals with the institutional and social context while integrating EEB. Within AT, only actions of the subject (Leont'ev, 1981) are observable. The actions of the teacher are thereby going to inform about her/his, activity. The types of such actions are described in the next section.

2. DATA AND METHODOLOGY

The data consider thirty teachers and in a more particular way, a sub-sample of six teachers. For the latter, data are more numerous including observations in their classes and several interviews. We firstly analysed the activity of the teachers of the sub-sample. Secondly, a comparison with the analyses concerning the wider sample facilitated the production of results related to the regularities and the differences between teachers using EEB.

Data was used to investigate the three phases in the activity of a teacher teaching a mathematics lesson using EEB: the preparation of the lesson, its progress and the reflexive return the teacher makes on this lesson.

The activity of preparation is easily observable through the scenario, made by the teacher and provided to the students via the EEB. It is analysed firstly from the point of view of the choices of the EEB to be used. Then the scenario and the tasks chosen in the EEB by the teacher are analysed considering mainly the complexity of the given task (Robert, 1998) and the status of the knowledge involved in the students' activity: *new knowledge*, *knowledge in development* or *old knowledge* supposed to be already acquired.

The progress in class is analysed via the transcription of the lesson recording as well as the notes of the observers who are particularly sensitive to the types of use of the various tools: EEB, worksheets, blackboard and textbooks. The latter allows to note associations between these tools and to understand complementarities which they engender. To understand the way the teachers help students solving the tasks proposed through the EEB, the interactions in the classroom are also investigated. Their collective or individual character is particularly taken into account.

Finally, interviewing the teacher provides access to her/his reflexive work after the lesson. Special attention is given to the project of modifications to bring to the lesson itself but also to the whole teaching process. Let us however note that these last data are declarative and not actually observed.

3. RESULTS AND INTERPRETATIONS

The data analysis shows that using EEB comes along with multiple modifications in the teacher's activity. Engeström's model supplies a unifying frame susceptible to interpret the plurality of the analysis's results. The first subsection below gathers the results characterising the activity of teachers using EEB by referring to the "production system" of Engeström's model. The focus is afterwards put on the social dimension of the activity of the teachers. The last subsection illustrates the dynamics of this activity observed over the three years of experiment.

3.1. The “production system” of the teacher’s activity

The main result here is that the object of the activity, i.e. the mathematical work of the students, has a great regularity in all the data analysis. This regularity is expressed by both a generic schema of preparation and progress of lesson with an EEB and by similar responses to the tensions identified between the poles of the triangle.

3.1.1. Generic schema

All the lesson-observations show that the scenario is constituted by an orderly suite of exercises presented in a numerical work sheet. Only knowledge in development or old knowledge is concerned. It seems unlikely to make students work on new knowledge with EEB because such tools are essentially designed for training activities only. Moreover, the objectives of the teachers for these lessons are always limited to non-complex tasks.

The progress of the sessions split generally into three phases. The first phase of “starting up” is very brief; the teacher tells the students to settle down, to connect and to download the numerical exercise sheet that she/he had prepared. During the second phase, which is very long, the students work individually and the teacher moves from one student to another to provide help, the interventions are thus mainly individual. The final phase is always extremely brief. The teacher declares the end of the session and asks to switch off the computers. Even if these three phases could be usual for a “training session”, their durations are particularly specific to the EEB context and seem to arise from the influence of the EEB on the object of the activity.

3.1.2. Dealing with tensions

Let us see how Beatrix, a high school teacher, begins a session intending to make students revise linear functions:

Sit down, rather one by table (...) When you arrive at the working session (the numerical exercise sheet); you pay attention on the comments that I gave you, that I wrote at the beginning. (...). You call me to show me if it is all right. I want to see some good work (...). And you do not forget concerning exercise 7 and 8, to write on your exercises book how you found the right answer (...)

We notice that Beatrix insists on the reading of the comments that she wrote more than on the reading of the statements of exercises which are in the EEB. Beatrix wants also to check and confirm herself the results of the students while the EEB could do it also.

These two elements, observed in several cases, illustrate in our opinion, tensions between the subject and the tool. The teachers seem to have the feeling to be in “competition” with the EEB, i.e. it disrupts well-established patterns of their activity.

The numerical work sheets are generally very precise and too long to be accomplished within one session. Questioned on this point, teachers specify that they are afraid that students miss work or do not work in a way that suit them. Everything seems to go on as if the teachers, taking the risk’ to introduce a new tool into their learning process, control as much as possible the variability of the situation.

Finally, a recurring difficulty is highlighted by all teachers. Working with EEB allows students to check their answers without having to explicit the processes. However, teachers’ aims usually focus on the process more than the answer. For instance, Beatrix specifies at the end of her first intervention:

*(...). And you do not forget concerning exercise 7 and 8, to write on your exercises book **how you found the good answer.** (...)*

These two difficulties could be interpreted in terms of tensions between tools and object of the activity, that the teacher has to manage.

3.2. Influence of the social dimension on the teacher’s activity

The “production system” is not sufficient to explain all the complexity of the subjects’ activity. The use of technologies could be felt as difficult by teachers, which sometimes makes them reticent to this use. If teachers are not ready to fully use the EEB, one can wonder why some of them choose to use it. The study of the whole system, including the poles: rules, community and division of the labour, brings elements of explanation.

In the French context, teachers are asked (through curricula recommendations) to use technology on a regular-basis. In addition, they also have to provide individualized assistance to weak students. Thus EEB may appear as tools which make it possible to answer both these two institutional injunctions. This shows how rules can influence teachers’ decision-making.

Moreover, we notice that, even if the teachers are apparently free to choose the EEB they prefer, it seems that the rules of membership in a community have a strong influence on this choice. For instance, the choice of the EEB to be used is the same for all the teachers of professional high schools or for most of the teachers belonging to the same regional education authority.

Finally, some EEB offer environments that facilitate cooperation within the educative community; such as group of teachers collaborating with EEB designers to create suitable exercises.

3.3. Dynamics of the teacher’s activity

Any activity modifies the reality which surrounds it as well as the subject itself. Thus, the model introduced in first section above requires a dynamic reading: the activity is going to produce results which are going to modify the

subject and its environment. The outcomes of the activity system are transformations of reality by the subject's activity. We consider that these changes may affect the "state" of students as well as the "state" of the subject (the teacher).

3.3.1. Evolution of the subject

One of the first results is the modification of the subject. Teachers declared that the EEB-based lessons had enabled them to test extremely simple exercises that they might not otherwise have thought of using, but which appeared useful in the teaching process. They also became aware of student's errors that they had not suspected; which commits them to adjust their teaching practices taking into account these precise points. For example, Claude noticed, thanks to a randomisation of parameters in an EEB exercise, that his students did not understand that a linear function $f(x) = ax$ was a particular case of the function $f(x) = ax+b$.

An evolution concerning all the teachers observed is the articulation by various devices of the work on computer and the paper-and-pencil work, and more generally the integration of the work with an EEB in the whole teaching process. It is mainly in developing these intermediate devices that the teachers are going to exercise their creativity and are thus going to be transformed themselves.

3.3.2. Modification of the social dimensions

Following the use of an EEB, a teacher can decide to participate in the community of its users and by the same to exchange for example through forums with others teachers and, in certain cases, to get organised to make a division of labour. She/he can also convince colleagues of the same high school to work together so it can facilitate her/his task by a working division. But it also can complicate it when for example the computer room is little available. Finally, some teachers may have fruitful exchanges with the developers of the EEB.

It is also possible that rules change. For instance, due to financial restrictions, institutional injunctions to make sessions of Individualised Assistance for weak students, might disappear..

4. CONCLUDING REMARKS

The introduction of a new tool, an EEB, in the teaching process is an innovation bringing research questions which mainly are: How and why do teachers use EEB? What effect does this use have on their teaching activity? The use of Engeström's model enabled us to answer these questions.

Firstly, the top of Engeström's model i.e. the "production system" brings to light on the one hand a general view on how do teachers implement EEB in their teaching through a generic format of EEB lessons. On the other hand, focusing on some tensions between the triangle's poles help to understand how teachers deal with some constraints due to the specific design of these technology tools.

Nevertheless, even if teachers seem to manage to implement EEB, this remains difficult for them relatively to the whole teaching process. These difficulties are mainly due to the fact that using EEB disturbs the well-established activity. For instance, a systematic use of EEB would entail to work only on knowledge in progress without collective conclusion and thus would prevent introducing new notions. Further, we showed that students using EEB focused on results of exercises rather than on solving processes.

The social dimensions i.e. the bottom of Engeström's model allowed understanding why, in spite of these inconveniences, some teachers choose to use EEB. Finally, the study of the dynamic aspects of the model showed how this activity is not stabilised but is the result of various negotiations between strengths in movement.

However the very general character of the model does not seem to allow taking into account specific aspects of the activity connected to the mathematical content at stake. To synthesise, we could say that this model offers a systemic vision allowing drawing the shape of the teacher's activity in its entirety, but at the same time it masks the access to a level of singularity often essential in mathematics education research.

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BIOGRAPHICAL NOTE:

Maha Abboud-Blanchard is Associate professor of mathematics education at the UCP and member of the LDAR research team of didactics of mathematics, University Paris-Diderot. Her research interests concern the use of technology in mathematics teaching and in mathematics teacher education. She is the leader of a university team working on developing resources for the training of secondary teachers with a focus on the use of technologies. She had also led, or been involved in, several national projects aiming at understanding mathematics teachers' practices in technology environments and the effects of professional development on such practices.

Claire Cazes is Associate professor of mathematics education at the UPMC (University Pierre et Marie Curie) and a member of LDAR research team of didactics of mathematics, University Paris-Diderot. She is in charge of the ICT course for future teachers at UPMC. Her subjects of research are the conception, the use and the integration of ICT in mathematics education. She has already participated in several national research projects (GUPTEn), European projects (TELMA, REMATH, Edumatic, ActivMath) and International projects (PreNum-AC). All these projects concern the conception, the use, the integration and the spread of the ICT and implement cross-experiments between various countries.

