Three ways that use ICT to enlarge students' roles in learning

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How can the academic success of students be better ensured? Many math teachers ask this question. Educational researchers have proposed multiple solutions. In our own works we have considered three of them: diversifying the taught knowledge's sources of references and re-contextualize it, involving students in their learning process by giving them various responsibilities, enriching the class's didactical "milieu" with resources and digital tools. In this report we will focus on the second and third propositions with one main question: how can information and communication technologies help increase students' responsibilities in learning? We will expose three examples of how this aim could be achieved.

Keywords: Cooperative learning, teaching methods, computer assisted instruction, students' topos, anthropological theory of didactics.

Focus and rationale

Giving responsibility to students for their learning is a concern that educational researchers have taken for many years. For example Barnes (1977) or Lee and Smith (1996) show that achievement gains are significant when teachers enhance collective responsibilities, Scardamalia (2002) explores some possibilities of computer-supported environments and Coffman (2003) proposes strategie, Theories also exist that give a frame to this issue, such as the Joint Action Theory in Didactics (Sensevy, 2010) or the Cooperative Learning theory (Slavin, 1995). Our purpose in this paper is to expose three examples of how web resources and digital intelligent systems allow math teachers to involve their students in cooperative activities where they are authors of the lesson tracks, where peer learning is promoted and where curricula are individualized. The intelligent system that will be used in the classroom is the web platform LABOMEP (http://www.labomep.net/). We will show that it is a tool likely to foster student-to-student monitoring, autonomous training and self-evaluation.

Theoretical framework

We will use in this paper concepts from the Anthropological Theory of Didactics (ATD) (Chevallard, 2002, 2006; Wozniak et al., 2008; Winslow, 2011), In ATD, learning and teaching are interpreted as ordinary human activities that can be described and analysed through the general concept praxeologies: "A *praxeology* is, in some way, the basic unit into which one can analyse human action at large." (Chevallard, 2006). At first a praxeology is built around a *type of task* which is usually expressed by a verb and a precise object. For example, "to climb a staircase" is a type of task, but to climb, short, is not one" (Chevallard, 1998, our translation). Secondly a praxeology precise a *technique*, a way to realize the type of task, a know-how. This technique is then often justified and lightened by a *technology*, a reasoned discourse which states that the technique is suitable for the type of task and explain how to perform it. "At his turn, the technological discourse contains some statements, more or less explicit, for which one can ask the reason. We then reach a higher level of justification-explanation-production, the theoretical one" (Ibid.).

Another theoretical concept on which we rely in this paper is that of *topos*:

> In some contexts, didactic tasks actually are *cooperative*, meaning that they must be performed *together* by *several* persons $x_1, \ldots, x_n$, the *actors* in the task. It will be said that each of the actors x_i must in this case perform certain *gestures*, the whole of which constitutes its *role* in the fulfillment of the cooperative task *t*, these gestures being both differentiated (according to the actors) and coordinated by the collectively implemented technique τ. Some of these gestures will be seen as separate tasks, *t'*, in the accomplishment of which x_i will act (momentarily) in a *relative autonomy* compared to the other actors in the task. The set of all these tasks, which is a subset of the *role* of x_i when *t* is performed according to τ, is then called the *topos* of x_i in *t*. (Chevallard, 1998, p. 108, our translation)

A student's *topos* is thus the set of all of the gestures he will have to accomplish in didactic autonomy. In his dictionary of didactic, Chevallard (1996) describes at least three types of student's or teacher's *topos*: 1/ the math disciple/pupil who just listens and observes what is done by the master/teacher; 2/ the math practitioner who masters some techniques in order to realize some tasks and is guided by the animator/teacher; 3/ the math student/researcher who masters the theoretical and technological parts of the praxeologies and has a relative didactic autonomy when studying research question under the direction of its director/teacher. A way to look at the students' *topos* is to focus on what happens with their public speeches or texts. Most of time, these discourses are just communicated and appear in the milieu (Brousseau, 1997), but they are not included in the shared praxeologies which constitute the lesson and that is here termed the *class's praxeological equipment* (Salone, 2015b). Writing the *class's praxeological equipment* is usually a type of task reserved to the teacher; it is an element of his *topos*. The *topos* of the students relatively to the *class's praxeological equipment* is then just to copy and memorize it. But, in some contexts, it may be a cooperative work, so we proposes a four levels scale to analyse how students' public discourses evolve in a classroom: 1/ they are communicated; 2/ they are discussed; 3/ they are included in the *class's praxeological equipment*; 4/ they program the study. At first level, students' public discourses exist in the class' milieu. At second level, they become a local reference: students and teachers refer to them when debating. At third level, excerpts of the students' public discourses constitute the *class's praxeological equipment* and excerpts of them are directly inserted, with no rewording by the teacher; at fourth level, their function is to organize the study

In order to give the teachers some tools to go through these for levels, we develop some *didactic plans*. A *didactic plan* is a teaching technology, a way to conduct the study in a classroom. Chevallard (2002, p. 7) proposes some examples: a lecture course is "teaching by giving a discourse on some subject", a seminar is "a small group of advanced students […] engaged in original research or intensive study under the guidance of a professor […]". Thus a *didactic plan* aims to shape the didactic relation between the teacher's *topos* and the students's *topos*; in this respect it contributes to the evolution of the didactical contract (Brousseau, 1997).

In this paper we describe *didactic plans* where students are involved in cooperative tasks with a relative autonomy, where they have a math practitioner *topos* and where their public discourses are at second and third levels (see above).

Methodology

Our research was conducted from 2010 to 2016 in math classes ranging from primary school to high school levels. It began with a team of three teachers, including myself, and twelve classes in middle school (students aged from 11 to 15 years), with two classes per grade (from grade 5 to grade 9). Later the team was joined by three more teachers from middle school (four classes per teacher), two teachers from high school (grade 10 to 12, three classes per teacher) and five teachers from primary schools (grade 4 and 5, one class per teacher). In addition two teacher's trainers joined the team. All the teachers involved in the research project agreed to implement *study and research activities* on specific topics and various *didactic plans* designed by an upstream engineering in order to diversify knowledge's sources of reference and to open classes on their surrounding world (Salone, 2015a). Teachers remained free to adapt and insert these activities and plans into their own mathematical progressions. For the research needs, they collected data in their classes: lectures, students' documents, teacher's online textbooks[1], students' notebooks. Twice or three times a year, we visited one of these teachers (that means we observed their classes without interacting) in order to make audio recordings of sessions, to take photographs of the classrooms and to interview some students that were chosen randomly. We did informal interviews with open questions on how the students appreciated the course and where notes were taken. From 2014 to 2016, the whole team also met twice a year in order to share teaching experiences. This was an opportunity to improve the *didactic plans* and to realize informal interviews of the teachers or to refine some of our *a posteriori* analysis.

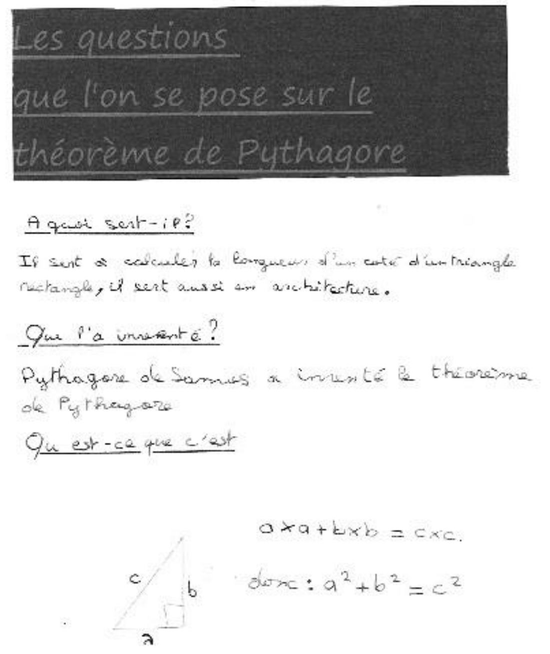
Learning the Pythagoras' theorem

In France, the Pythagoras'theorem is studied in grade 8. The Ministère de l'Éducation Nationale (2008) imposes two abilities: 1/ to characterize the right-angled triangle with the Pythagorean equality; 2/ to calculate the length of a side of a right-angled triangle from the lengths of the two others. It states also that the direct theorem must not be distinguished from its reciprocal (nor from its contraposed form). The case we report here concerns a class at third level of the middle school, with pupils aged 13-14 years (grade 8). The objective was the study of the Pythagoras' theorem. The teacher's online textbook shows his progression: 1/ a survey, at home, of the Pythagoras' theorem; 2/ group works to product synthesis on what is the Pythagorean theorem and its uses; 3/ a tutored training with Labomep; 4/ a selection of exercises' models

Exploration of the theorem and of its uses

As already said, the study began with an exploratory survey conducted at home, on the web and by asking the close family. In the first session students had realized written presentations on Pythagoras and his theorem (Salone, 2015a, p. 323):

[1] In France, teachers are required to write each day a summary of what they have taught in an online textbook. This textbook can be consulted by the students and their parents.


Les questions
que l'on se pose sur le
théorème de Pythagore

A quoi sert-il?

Il sert à calculer la longueur d'un coter d'un triangle rectangle, il sert aussi en architecture.

Qui l'a inventé ?

Pythagore de Samus a inventé le théorème de Pythagore

Qu est-ce que c'est

$a \times a + b \times b = c \times c.$

donc : $a^2 + b^2 = c^2$

The questions we ask about Pythagoras' theorem

<u>What are its uses?</u>

It is used to calculate the length of a right-angled triangle. It is also used in architecture.

<u>Who invented it?</u>

Pythagoras from Samos invented the Pythagoras' theorem

<u>What is it?</u>

Figure 1: Excerpt of a presentation on Pythagoras (left) and our translation (right)

Four of these presentations were exposed on the blackboard and orally presented by their authors (10 minutes). The teacher then asked some questions: "Does someone have found some more information about Pythagoras?", "Do you agree with these statements of the theorem?", "What the Pythagoras' equality allows us to calculate or to do?" Then he invited the students to freely constitute six peer groups (4 to 6 students per group) to answer these questions and to produce a shared synthesis. In the groups, the students collected and compared their presentations. Their works lead to the emergence of shared statements of the theorem, some uses of it and some problems in line with the official programs. After 30 minutes, the teacher ordered each group to copy one single statement on the notebooks. He had a glance to these statements but, since they all were right, he did not reword them. His first teaching objective was thus reached. In addition, he exposed five of the students' synthesis on the classroom's walls. In this session, the students' *topos* was thus quite unusual; indeed they were first responsible at home of their own first encounter with the theorem (Chevallard, 1998); second they produced a synthesis in peer groups, by reviewing collaboratively one another's works, while the teacher facilitated their work; third they were the authors of the theoretical part of the *class's praxeological equipment* (third level on the *students' public discourse* scale). In this *didactic plan*, the ICT were a tool to access web resources. In the interviews, some students reported being pleasantly surprised by all the uses of the theorem.

Tutored training with a digital media

During a second session, the teacher animated a computer training shaped by a *didactic plan* we call a "tutored training" (Salone, 2015a). It's a moment where students perform training exercises and where they help each other and self-evaluate. In this *didactic plan* a digital media, here the web platform for math teachers Labomep (http://www.labomep.net), provides series of type of tasks. The teacher has to subscribe and then he is allowed to access and deposit resources to organize his courses. Many exercises are thus available, sorted by school grades, chapters and themes. Students may access

Labomep freely, without subscription. But the teachers of our team preferred to enrol their students so that they could control their works (see further). At first the teacher video-projected one problem from the series (Figure 2, left). Each student then individually sought an answer for it. Then the first students who had one consulted with the teacher who evaluated them. After a few minutes, some of the students who had correct responses were invited to help others. At this moment, these students had a *topos* enlarged with teaching task: they gave technological-theoretical explanations and methodological advices, they realized assessments. Meanwhile the teacher too had a specific *topos*: he regulated the activity, reminding some rules, giving some advices. When everyone had come to an answer techniques were finally discussed by the whole classroom and a common solution was chosen and copied in the notebooks (Figure 2, right). The process could then start again with a new exercise from the same set or from another one. In a third session, not observed, the students had also to gather in a file the problems along with their solutions (one problem from each Labomep series). Thus in these sessions several types of mathematical tasks associated with the Pythagoras' theorem appeared through problems and techniques gradually emerged. The students' *topos* was enlarged with monitoring tasks usually reserved for teachers and with writing tasks in order to constitute the *class's praxeological equipment*. ICT were at the heart of this *didactic plan* as they provided sequences of problems and allowed the existence of a joint action. In interviews, students often reflected the feeling they had that tutored trainings, with peer to peer exchanges, improve their understanding of mathematics. Teachers also highlighted that a long-term regular use of such a *didactic plan* enables students with learning difficulties to keep up with their classmates.

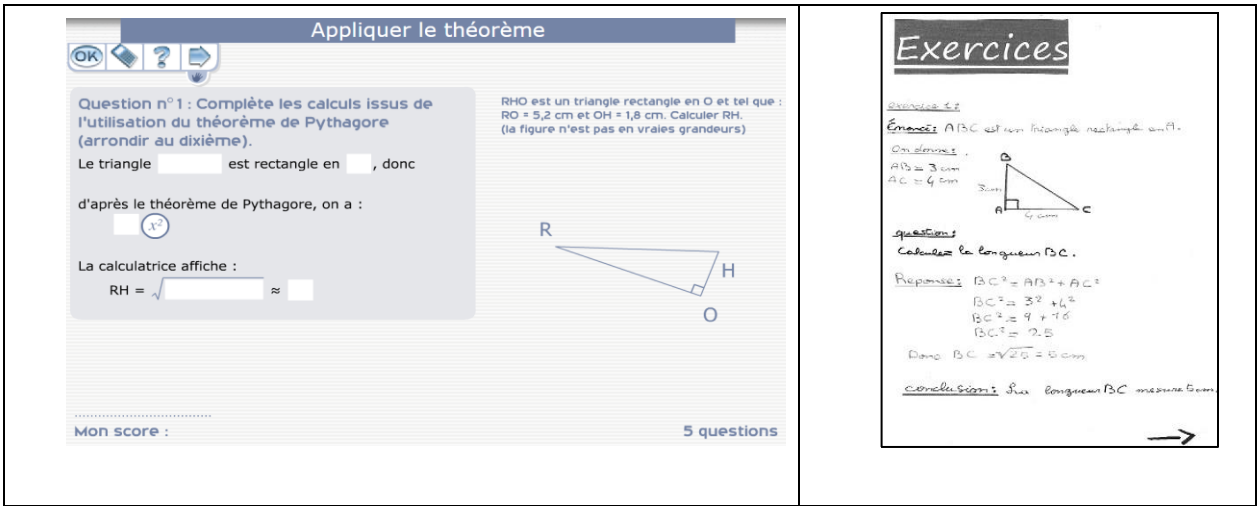


Figure 2: An exercise from Labomep (left) and a shared one (right)

Self-training and assessments

Websites as Labomep are not only resources for interactive exercises. They are also intelligent systems that assess the performance of individual students. In several of the classes involved in our research, teachers took advantage of this potential to develop training sessions in relative autonomy. Each student had a personal account on Labomep and trained alone or with a classmate. The sets of exercises are either freely decided or defined in advance by the teacher. At the end of a series, Labomep assigns a score and suggests trying again if needed. Video animations reminiscent of technological-theoretical elements are also directly accessible or proposed. The greatest advantage of this *didactic plan* is that it can be continued outside the class. Indeed each student can extend the studies conducted in classroom by training, revision or exploratory sessions at home. Figure 3 shows an example of individual assessment which is made by Labomep and which the teacher can view. The first column is the name and first name of the student (here a generic one), the second column contains the title of the series, the third one is a score, the forth and the fifth ones are day and time. In the third column, the score is at first a mark (1 over 5 here) and the five rectangles corresponding to the five exercises of the series are coloured: when the colour is red, that means the student didn't succeed at all (he had two attempts to succeed), when it is light green he succeeded at the second try, when it is green he succeeded at the first try, and when it is blue he didn't answer the exercise.

Figure 3: An individual assessment with Labomep

To go back to Pythagoras' theorem, Figure 4 shows the activity of two students on it and on the Pythagorean triples. This is an extract from a page with global statistics generated by Labomep that informs us about the different issues they addressed, adding scores or achieved grades, and the dates, times and durations of sessions. The two students, which we will call here Ali and Ame, had different profiles: Ali was ranked among the top students in his class, whereas Ame was facing some learning difficulties. Data on dates and hours show that both have used Labomep 3 times: twice during classroom sessions, on 24/09/2012 and 01/10/2012, and once outside the classroom on 03/10/2012. In class, within an hour and forty minutes of activity (rows 1 to 7), Ali mastered the first two types of tasks (applying the theorem and showing that a triangle is not right-angled). For the first type of task (rows 1 to 4), his score is three times 0/5 and then it becomes 5/5. For the second task (rows 5 and 6), his scores are 1/5 and 5/5. But he only achieved a score of 1/5 for the third type, at row 7 (use the Pythagorean triplets). Within the same time frame, Ame successfully completed the first two types of tasks, with a maximum score of two out of five for the first one (rows 13 to 18) and one out of five for the other (row 19).

ROW	eleveclasse	num	nom ressource	score	sur	note	meilleur ?	date	heure	duree
1	ALI C:4ième Satie	1	Appliquer le théorème	0	5	**0,00**	n	2012-09-24	11:00:35	**00:08:43**
2	ALI C:4ième Satie	1	Appliquer le théorème	0	5	**0,00**	n	2012-09-24	11:09:18	**00:06:57**
3	ALI C:4ième Satie	1	Appliquer le théorème	0	5	**0,00**	n	2012-09-24	11:16:15	**00:11:39**
4	ALI C:4ième Satie	1	Appliquer le théorème	5	5	**20,00**	o	2012-10-01	14:07:30	**00:28:09**
5	ALI C:4ième Satie	2	Démontrer qu'un triangle n'est pas rectangle	1	5	**4,00**	n	2012-10-01	14:35:57	**00:05:09**
6	ALI C:4ième Satie	2	Démontrer qu'un triangle n'est pas rectangle	5	5	**20,00**	o	2012-10-01	16:54:25	**00:10:59**
7	ALI C:4ième Satie	3	Triplets pythagoriciens	1	5	**4,00**	n	2012-10-01	17:05:53	**00:31:22**
8	ALI C:4ième Satie	3	Triplets pythagoriciens	1	5	**4,00**	n	2012-10-03	18:27:47	**01:00:28**
9	ALI C:4ième Satie	3	Triplets pythagoriciens	2	5	**8,00**	o	2012-10-03	19:28:15	**00:19:23**
10	ALI C:4ième Satie	3	Triplets pythagoriciens	2	5	**8,00**	n	2012-10-03	19:47:47	**00:07:46**
11	ALI C:4ième Satie	4	En deux étapes	5	5	**20,00**	o	2012-10-03	19:55:41	**00:53:14**
12	ALI C:4ième Satie	5	En deux étapes (bis)	1	5	**4,00**	o	2012-10-03	20:49:05	**00:05:11**
	AL ...Résultat					*7,66666667*				***04:09:00***
13	AMEF4ième Satie	1	Appliquer le théorème	0	5	**0,00**	n	2012-09-24	10:57:19	**00:19:55**
14	AMEF4ième Satie	1	Appliquer le théorème	0	5	**0,00**	n	2012-09-24	11:17:15	**00:11:11**
15	AMEF4ième Satie	1	Appliquer le théorème	0	5	**0,00**	n	2012-10-01	14:12:32	**00:09:23**
16	AMEF4ième Satie	1	Appliquer le théorème	0	5	**0,00**	n	2012-10-01	14:21:56	**00:17:09**
17	AMEF4ième Satie	1	Appliquer le théorème	0	5	**0,00**	n	2012-10-01	14:39:05	**00:01:58**
18	AMEF4ième Satie	1	Appliquer le théorème	2	5	**8,00**	o	2012-10-01	16:57:29	**00:23:50**
19	AMEF4ième Satie	2	Démontrer qu'un triangle n'est pas rectangle	1	5	**4,00**	n	2012-10-01	17:21:31	**00:14:19**
20	AMEF4ième Satie	1	Appliquer le théorème	0	5	**0,00**	n	2012-10-02	15:10:30	**00:03:03**
21	AMEF4ième Satie	2	Démontrer qu'un triangle n'est pas rectangle	3	5	**12,00**	o	2012-10-02	15:13:40	**00:11:48**
	AM Résultat					*2,66666667*				***01:52:36***

Figure 4: Excerpt from statistical assessments of students in Labomep

Out of the classroom the path differences are even more marked. Ali returned to Labomep, two days later, more than two hours in the evening (rows 8 to 12); he trained himself to solve the third type and didn't succeed (his best score is 2/5). After that he went on working on two other types of more complex problems (rows 11 and 12). Ame just spent a quarter of an hour taking the first two types, in the afternoon one day after the second session (rows 20 and 21). He partially succeeded the second type of tasks, reaching a score of three out of five. Thus, with intelligent digital systems such as Labomep in such a *didactic plan*, courses and students' paths can be individualized. According to teachers, it is very beneficial for learning: it consolidates the skills of all students. Those who have difficulties have tools to progress at their own pace and perform better evaluations, those who already have a good level complement their knowledge. Some teachers have also chosen to look at these individual activities outside the classroom so that everyone's work is rewarded regardless of the initial or achieved levels in mathematics. Quarterly average scores are thereby increased, which greatly helps to maintain students' motivation.

Conclusion and perspectives.

Through these examples we have therefore tried to identify some benefits on learning induced by the use of *didactic plans* including ICT and which enlarge students' *topos*. The first one concerns the *class's praxeological equipment*: students become authors of the lecture, of its content and its programming. The second benefit is related to the joint action: ICT facilitate peer exchanges in *didactic plans* where students endorse teaching tasks that are usually assigned to teachers. The third benefit is the differentiation of learning: intelligent tutoring systems such as Labomep allow tasks to be performed in individualized ways and to be continued at home. Can we conclude that students are more motivated when using ICT? And does this improve their learning of mathematics? The general consensus amongst the participating teachers and students was yes. But there are other factors that might explain this conclusion. First we worked with an extremely motivated team of teachers who were very dynamic and keen on interesting their classes. Second today's students easily understand and appreciate ICT related activities. So it is not sure that these methods would ensure success for all students. Our research objectives are now to study the conditions and constraints of implementing such *didactic plans* in regular classes.

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