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Resources, at the core of mathematics teachers' work

Ghislaine Gueudet
CREAD, IUFM Bretagne UBO
ghislaine.gueudet@bretagne.iufm.fr

Mathematics teachers work with resources in class and out of class. Textbooks, in particular, hold a central place in this material. Nevertheless, the available resources evolve, with an increasing amount of online resources: software, lesson plans, classroom videos etc.
This important change led us to propose a study of mathematics teachers documentation. Mathematics teachers select resources, combine them, use them, revise them, amongst others. Teachers' documentation is both this work and its outcome. Teachers' documentation work is central to their professional activity; it influences the professional activity, which evolves along what we call professional geneses.
In this conference, I introduce a specific perspective on teachers resources, which enlightens in particular the changes caused by digitalization, and in particular Internet resources.

Keywords: *Communities, Documentation, Internet, Professional development, Resources*

Introduction

Mathematics teachers work with resources (Adler, 2000), in class and out of class. This fact has been considered by many researchers focusing on curriculum material (Remillard, Herbel-Eisenmann, & Lloyd, 2008). Textbooks, in particular, hold a central place in this material (Pepin, 2009). Nevertheless, the available resources evolve, with an increasing amount of online resources: software, lesson plans, classroom videos etc.
This important change suggests possible connections, between the study of traditional curriculum material, and the study of technology in mathematics education. It also enlightens the evolving role of the teacher; he/she can no longer be considered as a passive resource user, he/she becomes a potential designer of her own teaching resources.
These reasons led us (Gueudet & Trouche 2012) to propose a study of mathematics teachers documentation. Mathematics teachers select resources, combine them, use them, revise them, amongst others. Teachers' documentation is both this work and its outcome. Teachers' documentation work is central to their professional activity; it influences the professional activity, which evolves along what we call professional geneses.
In this conference, I introduce a specific perspective on teachers resources, which enlightens in particular the changes caused by digitalization, and in particular Internet resources. I then present a theoretical approach for the study of teachers documentation work, conceptualising the articulation between documentation and professional development. I illustrate this approach with case studies, coming from several research projects, considering the documentation work of primary and secondary school teachers, and its consequences for their professional development. A specific interest is devoted to teachers communities and their work with resources.

1.Mathematics teachers resources

Teaching mathematics requires various resources; I do not intend here to propose a full description of these resources. My aim in this section is, on the one hand, to introduce a specific perspective on resources, inspired by the work of Adler (2000); on the other hand, to analyse the current evolutions yielded by the Internet in mathematics teachers resources.

1.1Conceptualisation of resources

Resources for mathematics teachers exceed curriculum material. The origin of this statement, in our work, comes from our interest for Internet resources (Gueudet & Trouche 2009). Online exercises, a digital textbook are resources for teachers. These exercises, this textbook, are offered on a website, which is likely to include a forum for its users. Discussions on this forum can also constitute resources - for example, a teacher can declare that she especially appreciates a given activity in the textbook, and this comment will act as an advice for another teacher reading it -. This statement leads to consider that any discussion between teachers also can constitute a resource; same for the discussions with students.
For other reasons, Adler (2000) has similarly encountered the need for a concept of resources in mathematics teaching which focuses more on how a given object intervenes in teaching than on its nature.
“ It is possible to think about resource as the verb re-source, to source again or differently. This turn is provocative. The

purpose is to draw attention to resources and their use, to question taken-for-granted meanings." (Adler 2000, p. 207).
Adler distinguishes between human resources (the mathematics teacher herself, her knowledge), material resources and socio-cultural resources (such as language and time). With such a perspective, what matters is not the intention which prevailed, when the resource has been initially elaborated, but its intervention in mathematics teaching, its use, by a teacher, for teaching objectives. A movie theater can become a resource for the teaching of mathematics, if the teacher proposes to her pupils to count the seats, for example.

While our study mostly concerns curriculum material, its current evolutions and the consequences of these evolutions, we retain nevertheless Adler's perspective, focusing on "what intervenes in the teaching of mathematics". With this perspective, I will focus on the changes brought by the Internet in the resources available for the teaching of mathematics.

1.2 Internet and resources evolutions

The Internet naturally introduces evolutions in the available resources. Teachers looking for resources on the Internet have to choose amongst a profusion of websites, files and software proposed for downloading. The evolutions are not limited to the number, or the kind of available resources, they also concern, in particular, their design modes, and their quality assessment.

1.2.1 Design modes

The process of designing textbooks (traditional paper textbooks) can be very different, from one country to another, according to the national policy. In some countries, textbooks are published by private publishers, with no control of their content. In others, a national authority controls the book before its publication; in some cases, for each grade level a unique, official textbook exists, written and published by the institution. Whatever the national policy is, a teacher wishing to write a textbook faces a difficult and long work; a user of a textbook can not modify its content, according to his own needs or perspectives.

The situation, with websites, is completely different. Each teacher, equipped with a computer connected to the Internet can easily develop teaching resources, and publish them on this website, for the use of other colleagues.

Naturally, the official institution can also develop and propose Internet resources. In Mexico, the Enciclomedia website has been produced in the context of a national project (Trigueros & Lozano 2007, Trouche, Drijvers, Gueudet & Sacristan to appear). The educational authorities formed teams of specialists in education to transform classical textbooks in online resources, with an aim of teacher education. This kind of design can be considered as "top-down": specialists, officially recognized by the ministry, conceive resources for teachers. These teachers are considered as users, who will develop their own practice by the use of these resources.

Simultaneously, Internet opens the possibility of new design modes. In particular, communities of teachers use these possibilities to develop and broadcast Internet resources. The Geogebra1 community (Lavicza et al. 2010) gathers teachers and researchers all over the world, designing resources, organizing training sessions, conferences around this free dynamic geometry software. In France, the website of the Sesamath association offers various kinds of resources in mathematics, for grade 6 to 10; it records more than 1.3 million connexions each month. The association comprises around 70 members, who develop online interactive exercises and different kinds of software. Teachers work with the association members to write free online textbooks. A specific website, Sesaprof (figure 1), is devoted to Sesamath resources users. They can formulate their remarks, suggestions, or even inscribe themselves in design groups, using an online platform to develop new exercises.

Figure 1. .Sesaprof, a website for Sesamath resources users

Alongside teachers associations, groups gathering teachers and researchers also use digital networks to design resources. The National Centre for Excellence in the Teaching of Mathematics in UK is a noticeable example. The NCETM1 offers both resources and a sustainable national infrastructure for mathematics-specific Continuing Professional Development (CPD). The NCETM has reached nearly 60,000 registered users. Interestingly the numbers of users are increasing by approx 100 per day and users are staying longer suggesting more in depth interaction. Research works demonstrate that the NCETM impacts the way teachers work and interact together (Hoyles 2010). The NCETM provides and signposts resources to teachers and supports mathematics education networks, which can include universities and the whole range of CPD providers throughout England. At the same time, the National Centre encourages schools and colleges to learn from their own practice through collaboration among staff and by sharing good practice locally, regionally and nationally. These collaborations can take place face-to-face at national and regional events and in local network meetings, facilitated by a team of NCETM staff with expertise in different phases of education from primary to further education, spread across the nine regions of England, or virtually, through interactions on the NCETM portal. The NCTEM claims, on its website, that it provides “high quality” resources. This claim raises the issue of quality, for Internet resources for mathematics, and of the assessment of this quality.

1.2.2 Quality assessment

As mentioned above, in France the texbook market is free; there is no control of the validity of the textbooks content. Nevertheless, for digital resources, an official, national label exists (RIP, for Recognized of Pedagogical Interest). The quality of online resources seems to raise specific questions; this is a direct consequence of the new design modes evoked above, in particular the possibility fro any individual to publish resources.
Defining the quality of an online resource, for the teaching of mathematics, is not straightforward. Which criteria can guarantee this quality? The expertise of the authors can not intervene as criteria, or this would discard the new, bottom-up design possibilities. Quality criteria have to take into account the mathematical content, the didactical aspects, the ergonomic dimension (Trouche et al. to appear). Nevertheless, these dimensions do not ensure the ease of appropriation by the user (a resource that nobody uses can hardly be considered as a high-quality resource); at the same time, the number of users can not account as guaranteeing quality. Another question is: who will assess the quality? Once again, preserving the bottom-up design possibilities pleads for avoiding the assessment by experts, or by an institutional authority.
In the Intergeo project1, resources are offered on a platform, to support the use of dynamic geometry software (Kortenkamp et al., 2010). An important aspect of the project is the assessment of the quality of these resources (Trgalovà, Jahn, & Soury-Lavergne, 2010, p. 1162). Any registered user can propose a resource. This choice creates a large repertoire of resources, but makes at the same time the issue of quality assessment essential. In Intergeo, the main

tool for quality assessment is a questionnaire, fullfilled by the users. Given the aim of the Intergeo project, it focuses on the exploitation of the potential of the geometry software. The answers to the questionnaire are automatically collected and treated, and this treatment leads to a label (a number of stars) associated to the resource on the website.
The profusion of resources calls for quality assessment; but the new modes of design require new modes of quality assessment. An important part has to be played by the users, in the assessment of resources quality, in particular assessing the possibilities of appropriation of a resource requires to ask users.
These new phenomena indicate the need for specific research, on the topic of mathematics teachers resources, and their use. Moreover, the deep changes require a specific approach, both on a theoretical and on a methodological level; I present it in the next section.

2. Resources use and teachers professional development

2.1 Documentational approach: theory, and methodology

As mentionned above, I refer here to the conceptualisation of resources introduced by Adler (2000), focusing on the interactions between teachers and ressources intervening in their professional activity.
Our specific interest in digital resources also leads to consider research about technology. The interactions with technological tools, and their consequences for knowledge evolutions, have been extensively studied in the case of students using various kinds of software, on computers or calculators. These processes have been in particular conceptualized within the instrumental approach (Guin et al. 2005), grounded in cognitive ergonomics (Rabardel 1995). Rabardel distinguishes an artefact, available for a given user, and an instrument, which is developed by the user, starting from this artefact, in the course of his situated action. These development processes, the instrumental geneses, are grounded, for a given subject, in the appropriation and the transformation of the artefact, for a given class of situations, through a variety of usage contexts. Through this variety of contexts, utilisation schemes of the artefact are constituted.
A scheme (Vergnaud 1998) is an invariant organization of the activity, which comprises in particular rules of action, and is structured by operational invariants developed in the course of this targeted activity, in various contexts met for the same class of situations, and which pilot the activity. This definition can be represented by the equation: instrument = artefact+ scheme.
Combining these different theoretical references, we introduced (Gueudet & Trouche 2009) a distinction between available resources, and a document, developed by the teacher in the course of her interactions with these resources, for a given objective.
This perspective – the documentational approach- shares some features of the instrumental approach (but at the smae time, focuses much more on what is conceived by the teacher). The definition of a document can be represented by the equation: document = resources + scheme. The corresponding development process is called a documentational genesis. The geneses are long-term processes: schemes are developed across various contexts, encountered for a given class of situations. A class of situation, for a teacher, is a set of professional activities with a similar aim. For example, “preparing and setting up the introduction of functions”, “preparing and setting up applications exercises in algebra” are classes of situations, that the teacher encounters in different contexts (different classes, different years).
These geneses are naturally influenced by the institutional environment.

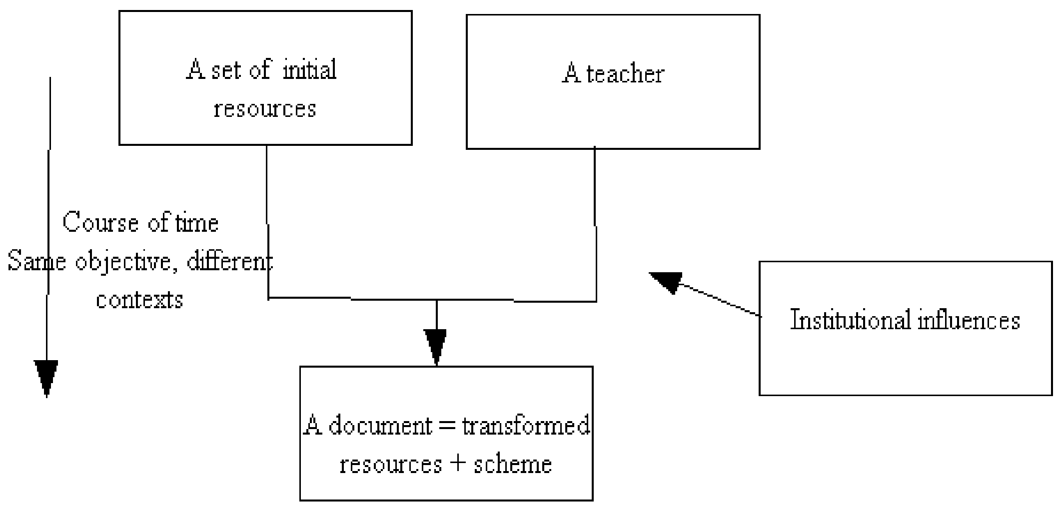

Figure 2. A documentational genesis

Resources intervene in all aspects of the teacher's work. What we call the documentation work: collecting resources, transforming them, setting them up in class etc. is central in the teachers professional activity. Thereof the documentational geneses hold a central place within teachers professional development. During their career, teachers constitute an evolving, and structured, system of resources; this system is associated with a system of documents (or documentation system), composed of the system of resources, associated with the corresponding professional knowledge.
The study of teachers documentation work requires a specific methodology. This documentation work happens indeed in many places, in-class and out-of-class, in school and out-of school; it involves different groups. The geneses are long-term processes, associating stabilities and evolutions; the teachers interact with multiple resources.
For this reason, we designed a methodology, entitled “reflexive investigation methodology” (Gueudet & Trouche 2012). The aim of this methodology is to follow, as completely as possible, a teacher's documentation work. This aim requires an active collaboration of the teacher followed: only the teacher herself has a complete access to her activity and resources.
For a given year, the follow-up lasts at least three weeks. During these three weeks:
the teachers fills in a logbook, describing her professional activity (in-class and out-of-class), the resources used and produced, the agents involved;
a lesson is observed and videotaped ;
interviews of the teacher by the researcher are organised;
during all the three weeks, the researcher collects as far as possible all the teachers' material resources: files, e-mails on the computer; written notes, students sheets etc.
To analyse these data, we associate quantitative and qualitative exploitation. We notice the different activities mentioned, and the time devoted to each activity; the resources intervening, the corresponding activities; the groups where the teacher is involved, the exchanges of resources with these groups. We present here a case study issued from a research project using this methodology.

2.2 A case study at primary school: integration of the virtual abacus

The aim of the research project where this study took place was to follow the integration of various software by primary school teachers, in their teaching of mathematics. In this particular case, the software involved was a virtual abacus. We followed its integration by Carlos, an experienced primary school teacher (Poisard, Bueno-Ravel & Gueudet 2011).

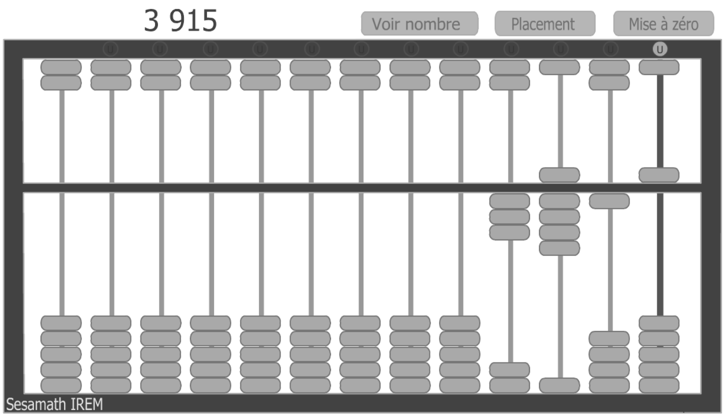

Figure 3. *The virtual abacus online, displaying 3915*

Carlos took part during two years to a research and development group, with five other colleagues and three researchers. Several resources were presented and discussed in the group; he retained the virtual abacus, and still uses it very regularly, mostly with grade 3 classes. Naturally, his participation in the group is an important factor, explaining his integration of the abacus. But other factors intervened as well: his resource system; the institutional incentives, and his professional knowledge about the teaching of numeration.
In his resource system, his usual textbook has been determining. This textbook proposes indeed an activity with material abacus. Carlos found interesting the mathematics content of this activity; but he was not able to organize it in class. Trying to use material abacus with his pupils, he observed that it was for him almost impossible to check whether they displayed the correct number or not: if a pupil touches the abacus, the beads move... On the virtual abacus (figure 3), there is no such risk. Moreover, the button “display the number” shows, in digits, the number represented by the

position of the beads.

The institutional conditions represent another important factor for this integration. In France at primary school, teachers have to assess skills regarding the use of the computer, and of Internet; they deliver to the pupils a certificate (labelled B2i1). Working with the virtual abacus in the computer lab provides Carlos with the opportunity of assessing some of these skills (starting a computer, opening a software etc.).

The virtual abacus articulates with Carlos' resources, and is consistent with institutional expectations. Nevertheless, these factors are not sufficient to explain its integration by Carlos: his professional knowledge also played a major role. This knowledge has several aspects: didactical knowledge, about the teaching and learning of numeration. The objective of working on “grouping and exchanging” (five lower beads against one upper, two upper beads on one rod against one lower bead on the rod on the left etc.) is central for him, since he noticed students' difficulties with the meaning of numbers' writing, along his teaching experience, and in particular while teaching division. Carlos also developed professional knowledge about organizing group work in the classroom; the computer lab has only eight computers, for 20 pupils, but this is not an obstacle for him. Carlos has also developed knowledge about introducing new tools in the classroom, and working on writing directions for use, with the calculator in particular. He introduces the abacus is class in a similar way: he first gives material abacus, then proposes a work in the computer lab, where the pupils have to discover how it works: the meaning of each bead, of the rods, and the role of the central beam. The class discusses different interpretations, before a collective writing of directions for use.

Following Carlos' work, we observed a genesis. Carlos developed a document, involving resources: the virtual abacus, but also the classroom textbook, the written directions for use... This document also comprises professional knowledge. The already existing knowledge guided Carlos' choices, in an instrumentalisation process; but the use of the virtual abacus also lead to the development by Carlos of new knowledge, about the abacus itself and its use, and about the teaching and learning of numeration.

The documentational approach can be used to study the work of individual teachers. It permits, as in in the case presented above, to follow their integration of specific resources. It also allows, more generally, a study of their professional development, via this focus on resources: resources evolutions, along the time, can be considered as indicators of professional evolutions. Moreover, the documentational approach can be used to study professional development within groups of teachers; we present it in the next section.

3.Collective documentation work and teacher education: example of the Pairform@nce program in France

The digital means permit new forms of teacher collaboration. Teachers' documentation work can be individual, or collective, when teachers work together to prepare a lesson, an exam text etc. Teachers communities of practice (Wenger 1998) in particular have shared repertoires of resources: the community resources system. In the context of teacher education, collective documentation work can be used with an objective of teacher professional development. We present here the example of a study about such a teachers education program, the Pairform@nce program in France.

3.1 Presentation of the Pairform@nce program

The program Pairform@nce (organised by the national ministry of education in France) offers in-service training paths, aiming to provide sustainable ICT integration for all school levels and all topics. These paths are templates for training programs, which might be implemented across the whole country. These training programs are a blend of face-to-face and distance learning. They are grounded in the collective design of lessons, by teams of trainees.

Figure 4. Pairform@nce, a training path on the national platform

There are thus three sets of actors in Pairform@nce: the trainees, following a training program; the trainers, setting up and managing the training; and the designers of the path which frames the training. Naturally, the students who take part in lessons designed by teachers following the training program are also important actors.
In the context of a design and research project , our team has designed several training paths, in particular a path about the use of "dynamic geometry for inquiry-based mathematics learning" (Soury-Lavergne et al. 2011). In France, the official curriculum for middle school suggests the use of inquiry in class. It also suggests the use of dynamic geometry software (DGS). Nevertheless, in class DGS is not much used and investigation is not often organised. The training path "Investigation with dynamic geometry at middle school" thus faces a double challenge.
The aim of the path is that the trainees design and test a lesson giving real responsibilities to the pupils, regarding the use of dynamic geometry, and regarding geometry itself. The training takes place over 13 weeks (excluding holidays); it comprises three face-to-face workshops of one day each. Between these face-to-face days, continuing work is done, using e-mail, and the distance training platform.
We have implemented this path in several training, and followed the work of the teams of trainees. We proposed questionnaires to the trainees, and followed moreover all their discussions, during the workshops in presence or on the platform.

3.2 Example, a team of trainees working with dynamic geometry

We consider that the elaboration of lessons by the teams belong to the trainees documentation work. Many resources, and professional knowledge, are involved in this work. We have selected here the work of a team of trainees, to illustrate the use of our theoretical frame, and to investigate the possible 'impact' of such a training, impact that we conceptualize in terms of geneses.
The team was composed of four teachers (Mary, Fanny, Clara and Georges), all of them teaching in different schools, but in the same city; they did not know each other before the beginning of the training. Each of them had grade 9 classes; they quickly decided, during the first workshop, that they will design a lesson for this level, all the more considering the fact that grade 9, students had laptops, borrowed for one year from the local authorities. These laptops were equipped with GeoGebra, thus the team picked this software for their lesson preparation.
The scenario they designed was concerning the "angle at the centre" theorem; its aim was to introduce two related results ("in a circle, the size of an inscribed angle is half of the size of the corresponding angle at the centre"; "in a circle, the angles subtended over the same arc are of the same size"). Two hours in class were dedicated to an inquiry based activity about these results. During the first hour, the students worked in pairs on the computer; during the second hour a synthesis of the obtained results was made, and the teacher wrote the theorems and proposed application exercises. For the first hour, the students had a worksheet to fill, and a GeoGebra file to complete (Figure 5); the mathematical situation was presented as a soccer training.

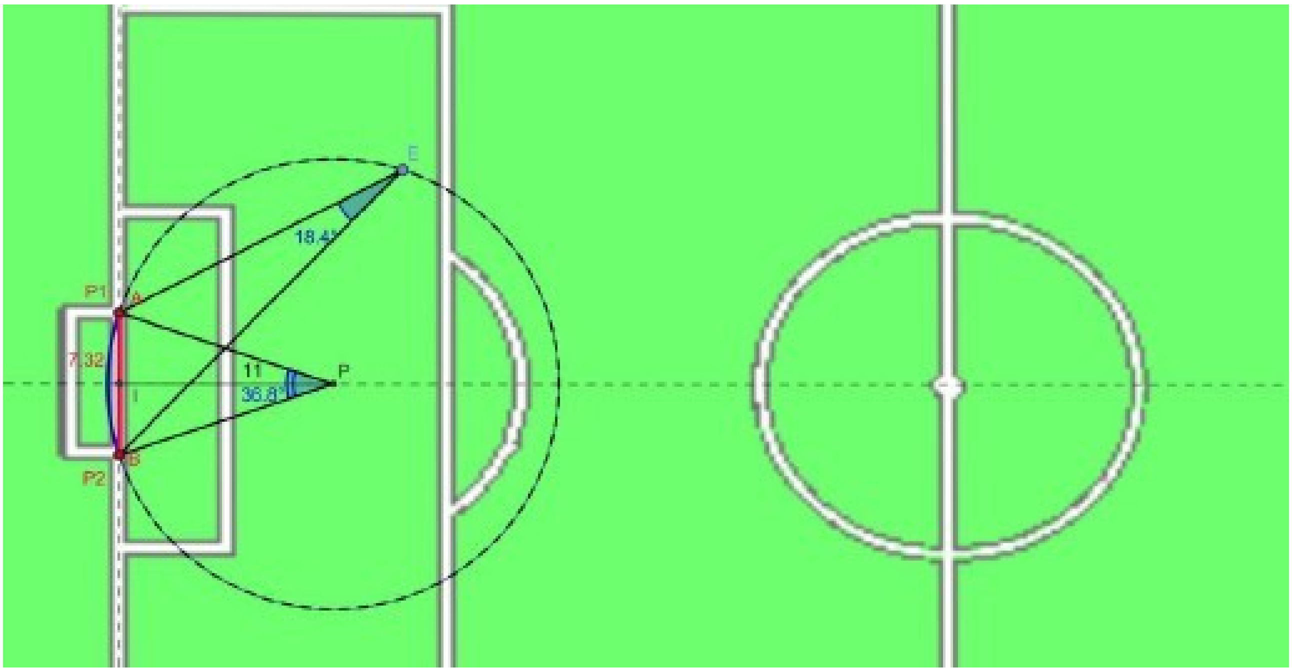

Figure 5. The GeoGebra file in team 1 activity. The points A, B and P were given, with fixed positions. Point E can move on an arc of circle, of extremities A and B.

On the GeoGebra file, the goal is represented by a segment [AB], and P is the point to shoot penalties. The students had to display the measure of the shooting angle, for a player placed on P. Then they had to build a point E, belonging to the arc of circle of centre P, with extremities A and B (and naturally on the field, outside of the goals). The size of the shooting angle, for a player placed on point E, should be displayed. E had to be dragged along the circle, and the students were supposed to observe the modification of the angles size, and to compare the size of both angles. All these successive steps have been described on a worksheet given to the students. This kind of student's activity, consisting in dragging a figure to observe invariant properties or measures is one of the most widespread use of dynamic geometry among teachers, although it has been shown that it does not take the best advantage of the dynamic geometry added-value for learning (Ruthven et al. 2005).

This lesson was the object of a first trial by Fanny in her class; Clara observed it and took notes. Clara wrote down some students difficulties (notes available on the platform): some with the GeoGebra figure, in particular a wrong construction of the circle; some with the vocabulary, for example "shooting angle" does not make sense for some students. After this observation, Clara proposed a sheet to the team with different written hints (eleven different hints, according to the difficulties encountered). She tried these hints in her own class; it turned out to be very complicated and difficult to choose the appropriate hint. Georges has observed this session, and has reported the difficulties to the group. During the third workshop, the team worked on a better choice of possible hints.

For this team, it was important to make the lesson part of the usual curriculum: these theorems had to be introduced, the "inquiry-based" lesson took place within the usual teaching. Several observations indicate that the members of the team seemed to consider of most importance to stay within the official curriculum objectives, even for inquiry. Questioned by the trainers about their choice, they have confirmed that they wanted to avoid loosing time, working on the computer, with an inquiry-based approach. This shared knowledge of the team has influenced the choice of theme for the lesson. We infer that, during the training, they started to develop a document for the class of situations "organising inquiry in geometry". This document has included resources (GeoGebra in particular), but also professional knowledge like "the official curriculum has to be completed, within a short time", and "the inquiry-with-ICT lessons must correspond to objectives of the usual teaching".

Another choice of the team was to start with a "real life" situation. It seemed especially important for Clara and Georges, according to the 'distant discussions' via the platform, or via email. Georges built the GeoGebra file to be given to the students. In one of his emails to the team (they preferred to use email than to write on the available forum on the platform), he declared:

"I have found a nice soccer field image, and I know how to insert it in GeoGebra!" and Clara answered with congratulations: it clearly indicates their will to make the situation looking as "real" as possible.

Clara also added comments on a first version of the student's sheet (uploaded on the platform), proposed by Mary for the "soccer situation". While Mary asked the students to write the size of "angle AMB, in degrees", Clara crossed this sentence out, and commented: "We discussed it and decided not to name the angles, to have a more concrete activity".

Indeed, on the final version of the students' sheet, the sentences were: "size of the shooting angle, if the player is on the penalty point" and "size of the shooting angle, if the player is on the circle". We interpret the corresponding process as follows. Clara and George had a shared conviction, about "real life" situation fostering inquiry. This conviction has influenced the team's choices. We do not claim that Mary and Fanny now share this conviction. But their use of the "soccer" lesson might lead them to develop it (perhaps not the first time they use it, but along several uses).
The choice of possible hints was also an important aspect of the team's documentation work. Clara's observation of Fanny's class leaded her to propose these hints. Clara's own trial of the "soccer" lesson occurred only a few days after Fanny's, and the members of the team did not have time to comment on the proposed hints before she used them; these hints were only discussed during the third workshop.
All the members of the team agreed about the idea of planning hints, in case that students would encounter difficulties. They seemed to share the conviction that: "for an inquiry lesson, the teacher must intervene when students encounter too much difficulties. But these interventions must be carefully prepared, to avoid saying too much about the answer". But they also said that eleven different hints were too much, and too difficult to manage for the teacher; so they started to make choices amongst Clara's propositions. In particular, the hints concerning the use of language, and the mathematical meaning of the everyday language were considered as important by all the members. Such hints were strongly connected with the previous choice of "real life" situations, which yielded a need for mathematical modelling, and the connected potential difficulties. We hypothesize that the document developed at the beginning by members of this team included operational invariants like "the mathematical interpretation of the non-mathematical language is difficult for students" and "the language difficulties have to be anticipated, while planning an inquiry-based lesson". This team also seemed to have developed an operational invariant that could be expressed as "an inquiry-based activity should start with a mathematical modelling".
Naturally, additional observation is required, to assert that this new knowledge influences the teachers practices, even after the end of the teacher education program. Research about teacher education, grounded in teacher collaboration (Jaworski 2008) often concern programs that last at least two years. We worked during a few months; the impact of such a short training is probably more limited.

4. Conclusion

Our aim, in this conference, was to give an overview of our work in progress. The deep changes in teachers work introduced by digitalization require a new theoretical perspective, for the study of this work and of its consequences for profesionnal development. We have presented this approach, and its use in two research projects. More examples, theoretical work, and other perspectives can be found in Gueudet, Pepin & Trouche 2012. The research field of teachers resources remains open; new directions are now investigated:
- About the resources themselves, their design, their analysis. Research in mathematics education does not, for the moment, provide accessible tools for reasearchers or teachers intending to analyze a mathematical website for example;
- About the use of resources, and the link between the authors intentions and the actual use by teachers, by students. This is a major issue for resources authors in particular;
- Only a few studies consider the use of resources by students -and none of it considers the use of websites by students, and its consequences in class, as far as we know.
These are only a few examples of possible research directions. Moreover, beyond research on resources, we consider more generally that research in mathematics education has to take into account more and more the resrouces aspect, whatever the research question is.

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