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# **Mathematics Teachers' Interaction with Digital Curriculum Resources: opportunities to develop teachers' mathematics-didactical design capacity**

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## **Abstract**

This particular paper reports on the investigation of (selected) French mathematics teachers' interactions with and use of a commonly used mathematics e-textbook (Sesamath), individually and collectively. Using three recent studies on teachers' work with Sesamath, and leaning on theoretical frames from the area of curriculum design and instructional design with technology, we identify several dimensions of "design", that is mathematics teachers working as designers. Moreover, we claim that the affordances of digital resources are related to the opportunities for "design" by mathematics teachers, of their own curriculum materials in/for instruction; and for the development of teachers' *mathematics-didactical design capacity*.

This paper is one of four in the AERA 2016 symposium on digital resources/curriculum materials, including e-textbooks, in mathematics education. The focus is on the resources' design and analysis; and teachers' and students' interaction with them. As digital resources are increasingly present in classrooms around the world, it is important to investigate their features, and in which ways they influence, afford, or indeed may transform, particular educational processes and practices. The underlying questions of the symposium are: What are the "new" digital curriculum resources, and what are the features of those resources, that influence mathematics teachers' instructional design? What are students' interactions and modes of engagement with those resources? In which ways do these resources stimulate new educational dynamics?

This particular paper reports on the investigation of (selected) French mathematics teachers' interactions with and use of a commonly used mathematics e-textbook, individually and collectively.

## **Introduction**

Internationally, much research in mathematics education has focused on teachers' interactions with and use of curriculum resources (Lloyd, Remillard, & Herbel-Eisenman, 2009; Pepin, Gueudet, & Trouche, 2013). At the same time, a shift from text-based to digital interactive school curriculum materials (Resnick, 2011) is providing teachers with more interactive materials, and hence has the potential to transform educational processes and bring about new educational dynamics (Pepin, Gueudet, Yerushalmy, Trouche & Chazan, 2015). These new resources are likely to allow for flexible use and multiple modes of engagement by teachers (Remillard, 2014). Moreover, there is evidence that the design, selection and implementation of e-resources are increasingly driven by practicing teachers (Gueudet, Pepin, Sabra, & Trouche, 2016), with an expanding market of resources available on the Internet. However, little is known about the impact of such shifts on mathematics teachers' work.

Whilst previously teachers were typically the "implementers" of curriculum materials, which had been developed by professional curriculum designers and mathematicians (typically working for the national ministries), now mathematics teachers have

become “designers”, or act as “partners” in the design of curriculum materials. This is often not only welcomed by teacher educators (i.e. those working in teacher education and professional development of teachers), but wished for, as it is recognized that when teachers interact with curriculum resources, they develop knowledge - individually when preparing their lessons, and collectively in professional development sessions and other interactions with their colleagues. Moreover, the collective dimension is an important aspect of teachers’ professional development and capacity building (e.g. Gueudet, Pepin & Trouche 2013; Jaworski, 2001; Krainer, 1993).

Our argument is that different resources, in particular digital resources including e-textbooks, offer incentives and enormous opportunities for mathematics teachers’ “design”, both individually and in collectives. Indeed, these resources might be the vehicle to develop what we named *mathematics-didactical design capacity*. However, how teachers take up these offers, and how they work as “designers”, is unclear.

In this study we investigate the following questions:

- 1- How do (selected) mathematics teachers interact with “new” digital curriculum resources?
- 2- Is there evidence that the “new” resources elicit different practices and engagement, in terms of “design practices”?
- 3- In which ways can we understand teachers’ interactions with digital resources in terms of “design”?

The research is based on (at least) three French studies:

- a- The investigation of Vera, as she engages with digital resources in the preparation of her teaching, and in her classroom instruction (see Pepin, Gueudet & Trouche, 2015- AERA 2015 presentation);
- b- A study of one French teacher’s, Valeria’s, work with Open Educational Resources in her mathematics teaching (by Gruson, Gueudet, Le Hénaff, & Lebaud, 2016);
- c- The study of the collective design processes of selected teachers of the Sesamath association of the design of a grade 10 e-textbook, more particularly the function chapter (see Gueudet, Pepin, Sabra, & Trouche, 2016).

### **Literature background/theoretical frames**

Mathematics teachers’ interaction with different resources has been theorized in various ways (e.g. Gueudet & Trouche, 2009; Pepin, Gueudet & Trouche, 2013; Remillard, 2005). What is clear from these theoretical frames is that such interaction is a participatory two-way process, of mutual adaptation, in which teachers are influenced by the resources (given that each resource has different affordances and constraints), and at the same time the design and use of the resources is influenced by the teachers. Making sense of, and using, classroom resources to design and enact instruction, adapting and appropriating the resources, places a demand on a specific teacher capacity: teachers enhance their *mathematics-didactical design capacity* (Pepin, 2015) - the capacity to utilize and transform existing curricular resources effectively, and to design/create new materials, for the purpose of effective mathematics instruction (Brown, 2009).

However, it is not clear what “design” means in this context, or indeed in which ways teachers act and work as “designers”. In a recent special issue of JMTE (see Pepin & Jones, 2016), we have problematized the notion of “teachers as partners in task design”. Moreover, in an earlier issue of ZDM (see Pepin, Gueudet, & Trouche 2013), we have argued that different processes are at stake in mathematics teachers’ work with curriculum resources, amongst them one or more of the following:

- In choosing tasks, the processes involved are likely to be ‘adoption’ (of, say, textbook tasks; see, for example, Ball & Cohen 1996) and/or ‘integration’ of the tasks (in the case of, say, digital technologies; see, for example, Ruthven & Hennessy 2002);
- Given teacher-task interaction is a two-way process, the process is one of ‘appropriation’ (Gueudet et al. 2012; Remillard et al. 2008);
- With the transformative potential of the teacher-task relationship, there are ‘educative’ curriculum materials (Davis & Krajcik 2005) that are intended to promote teacher learning (for example, materials which help teachers to develop pedagogical design capacity; see Brown, 2009).

In terms of “partnership”, Jones and Pepin (2016) refer to research works of Coburn Penuel and Geil (2013, p. 2) who refer to many different arrangements such as “consulting relationships”, “university-school partnerships”, “research projects”, to name but a few. More specific terms also currently in use include ‘research-practice partnerships’, defined by Coburn et al. (ibid), as “long-term, mutualistic collaborations between practitioners and researchers that are intentionally organized to investigate problems of practice and solutions for improving district outcomes”, and ‘design-based implementation research’, defined by Penuel, Fishman, Cheng, and Sabelli (2011, p. 311), which is said to include a commitment to “iterative, collaborative design” and a concern with “developing theory related to both classroom learning and implementation through systematic inquiry” and “developing capacity for sustaining change in systems”.

As well as such forms of partnership, notions such as ‘mathematics education as a design science’ (Wittmann, 1995), ‘teaching as design’ (Brown & Edelson, 2003), and the ‘teacher as designer’ (Maher, 1987) have gained attention – sometimes as a form of professional development such as ‘Teacher Design Research’ (TDR) (Bannan-Ritland, 2008). Applying the design metaphor to teaching is useful, Brown (2009 p. 23) explains, because it “calls attention to the constructive interplay that takes place during instruction between agent (teachers) and tools (curriculum materials)”. The European traditions of didactical research, in particular didactical engineering (Artigue 1994; Brousseau 1997), has contributed to regard the teacher as a “designer” or “didactical engineer”. Didactical design, in Ruthven et al.’s (2009, p. 329) words, is “the design of learning environments and teaching sequences informed by close analysis of the specific topic of concern and its framing within a particular subject area”. Moreover, Sensevy (2012) has developed the notion of collaborative didactical engineering where primary school teachers, teacher educators and researchers work together on didactical designs.

For this paper, we use notions of “design” from the web which define design as “the creation of a plan ...for the construction of an object or a system. ... In some cases the direct construction of an object (e.g. engineering) is also considered to be design. ... Thus "design" may be a substantive referring to a categorical abstraction of a

created thing or things (the design of something), or a verb for the process of creation, as is made clear by grammatical context.” (Wikipedia) Moreover, “instructional design” is defined as the practice of creating "instructional experiences which make the acquisition of knowledge and skill more efficient, effective, and appealing." (Wikipedia)

In terms of mathematics teachers as designers, we benefit from the literature on teacher involvement in designing technology enhanced learning (e.g. Kali, McKenney, & Sagy, 2015), which claims that whilst teachers clearly benefit from being involved in the design, “far less is known about shaping that involvement to yield those benefits” (p. 173). Indeed, they assert that “research is needed to understand how teachers learn through design; how teacher design activities may be supported; and how teacher involvement in design in various ways impacts the quality of the artifacts created, their implementation, and ultimately, student learning”. (p. 173, *ibid*)

Interestingly, Kirschner (2015) links teachers’ developing competences for instructional designing for technology-enhanced learning (TEL) to basic competence development, those of other/all professionals, i.e. by “gathering information”; “analyse and diagnose”; “determine actions”; “carry out actions”; and “evaluate”, in other words “designing”. He considers that these are the core features of any professional development (in any profession), and that the added aspect of TEL should not be regarded as a “new” paradigm. Indeed, he insists “ teachers are designers - of all learning, including TEL” (p. 320). Considering teachers working in collectives, Voogt and colleagues (2015) argue that, whilst it is assumed that the activities teachers undertake during collaborative (TEL) design of curricular materials can be beneficial for teacher learning, there seems to be a scarcity of research studies in this field.

### **The three studies**

In this section we present (1) the context of Sesamath; (2) an overview of the research designs and data collection strategies of the three studies; and (3) a presentation of each study’s research questions and their results/findings with respect to (a) teachers working with the Sesamath e-textbook and other digital resources; and (b) teachers as designers.

#### *(1) The context of Sesamath*

The context consisted of the French teacher association Sesamath. Typically, in France, textbooks as well as e-textbooks, are designed by small teams of authors (four to six people) involving teacher educators and/or inspectors; and they are produced and sold by commercial publishers. The case of the e-textbooks designed by the Sésamath association is very different, mainly due to their authorship, as Sésamath is a French association of practising mathematics teachers (mainly from middle schools). It has been created in 2001, and one of its goals has been to “freely distribute resources for mathematics teaching”. Today Sesamath has 70 subscribers, overseen by a board (of about 10 teachers). Its website receives about one million visits each month. The main reason for its success appears to be the object of its activity: designing resources with/for teachers. Sésamath provides a repertoire of teaching resources: online exercises (Mathenpoche (MeP) standing for “mathematics

in the pocket”); textbooks; a dynamic geometry system (TracenPoche, standing for “drawing in the pocket”); simulation geometry instruments/applets, etc. Sésamath also developed LaboMEP, a Virtual Learning Environment encompassing all these resources and designed for teacher-student communication. All Sésamath resources are designed by groups of teachers working collaboratively (for example, on a textbook section) on a distant platform.

*(2) Research design/s and data collection strategies of the three studies*

All three studies used the documentational approach of didactics (DAD; Gueudet & Trouche, 2009; Gueudet, Pepin, & Trouche 2012; see also study 2) to investigate French mathematics teachers’ work (at lower secondary level) (1) with the schools’ chosen e-textbook, Sésamath, (in the case of study 1); (2) with Sesamath plus other Open Educational Resources (OERs) (in the case of study 2); and (3) in terms of studying a selected groups’ design of a particular chapter (functions) of the e-textbook. Study 2 and 3 also used Cultural-Historical Activity Theory (CHAT, Engeström, 2001), as conceptual frames for understanding the processes of activities.

DAD typically includes a reflective investigation methodology, and analyses of data with respect to: (1) all resources used/observed/mentioned; (2) teachers’ stated aims of activities (for resources used); (3) observed actions with resources; (4) teacher stated beliefs (with respect to their use of the resource/s); (5) stated and observed patterns of use/change.

Data sources of studies 1 and 2 included (1) video-recorded lesson observations; (2) teacher interviews concerning their use of the e-textbook resources/OERs for (a) lesson preparation; (b) instruction; and (c) assessment; and (3) teacher log books and schematic representations of the teacher’s resource system (SRRS- see Gueudet, Pepin & Trouche 2013). The folder “Vera’s lesson cycle” (study 1) contains videos of four moments: *preparing; enacting; evaluating; reflecting*.

Moreover, in study 2, for the case of a mathematics teacher (Valeria), the following data were collected:

- General data: a questionnaire about the teacher’s profile; a general interview on the teacher’s resources; a drawing, representing the teachers’ resource system (SRRS- see Gueudet, Pepin & Trouche, 2013).
- Data concerning a specific teaching unit: video of the preparation of a lesson; video of the lesson, interview after the lesson; logbook filled by the teacher during the lesson; the main resources are collected.

To analyze these data, the interviews were analysed with respect to the following themes: the different goals of the teacher’s activity; the resources used for each of these goals; how these resources were used; and which beliefs justify this use. Further, for this paper the focus was on the teacher’s activity concerning a given theme. Drawing on Chevallard (2006), four main moments in the teaching activity were considered: Exploration and Discovery; Course and Synthesis; Drill and Practice; and Assessment.

As mentioned earlier, Study 3 used both DAD and CHAT, as this combination appeared to be helpful for the analysis at Micro level (DAD), as well as at Macro

level (CHAT), when the processes at stake were those of the collective design of an e-textbook (Sesamath). The e-textbook development team (named here e-textcom) was followed from June 2009 to December 2013, during which time several types of data were collected. For study 3 the following data have been used:

- Web-based discussions strings, using one of the community's 'working tools': a mailing list; and the resources platform;
- The resources/materials offered by the members on the mailing list and platform, as well as the resources designed during the community's documentation work.

These discussions and resources/materials permitted the researchers to describe elements of the community activity system: its object; the division of labour; and the resources used. In order to identify potential documental geneses (see Gueudet & Trouche 2012), and also rules shared by the community, expressions of professional beliefs, most of them related to specific mathematical content, were retained from the discussion, and subsequently linked to personal resources, which the participant might have shared with the community. Subsequently, the content of these resources was then compared with the belief/s expressed. The identification of a belief matching the content of one or several resources was interpreted as evidence for the existence of an individual document. Discussions were followed further, in order to observe possible evolutions of teachers' belief/s, or whether they converged towards shared beliefs of the community – this was then interpreted as rules of the activity system. These beliefs were then compared with the commonly designed resources, to evidence (or not) the existence of shared documents.

### ***(3a) Study 1***

(see Pepin, Gueudet, and Trouche, AERA 2015)

In this study the researchers investigated one case teacher's (Vera) interaction with the French mathematics e-textbook Sesamath, drawing on the documental approach of didactics (Gueudet & Trouche, 2009; Gueudet, Pepin, & Trouche, 2012). Assuming that e-textbooks belong to new modes of design, her interactions were linked to the characteristics of the e-textbook, showing the different ways in which Vera used the e-textbook for her lesson preparations and the enactment of her percentage lessons (at grade 8). Moreover, particular attention was paid to the interplay between the e-textbook, the teacher and her grade 8 students, focusing on individualised work.

The research questions were the following:

- 1- What are the characteristics of the Sesamath e-textbook, how has it been developed over the years, and how is it different (or similar) to other commonly used traditional French textbooks?
- 2- How does Vera use Sesamath, inside and outside her mathematics classroom?
- 3- How can we conceptualise teachers' use of/interactions with e-textbooks (such as Sesamath); and what does that mean for methodological considerations in terms of teachers' work with e-textbooks (and the analysis of e-textbooks themselves)?

In terms of practical considerations, it was clear from the findings that there were many potential advantages to digital interactive textbooks. In the case of Sesamath, it

has now taken 20% of the French mathematics textbook market, possibly because it is of lower cost. It appears to make it easier for teachers to monitor student progress (through its associated resources), and the e-textbook is regularly updated (and cheaper to update) when required. In addition, it gave individual teachers, such as Vera, opportunities to create their own resources, individualised for their students, and or specific classes. It appeared that the interactivity of Sesamath afforded maximum flexibility (at least for Vera), for example in terms of the following:

- exercises were easily useable (and printable) in class: projection on IWB;
- differentiated exercises were provided according to the curriculum requirements;
- exercises were easily correctable in class: e.g. animated corrections;
- mathenpoche (and LaboMEP) allowed for providing homework (and holiday) exercises according to pupils' individual needs;
- LaboMEP allowed for individual follow up.

Furthermore, Vera could use the interactive character of the book to provide homework exercises in mathenpoche, and she could individually attend to pupils' work (at home and during holidays) with the help of LaboMEP - these were the useful tools she took from the e-textbooks. However, there were also uncertainties that arose: due to Wikipedia-style changes that were occasionally administered by the Sesamath author board, changes could occur any time; and particular exercises may have been changed, or removed, when Vera prepared her lessons. This called for improvisation and in-the-moment decision making, as Vera tried to manage unanticipated changes in the e-textbook, whilst also steering student progression toward academically important (perceived by her and demanded-by-the curriculum) learning goals. This was particularly notable, when she enacted her prepared lesson in a 'dialogic' and 'student-centered' way.

For mathematics teachers like Vera, Sesamath (or any other interactive textbook) is only one "brick" in their large resource system. To navigate through this large resource system, with many books (hard copy and e-textbooks) and an abundance of digital curriculum materials available, particular knowledge, experience and professional dispositions/beliefs are likely to play a critical role. In the resource system of Vera Sesamath played a crucial role, due to its flexibility of use – this made Vera a creative user of the curriculum resource.

In summary, it was argued that the e-textbook, or parts of it, became a useful tool for enacting and assessing particular differentiated textbook activities that could meet the needs of different learners in Vera's class. At the same time Vera used the e-textbook to create her own digital course material. Indeed, Vera proposed changes to selected content of the e-textbook, and hence became part of the authorship herself. Comparing these results with the literature, it became clear that the different, and 'dynamic', nature of e-textbooks not only provides opportunities for teachers, but also requires teachers to take more agency in selecting, designing and re-designing their curriculum resources. Hence, there is evidence that this 'differentness' offers challenges, in particular for inexperienced teachers who may expect the textbook to provide defined learning trajectories and progressions, and it is argued that the processes necessary to usefully work with interactive e-textbooks, and their associated resources, offer new opportunities for professional learning: learning to teach "with (and not by) the book".

### ***(3b) Study 2***



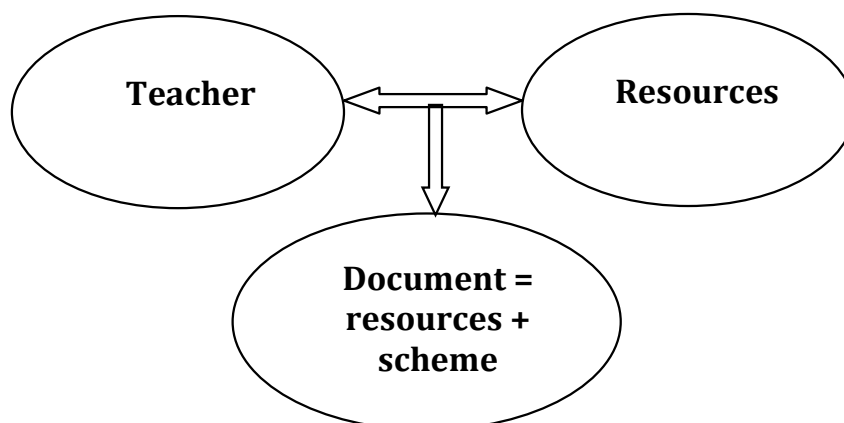
(see Gruson, B, Gueudet, G., Le Hénaff, C., and Lebaud, M.P., submitted)

Drawing on the guiding principles of *activity theory* (Vygotsky, 1978), this study considers that a subject, in this case a teacher, is engaged in a goal-directed activity: for example, preparing the text of an assessment for a grade 10 class about functions. For this goal, the teacher interacts with a variety of artifacts. These artifacts can be modified by him/her: according to his/her precise goal, the teacher can delete parts of the artifact, complete it, combine several artifacts etc. At the same time, the artifact influences the teacher's choices and can even lead to evolutions in the object of the activity. Rabardel (2002/1995) introduced the *instrumentation theory*, considering that along his/her use of an artifact in a goal-directed activity, a subject develops a mixed entity: an instrument, composed by the artefact and schemes of use of this artefact (Vergnaud,1998), where a scheme is a stable organization of the activity. It has several components: the aim of the activity (with possible sub-aims); rules of action; operational invariants, which can be concept-in-action or theorems –in-action. A concept-in-action is a concept considered as relevant; a theorem-in-action is a statement considered as true.

The instrumentation theory has been used in many research works concerning the use of software at school, mainly by students (see e. g. Guin, Ruthven & Trouche, 2005). The evolution of teachers' working contexts evoked above lead us to develop a specific theoretical approach, the *documentational approach of didactics* (Gueudet & Trouche, 2009; Gueudet, Pepin & Trouche, 2012), drawing on instrumentation theory and prolonging it.

Instead of focusing on “artifacts”, a more general notion of resource is used, following Adler (2000, p. 207) who suggests that “it is possible to think about resource as the verb re-source, to source again or differently”. A teacher engaged in a goal-directed activity interacts with resources of various kinds: textbooks, students' productions, software, e-mails exchanged with colleagues etc. He/she transforms these resources, sets them up in class with students etc. The outcome of the process is not only the recombined resources, but also the uses associated with these resources, and professional knowledge. The outcome is given the term “document”, coming from documentation engineering (Pédauque, 2006). In this field, a document is associated with a precise use. Within the documentational approach, we consider that along his/her use of resources, the teacher develops a *document*, combining resources and a scheme of didactic use of these resources (Vergnaud, 1998). The operational invariants (concepts-in-action and theorems-in-action, see above) are in this case professional beliefs (Rezat, 2010).

This process, called a documentational genesis, can be illustrated by the figure below (figure 1).



**Figure 1.** A documentational genesis

The documentational approach has been used to study documents developed by teachers at various levels, from primary to higher education. Most of the studies concern mathematics teachers at secondary school. They have evidenced that a teacher develops many documents, along his/her work, which are organized according to his/her activity. The structured set of these documents composes the teacher's *documentation system*. The documentation system comprises resources – which constitute the teacher's *resource system* - and schemes of use of these resources.

Using the theory presented above, research questions are the following:

- What kinds of OERs are present in the teachers' resource systems?
- What is the design work of the teacher with these OERs: How are these resources searched for, chosen; are they modified, associated with others? Which documents, incorporating OERs, are developed by the teacher?

These questions were investigated through case studies in two academic subjects: English and Mathematics. In this paper, only the mathematics case is reported on, the case of Valeria. The methodological stance used in the documentational approach is that of “reflexive investigation” (of the documentation system of a teacher) (see also Gueudet, Pepin, & Trouche, 2013).

Valeria is an experienced teacher; in her school she intervenes often as tutor for beginning teachers, and she regularly participates in in-service professional development projects (as a trainee). We observed two main kinds of OERs present in Valeria's resource system:

- (1) The first is LaboMEP, the virtual environment designed by the Sesamath association. Valeria uses it for a specific objective: at the beginning of a new chapter, for her grade 10 class, she programs interactive exercises from grade 9. Indeed she observed along the years that the students in grade 10 have very heterogeneous knowledge from grade 9 (they come from many different lower secondary schools). Programming these exercises in LaboMEP allows her to propose out-of-class work, that the students can do at their own pace; she has access to their results, and propose additional work if needed. In this case the OER, LaboMEP, which can be viewed as a e-textbook of the “toolkit” type (Pepin, Gueudet, Yerushalmy, Chazan, Trouche 2015), is used by the teacher because it permits to reach a particular objective: managing the heterogeneity of the students at the beginning of a new chapter. In this case, design means choosing the appropriate exercises on a large basis offered in LaboMEP. But she does not modify these interactive exercises.
- (2) The second kind are “introductory activities” (problems for discovering a notion) available on institutional repositories. At the beginning of a chapter, Valeria designs an introductory activity. She searches such activities in 3 or 4 textbooks (on paper), and on the web. She searches the web by typing her precise teaching objective: here, “variation of functions”. She obtains a list of

links, and chooses the institutional websites (from the ministry, or from the local authorities). She chooses 2 or 3 possible activities, prints them and compares them with the content of the textbook. This initial choice is a very important aspect of her design work: she has precise mathematical objectives. When we observed her, for the introduction of variations of functions, her choice was driven by a conviction: “a dynamic representation is useful to support the understanding of variations”. Because of this conviction, she retained one of the activities proposed on the web, because it incorporated a ready-made GeoGebra file. She modified the text of the problem, to use formulations and representations more familiar for her students.

We claim that Valeria has a high mathematics-didactical design capacity, which she developed during years of teaching. The interactions with resources, in particular digital resources played an important role in this development. LaboMEP supported the development of her professional ability to design teaching material to manage heterogeneity. The resources offered in institutional websites supported her ability to design introductory activities, in particular introductory activities using dynamic representations.

### ***(3c) Study 3***

(see Gueudet, Pepin, Sabra, & Trouche, 2015)

In this study the authors report on an investigation of the design/re-design processes of a grade 10 e-textbook by a self-organised and dynamic group of teachers, within the French teacher association Sésamath. Hence, the object of the study was the French Sésamath teacher association and its design of a Grade 10 e-textbook, more precisely the design of the 'functions' chapter. Cultural-Historical Activity Theory – CHAT (Engeström, 2001) and the Documentational Approach to Didactics (Gueudet & Trouche, 2009; Gueudet, Pepin, & Trouche, 2012) were used in order to study the following research questions:

- (1) What are the design processes attached to the Sésamath e-textbook?
- (2) Which are the factors shaping the choices of the teachers for the mathematical content of the e-textbook, and the structure of this content?
- (3) Which are the consequences of the design, in terms of evolutions of the community of authors?

The study focused in particular on moments of change, that is at a time when Sésamath published ‘dynamic’-type e-textbooks (in 2009): the text was available both online as a set of webpages; in a downloadable format (under a pdf, but also an odt format, allowing teachers to make modifications); and in hard copy. The digital textbooks (corresponding to a digital version of traditional paper textbook, in terms of content and structure) were accompanied by related animations on line: a set of MeP exercises, and extra exercises integrated in each chapter. After having successively published these dynamic e- textbooks for grade 7 (2006), grade 8 (2007), grade 9 (2008), and finally grade 6 (2009), Sésamath decided to design an e-textbook for grade 10 (first grade of upper secondary school). For that they gathered a group of members (evolving over time), here called e-textcom (standing for e-textbook community) for this purpose. This e-textbook, so it was planned, should correspond, in structure, to a “toolkit” collaboratively designed.

In terms of research design, data collection strategies and analysis, a case study approach (leaning on Yin, 2003) was used. The work of e-textcom was followed from June 2009 to December 2013, and the following data were used for analysis:

- Web-based discussions strings, using one of the community's 'working tools': a mailing list; and the resources platform;
- The resources/materials offered by the members on the mailing list and platform, as well as the resources designed during the community's documentation work.

These discussions and resources/materials permitted the research team to describe elements of the community activity system: its object; the division of labour; and the resources used. In order to identify potential documentational geneses, and also rules shared by the community, expressions of professional beliefs were retained, most of them related to specific mathematical content, from the discussion. When a given member expressed an opinion/belief, this was, if possible, linked to his/her personal resources, which s/he had shared with the community and compared the content of these resources with the belief expressed. The identification of a belief matching the content of one or several resources was interpreted as evidence for the existence of an individual document. Following on the discussion, potential evolutions of the belief/s could be observed, or whether teachers converged towards shared beliefs of the community – this was then interpreted as rules of the activity system. These beliefs were then compared with the commonly designed resources, to evidence (or not) the existence of shared documents.

In terms of results, three moments of change could be identified:

- (1) In the first moment there appeared to be a perceived need for negotiating the basic elements of a chapter and their progression: “from *bricks* to *atoms*, and from *atoms* to *kernels*”.
- (2) In the second moment the team expanded (to include IT developers) tried to design interactive resources: didactical reflection about dynamic visualisations.
- (3) In the third moment there appeared to be a need for negotiating the 'progression' (learning trajectory through the function chapter): from the organisation of *kernels* to the organisation of chapters.

The questions we studied here concerned the design processes, when a group of teachers collectively designs an e-textbook, more precisely the factors shaping the choices of content and structure; and the consequences of this design for the community. In terms of results we distinguished between (1) micro, and (2) macro level analysis, and have used different theoretical perspectives to develop deeper understandings at each:

- (1) At the micro level (using the documentational approach) we observed that the documentation systems of the e-textcom members had an important influence on the documents that were collectively developed, whilst the aim of these documents was similar. This happened during the first and the third moment: During the first moment, the teachers were aware of new possibilities offered by technology, and were willing to build a “toolkit”, which could help users to build multiple different

pathways through the topic area. Nevertheless, their own documents were far from this potential structure. Moreover, the content of their documents was also a consequence of the mathematical content itself: mathematics was not perceived as a set of bricks that could be arranged in any order. Different possibilities existed, but the notion of kernel emerged after a few months of discussion.

During the third moment, (when potential progressions were discussed) the collective design of a particular progression can be viewed as a result of the negotiation between the different members (each holding particular views on their individual choices), and the digital means did not open up new possibilities.

During the second moment, the teachers worked on the design of interactive exercises. Here the individual documents were less influential, since the object of the activity was entirely new, completely different from the usual documents of the teachers. They developed along this documentation work a collective document associating resources: dynamic mathematical text and representations, and a scheme incorporating new beliefs about the potential of dynamic representations for the teaching and learning of functions.

(2) At Macro level CHAT was used (e.g. division of labour etc.) to analyse the processes observed in then development of then documents. This highlighted the complex processes of collective documentational genesis. During the first moment, a tension occurred in the activity system between the object of the activity “designing a ‘toolkit’ type textbook”, and a belief shared by the members: “not all paths are relevant”. This tension was central in the documentational genesis: it led to the shared definition of kernels, and to the development of attached professional beliefs and rules of actions. During the second moment, another kind of collective genesis took place in the community. The object of the activity was not present in the members’ usual practice; previously shared beliefs and new beliefs combined, for the development of a common document, without tensions. During the third moment, we observed again a tension, occurring this time between the different beliefs of the members. Each teacher member of e-textcom has his/her own document for a progression on functions; during the discussion, a consensus was reached and all the different beliefs were respected.

In summary, and concerning the design processes of the Sesamth e-textbook (of a particular chapter), it appeared that, whilst there were ‘disruptions’ and advances due to technological innovations (i.e. interactive exercises), the initial ideas proved unattainable and the final design showed more continuity (of previous designs) than expected. The Sésamath teachers designing the e-textbook brought with them their own convictions of what was important for the learning of ‘functions’ (in terms of concepts) and how functions should be learnt. Whilst the technology could help them to introduce some structures in more flexible ways, the structures themselves were nevertheless shaped by teachers’ views of the mathematics and its teaching / learning. Several paths were possible for the teaching of ‘functions’; but offering several paths in the same textbook, even with digital means, proved to be difficult. Hence, we argue that whilst e- textbooks have the potential to fundamentally change mathematics teachers’ work, the revolution depends on didactical (and human) perceptions of the design.

## Discussion of results & Conclusions

In this paper we report on an analysis of three studies of teachers' work with Sesamath, a French e-textbook. We used the notion of "teacher/s as designer/s" to elicit (a) how teachers work with digital resources; and (b) in which ways digital resources and e-textbook/s provide suitable opportunities for mathematics teachers to develop their mathematics-didactical design capacities.

Moreover, we want to develop a conceptual framework, based on ideas of "design", for developing a deeper understanding of "mathematics teachers as designers", to analyse, and potentially enhance, design approaches in practice. For this we lean on work in curriculum design (i.e. "curricular spiders' web" by Van den Akker, 2003). Looking across the three cases analysed, the findings show that teachers' work with digital resources can be regarded in terms of interrelated dimensions of "designing":

- (1) Why are teachers designing? (e.g. dissatisfaction with textbook; to become less dependent on the textbook; to make teaching more varied)
- (2) What are their aims and goals? (e.g. to prepare a series of exemplary lessons for particular topic areas)
- (3) What is the audience? (e.g. fellow teachers; oneself; teachers nationwide; students)
- (4) What are they designing? (e.g. assessment questions)
- (5) How are they designing? (e.g. design approaches, sequences, strategies, styles)
- (6) What are the resources and tools used for the design task? (e.g. resources used)
- (7) With whom are they designing? (e.g. in a group, or individually; team membership)
- (8) Where are they designing? (e.g. in school, local pub, on the internet- the design environment)
- (9) When are they designing? (e.g. how long does the design take, which elements take most/least time)
- (10) How is the design evaluated (e.g. expert appraisal; peer appraisal; observation/interviews of/with users; assessing learning results)

Dimensions of design	Evidence in the studies	Which study
Why are they designing?	Dissatisfaction with current tasks & development of additional (better) tasks	S1, S2
	Provision of resources for peers/teachers; "philosophical reasons" to be found in the "charter" of Sesamath (e.g. mastering their own resources, mathematics for all, sharing for enriching)	S3
Aims and goals?	Development of an	S3

	<p>interactive e-textbook allowing teachers to adapt rather than adopt (e.g. reorganizing kernels)</p> <p>Development of learning progressions (“lesson plans” &amp; text to be delivered to students -via a beamer: “written trace”)</p>	S1
What is the audience?	<p>Teachers themselves &amp; their students (+ teacher colleagues, in Vera’s case)</p> <p>Fellow teachers, potentially every mathematics teacher</p>	S1, S2 S3
What are they designing?	<p>Chapter on functions</p> <p>Lesson on percentages</p> <p>Preparation and implementation of an introductory problem for variation of functions</p>	S3 S1 S2
How are they designing?	<p>Joint formulation of kernels for learning progression (e.g. “from atoms to kernels”)</p> <p>Selection and adaptation of existing OERs</p>	S3 S2
What are the materials and resources used for the design?	<p>National curriculum &amp; national teacher guide &amp; their knowledge of different textbooks &amp; content of the whole Sesamath resource system</p> <p>Internet Browser &amp; National repository “Eduscol” &amp; Institutional websites &amp; Textbooks (6-7 different) Sometimes: e-mails with colleagues; software (e.g. Geogebra) and video projector Students’ sheets LaboMep</p>	S3 S2

	Utilisation of LaboMEP for individualised teaching; and particularly for following individual pupils' work +& previous crucial resources (e.g. Vera's "bible")	S1
With whom are they designing?	Textcom group (selected Sesamath members) & the support of the Sesamath board  Mostly the teacher on her own, occasionally with colleagues	S3  S1, S2
Where are they designing?	On the web/virtual environment, without any face to face meeting (or very rarely)  At home or in school	S3  S1, S2
When are they designing; how much time is spent on it?	One week before the lesson: around one hour of preparation for each hour in class.  From 2009 to 2013: teachers needed an ongoing commitment to a "collective affair"	S2  S3
How is the design evaluated?	By the teacher herself based on knowledge of National Curriculum and inspectors' advice  By fellow/expert Sesamath colleagues & teacher trials in their classrooms The idea that a book is only a "current version" of something to be developed; continuous improvement by Sesamath members	S1, S2  S3

From our three studies it is clear that mathematics teachers' "design" has many different facets, amongst them the following:



- there are different rationales why teachers may design, or partake in design work;
- the aims and goals are likely to be different, and the content to be designed;
- the audiences are different;
- the ways of designing may be different, and the tools used for the design;
- when and where the design takes place may be different; and
- the evaluation of the design is likely to be different.

It appears that there are several dimensions, which can be identified:

- (1) an *individual-collective* dimension: In studies 1 and 2 individual teachers designed at first glance (in their individual lesson preparations), but they were also involved in collective design (“at a distance”) with the Sesamath community. In study 3 a collective designer group had been established from the start.
- (2) A “narrow to broad” *audience* dimension: the continuum ranged from personal use, *designer for/in personal instruction*, (i.e. study 1 and 2), to *designer/s for the public community* (i.e. study 3: Sesamath e-textbook/chapter designers). However, in the case of Sesamath these two extremes often become blurred when teachers developed materials “at home” and sent in their suggestions for change (of the particular chapter/tasks/activity), which subsequently got implemented (wikipedia approach- “dynamic balance” in terms of systems thinking).
- (3) An *approach* dimension (see Visscher-Voerman & Gustafson (2004) for an overview of various design approaches): ranging from a communicative/deliberate approach (e.g. ‘platform of ideas’, like with Sesamath); to linear/systematic approach (e.g. from national curriculum to textbook design); to ‘artistic’ approach (e.g. “beauty” in the eyes of ‘connoisseurs’).
- (4) *Quality assurance* dimension: ranging from “teacher assessment” (e.g. S1 and S2), to collective assessment (e.g. in the case of the Sesamath association), to expert assessment (e.g. other textbooks authored by inspectors or experts).

This study adds to knowledge in terms of (1) teachers’ interactions with/use of digital curriculum materials: it provides evidence that particular digital resources place particular demands on teachers’ work; and that particular resources’ affordances change teachers’ engagement with the resource and their curricular practice, and offer more (or less) opportunities for collective work. Moreover, it is claimed (2) that the affordances of digital resources also relate to the opportunities for “design” by mathematics teachers, of their own curriculum materials in/for instruction; and for the development of teachers’ *mathematics-didactical design capacity* (Pepin, 2015).

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