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STUDYING TEACHER COLLABORATION WITH THE DOCUMENTATIONAL APPROACH: FROM SHARED RESOURCE TO COMMON SCHEMES?

Birgit Pepin

Eindhoven University of Technology
b.e.u.pepin@tue.nl

Ghislaine Gueudet

CREAD, ESPE de Bretagne, UBO
Ghislaine.Gueudet@espe-bretagne.fr

In this theoretical contribution we discuss in which ways the Documentational Approach to Didactics, more particularly ‘schemes’, contribute to our understandings of mathematics teacher collaboration when they interact with (digital) curriculum resources, and of the outcomes of such interactions. We analyze three studies of mathematics teacher collaboration and interaction with resources through the lens of ‘scheme/s’. We contend that whilst theoretically we anticipated the existence of collective schemes, from our three studies we could not detect any regularity in the mobility of the same operational invariants. However, we can claim that the move from teachers’ individual to agreed shared schemes had, in turn, influenced and modified their individual schemes, and hence enhanced their professional learning.

The contribution we present here concerns Theme A of the ICMI study: “Theoretical perspectives on studying mathematics teacher collaboration”. We focus on the Documentational Approach to Didactics (DAD; Trouche, Gueudet & Pepin 2019), more particularly the notion of *scheme/s* (Vergnaud 1998), which has been used in several studies of mathematics teachers’ (and students’) collective work. The question we study here is linked with the two first questions proposed under Theme A (i.e. How do the different theoretical perspectives enhance understanding of the processes of teacher collaboration?; How do they enhance understanding of the outcomes of teacher collaboration?), and is formulated as: “How does DAD, in particular the notion of *scheme*, enhance our understanding of teacher collaboration and its outcomes?” We claim that within DAD, the concept of *scheme* is central for such understanding.

In what follows, we first recall the main elements of DAD, in particular the distinction between *resource* and *document*, the two interrelated processes of *instrumentation* and *instrumentalization* (Rabardel 2002), and we present in detail the perspective on teacher activity and teacher learning provided by *schemes* (Vergnaud 1998). Second, we draw on selected previous studies to evidence what we have learnt about teacher collective work and its outcomes, by drawing on DAD and schemes. In particular, we are interested in identifying individual and collective documents stemming from this work. Third, we discuss our theoretical results and their implications for further research perspectives, in terms of theory and of empirical studies.

Teacher collective work: the DAD theoretical perspective

DAD focuses on the interactions between teachers and resources, and on the consequences of these interactions. The definition of *resources* within DAD comes from the work of Adler (2000), considering as a resource anything likely to “re-source the teacher’s practice”. While Adler emphasizes the importance of “human resources”, for this study we propose to study resources (outside the teacher) shared within various groups involving teachers (Pepin & Gueudet 2018). Drawing on the instrumental approach (Rabardel 2002) which proposes a distinction between artefact

and instrument, DAD makes a distinction between *resource* and *document*. It considers that a given subject, engaged in a goal-directed activity, develops a document from a set of resources, associating recombined resources and a scheme of use (Vergnaud 1998) for these resources.

$$\text{Document} = \text{Resource} + \text{Scheme (for a particular goal)}$$

The process is called *documentational genesis*. Since we consider the interactions between teachers and resources within collectives, we claim that these geneses, or at least parts of these geneses, can be collective. We argue that this introduces a specific perspective on teachers' collective work, and we explain and illustrate this by leaning on the instrumental approach (Rabardel 2002) and, very importantly, by focusing on the concept of *scheme* (Vergnaud 1998).

Instrumentation/instrumentalization process/es and scheme/s

The documentational approach leans on, and extends, the instrumental approach developed by Rabardel (2002). For performing their teaching tasks, teachers, individually or in groups, interact with a set of resources. This interaction combines two interrelated processes: the process of instrumentation, where the selected resources support and influence the teacher's activity (i.e. the resources represent an interface between the knowledge, goals, and values of the author and the user); and the process of instrumentalization, where the teachers adapt the resources for their needs (i.e. the resources require craft in their use; they are inert objects that come alive only through interpretation and use by a practitioners). This productive interaction between an individual teacher, or a group of teachers, and a set of resources, guided by a teaching goal, through successive stages of (re-) design and implementation in class, gives birth to a hybrid entity, a document: this consists of the resources adapted and re-combined; and the ways the teachers use them, which include the stable organization of associated activities and particular usages, and contain the 'knowledge' guiding the usages.

In the instrumental approach, Rabardel (2002) defines a *utilization scheme* as a structure organizing a subject's activity with an artefact for a given goal. In the context of resource use, the utilization scheme includes both procedural schemes (e.g. how to use particular resources) and mental/cognitive schemes (e.g. global use strategy; knowledge about the means that the resource offers; concepts for a way of using the resource for a given class of tasks). We claim that this definition of scheme/s (and hence of documents) provides us with a better understanding of teachers' interactions with resources and of the consequences of such interactions.

Rabardel (2002) emphasizes the fact that schemes have an individual aspect, as schemes of a given subject or topic area, but also an essential social dimension. Indeed, the emergence of schemes is essentially a collective process, involving the users and the designers of the artefact; and moreover, their transmission is a social process. Rabardel (ibid.) has coined the term of "Social Utilization Schemes", and considers that the schemes developed by a subject result both from an individual development and from the assimilation of social schemes. However, he does not consider how schemes develop within groups of users.

In DAD we refer to the following definition of schemes, given by Vergnaud (1998), where a scheme has the following four components:

- The goal of the activity, sub goals and expectations;
- Rules of action, generating the behavior according to the features of the situation;

- Operational invariants: concepts-in-actions, which are concepts considered as relevant (e.g. “differentiation of teaching”), and theorems-in-action, which are propositions considered to be true (e.g. “the low-achieving students need more help from the teacher”);
- Possibilities of inferences (e.g. “in this class I need to adapt my scheme for differentiation because there are some very high-achieving students”).

These four components capture at the same time the stability of the activity’s organization and its potential for evolution, the balance between uniformity of activity and its variation. Indeed, the inferences can lead the subjects to adapt their rules of action to the specific features of the situation; the adaptations can lead to the emergence of new operational invariants, or even of new schemes.

To understand the importance of schemes, we go back to selected aspects of Vergnaud’s Theory of Conceptual Fields (TCF; 1998). According to TCF, a conceptual field is, at the same time, a set of situations and a set of concepts, all interrelated. Hence, the meaning of a concept cannot be analyzed through a single situation and, reciprocally, a situation cannot be analyzed through a single concept, but through many of them, creating systems. This means that a teacher’s professional learning/knowledge, and its development, is intrinsically intertwined with the situations in which the teacher develops that knowledge. Vergnaud (1998) contends that

The theory of knowledge as an adaptation process is essential; but what is it that adapts itself, and to what? The most reasonable answer to date is that what adapts are the forms of organization of activity, the schemes, and they adapt to situations. Therefore, the pair scheme/situation is conceptually more interesting and more powerful than the pair response/stimulus. (p. 85)

In many studies, documentational genesis has been examined as an individual process. Different teachers may develop different schemes for the same type of task. However, documentational (and instrumental) genesis also has a social dimension. The teachers develop schemes in the context of the professional development community, and they may develop others in the classroom community with their students. The next section, therefore, addresses the social perspective of the instrumental approach. Considering groups of teachers working together, the social perspective of the documentational approach raises several questions concerning teachers’ collective work. When groups of teachers engage in a collective work, they not only bring their own resources, but also their own schemes. What happens during the collective work? Do the interactions lead to evolutions in the individual schemes? Are common documents (including common schemes) developed?

We examine these questions in the next section, drawing on selected studies about teachers’ collective work using DAD.

Empirical studies of teacher collective work and identification of schemes

In this section we illustrate and explain three different collective works of mathematics teachers, and identify the schemes brought to and developed from the collective.

The impact of collective work on individual schemes

The study by Gueudet and Parra (2017) reports on the documentation work of two mathematics teachers (Valeria and Gwen) working together. Both were experienced teachers. In 2015-2016 when we followed them, both had a grade 11 class (specialized in mathematics and economics). Together they decided to design their course about tolerance intervals (with the binomial law), and to propose

a common assessment to the two classes at the end of the course. We followed the design and implementation of this course, with the reflective investigation method (Trouche, et al. 2019) associated with DAD.

We analyzed the data collected at the end of the follow-up and identified documents developed by the two teachers. In spite of their strong intention of collective work, all these documents were at least partly different. We claim that the main reason for this is that, as experienced teachers, they previously developed their own individual schemes, concerning the teaching of tolerance intervals. For example, for the aim “Teaching how to find a tolerance interval with a binomial law”, Valeria had developed a scheme encompassing the following theorem-in-action: “the students must learn to read the table of the binomial law and to find in it the endpoints of the interval”. Gwen had different theorems-in-action, in particular: “the technique to find the interval for the binomial law is too complex, and never assessed at the baccalaureate”; “students must learn to program their calculator”. Gwen proposed to work on an exercise with their students. This required to write (on the calculator) a program giving the binomial law tolerance interval, once the appropriate parameter had been entered. Valeria accepted and actually used this exercise. For her this was only an exercise, the program was not used further (she did not want her students to use the calculator as a “black-box”); whereas for Gwen, the programmed calculator was then used in each exercise requiring to find a tolerance interval. The common assessment included an exercise on tolerance intervals. They chose this exercise together; the text of the exercise incorporated a journal extract, and this corresponded to a shared operational invariant: “the students must learn to find information in a text”. However, the questions were modified, to propose the two different methods for finding a tolerance interval: with the table of the binomial law, for Valeria’s class; with the calculator, for Gwen’s class.

We retain several aspects from this example. Firstly, when common operational invariants exist, teachers can develop shared (at least partially shared) documents. This existence of shared operational invariants certainly fosters common work. Secondly, when operational invariants are different, even a collective work leads to different documents. We claim that this can also explain why teachers using the same resource (e.g. a textbook) work differently (e.g. with the textbook) in class. The operational invariants can evolve along the collective work: Valeria developed a new theorem-in-action about the interest to write a program on the calculator for tolerance intervals. However, during a short-term collective work, operational invariants are likely to remain stable.

Collective design work and new schemes

In Gueudet, Pepin, Sabra and Trouche (2016) we analyzed documentational geneses occurring along the work of a Community of Practice (CoP; Wenger 1998) designing a new e-textbook for grade 10, within the French association Sésamath. This CoP was followed from June 2009 to December 2013. We claim that this long-term design work, and the “extraordinary” nature of the aim (designing an e-textbook is not a usual activity for a secondary school mathematics teacher) produced phenomena concerning documentational geneses different from what we discussed above.

One of the shared goals of the CoP at the beginning of their work was: “deciding a structure of the e-textbook”. They first established together a list of 38 “atoms” (e.g. “Draw a graph compatible with a table of variations” in one atom), based on the official curriculum - these atoms corresponded to competencies of the new official curriculum. In the discussions between the authors, we observed a

shared theorem-in-action: “we need to support teachers for organizing their courses according to [national curriculum] competencies”. After this first stage, the members of the CoP discussed how these atoms should be organized in the e-textbook. The teachers of the CoP would have liked a networking structure, where all potential paths (considered by the teachers) were possible. However, they realised that this was not possible (because, if a notion of geometry is needed in an exercise about functions, the geometry course must be placed before this exercise). The discussions lead the members of the CoP to decide that the e-textbook was going to be structured in chapters. Then, each chapter would have a *kernel*, a list of techniques with a given order.

This list determined the content of the essentials, the introductory activities, and the basic exercises. Outside this kernel, more complex exercises were proposed, which could correspond to other, or several kernels. (p.195; Gueudet, et al. 2016)

The CoP developed a shared document for the goal “choosing the structure of a grade 10 e-textbook”. This document encompassed several resources, in particular the atoms, and shared schemes-of-use for these resources. In particular, the members of the CoP developed together theorems-in-action, such as “it is not possible to leave the possibility of any path to the users”; and “the techniques provide the coherence of a chapter”.

In this example the members of the CoP developed common documents, concerning the design of an e-textbook. Probably their uses of the e-textbook in class would differ, because of their pre-existing schemes. But for the activity of designing an e-textbook, they developed new and common documents, in particular common schemes.

Collective scheme and interpretation and adaptation at each level of collective work

The study reported in Pepin, Gueudet, and Trouche (2017) concerns a Norwegian teacher’s (Cora) documentation work within the context of a large European project (PRIMAS - <https://primas-project.eu>), where she worked in collaboration with a group of mathematics and science teachers of her region. The aim of the PRIMAS project was to develop capacity (in terms of inquiry-based teaching and learning) in mathematics and science education in schools; hence to develop instructional leaders (“multipliers”) who in turn would work with small groups of colleagues in school. The PRIMAS project in Norway offered, and Cora participated in, professional development (PD) sessions over 18 months, in addition to her work with colleagues in her school between PD sessions. The PRIMAS project provided curriculum resources designed by ‘expert designers’ (i.e. academics working at the universities of the partner teams). These materials included (1) mathematics and science tasks; and (2) modules developed for teacher professional development sessions. They were seen as the basis for the work/sessions with colleagues in school.

For this paper the following data were analyzed: (1) Cora’s general use of the PRIMAS modules (interview; Schematic Representation of Cora’s Resource System); and (2) her adaptation and use of a particular PRIMAS module and associated tasks on ‘division of fractions’ (lesson preparation; video observation; interview).

Results showed that in terms of documentation work, Cora worked at three levels, where the first two relate to collective (re-)design and the third to individual (re-)design of curriculum resources: (1) the re-design of tasks and PD modules in the university PD sessions (so that they corresponded to the Norwegian and the individual school contexts); (2) the re-design of tasks (and lessons using these

tasks) in Cora's school PD sessions; and (3) the re-design of tasks (and lessons) for Cora's own teaching. Hence, Cora re-designed and adapted the digital PRIMAS tasks, individually for her own lessons, in addition to her (re-) design work with and for her colleagues in her role as multiplier, as well as in the university PD sessions.

In terms of schemes, Cora's larger goal was to develop her inquiry-based learning skills, which included as general rule of action "to listen carefully to pupils" and build her lessons around pupil thinking. Hence, principles of good questioning were important for her – here we observe that initially she had operational invariants compatible with PRIMAS: e.g. "good questioning" as a concept-in-action. She used the PRIMAS modules, together with her colleagues, to develop "good questioning skills", and in turn enhance her understanding of student thinking. The digital PRIMAS resources provided her (and the group) with promising examples of how to adapt her questioning skills. These adaptations illustrated what we called *design flexibility* (Pepin, et al. 2017): e.g. by adapting the digital PRIMAS tools for lessons, Cora developed flexible ways of questioning in order to guide student thinking and to help them to make sense of the proposed activities. Her operational invariants related to the application of questioning principles to different topic areas in mathematics education, and Cora adapted her designs to the teaching context. In terms of inferences, differentiating tasks for different audiences, and with different resources, were part of Cora's expectations for attending to individuals in her class. Hence, we can claim that they were part of Cora's schemes that were reinforced and further developed by her work in PRIMAS.

From this study we retain that, first, teachers work at different levels with and in collectives. Second, it is noteworthy that whilst PRIMAS provided the resource/s and collective designs/modules, Cora worked with different shared schemes in different collectives: (1) in the university PD sessions, she developed shared schemes that linked to adaptations of resources to the Norwegian 'curriculum culture' context (e.g. schemes linked to questioning and formative assessment); (2) in the school PD sessions, particular resources and associated schemes were selected (by Cora and colleagues) and these were 'mixed' with individual schemes, in order to develop a certain coherence of instruction across the grade/s; and (3) in Cora's individual documentation work, she developed 'new' schemes by considering promising examples from PRIMAS resources and including them in her new individual schemes. It was clear that at each level the PRIMAS (designed) resources had an impact on teachers' associated scheme/s; at the same time in the different collectives Cora and the respective group of teachers shared and developed their schemes further. This became evident in the interviews and session observations, when the teachers talked about their mathematical-didactical thinking and practices.

Discussion and conclusions

In this section we explain and discuss what we have learnt from the three studies, and we forward three claims.

We have learnt the following from the three empirical studies about mathematics teachers' collective work by identifying schemes:

(1) From the study by Gueudet and Parra (2017): that the collective design of a lesson can lead to selected evolutions in participants' operational invariants, but not likely to the emergence of a completely shared scheme. When teachers engage collectively in an activity with a "usual" goal for

which they already developed an individual scheme, this scheme intervenes in the collective work. Eventually, it leads to different interpretations of the resources collectively designed, at least when the collective work only concerns a short period. Investigating the development of shared schemes for “usual” goals when the collective work develops over several years requires further study.

(2) From the Sésamath study: that in an “exceptional” collective work where the aim of the activity does not coincide with usual goals, teachers can develop shared schemes. Some initial schemes, corresponding to sub-goals, intervene in the collective work. The differences in mathematical/didactical opinions and beliefs can even generate conflicts; but the shared overarching goal leads to the negotiation of solutions, and eventually to the emergence of a shared scheme.

(3) From the PRIMAS study: that at each level of collective work, teachers can develop different schemes which link to the organization of the collective activity: some schemes become shared, others stay individual. Moreover, different kinds of resources have different impacts on the development of schemes, and the type of impact depends on previous schemes and experiences. What is not evident is how common schemes could develop; every group (and every teacher) seems to develop its own synergy in terms of schemes, even with expert-developed resources and common goals. It is likely that goals get interpreted differently at different levels of collectives, which in turn is likely to influence the schemes developed.

(4) From all three studies: that shared operational invariants influence the engagement in a collective work, and facilitate this collective work; that evolutions of individual schemes (or at least of components of these schemes) can result from the collective work.

What we claim: First, in order to provide an analysis of complex collaborative activities with a theoretical structure, we refer in this contribution to Vergnaud’s work of the TCF, and in particular the notion of *scheme*. Through analyzing common documents produced by collective actions, teacher learning through collective action can enrich teachers’ individual schemes. However, it might be that each individual, participating in a situation lived collectively, creates a ‘collective mindset/scheme’ shared by all members of the community. This collective mindset would be the *collective scheme* created together during the collective activity. At the same time, it appears that utilization schemes also acquire a social character, when schemes are elaborated and shared in collectives, and this may give rise to an appropriation by subjects.

Second, many studies referring to DAD have considered teachers’ work within CoP (e.g. Sabra & Trouche, 2011; Gueudet, Pepin & Trouche, 2013). The link between DAD and CoPs is natural, since one of the important aspects characterizing the CoPs is a shared repertoire of resources. The definition of “resource” within the CoP theory includes the resources as defined by Adler, but also other aspects. The repertoire of resources in a CoP is a product of the CoP’s practice, and at the same time it supports and contributes to shaping this practice. It also includes experiences, ways of addressing problems, which in DAD are situated within the “scheme” part of a document, and not within its “resource” part. Thus, we claim that using the concept of document, and scheme in particular, could be helpful to deepen our understanding of the repertoire of resources of a CoP, linking it with the concept of document system in DAD.

Third, when collective action is mentioned in the field of (mathematics) education (e.g. Community of Practice- Wenger 1998), it is mostly related to the formation of groups of teachers who intend to

modify or design school syllabi, re-design mathematical tasks, and/or create new pedagogic practices. It appears that in most studies the term ‘collective action’ has been appropriated, meaning teachers making decisions in groups, for particular goals. It is also inferred that this collective action reflects the group’s way of thinking, their collective scheme. It seems acceptable that individuals who live a certain situation in a group, act accordingly to their individual schemes, where a collective scheme appears to be the motor of the action, as Marcel (2005) contends that

a collective scheme would be a structure which generates collective action in a given situation. The difference [between individual scheme and collective scheme], however, lies in the fact that this collective pattern is ‘carried out’ by a group of acting individuals, not by a single individual. The collective scheme is built and mobilized by the team, as a social and cognitive entity” (Marcel, 2005, p. 651).

Leaning on Marcel (2005), we argue that the organization of patterns in individual schemes constitutes the specificity of the collective scheme, which has a cognitive surplus that would, in return, also influence individual schemes. That is, there would be some influence (not simply a joint) from individual schemes on the constitution of collective scheme and, in return, the new individual schemes would have been influenced and modified by this collective scheme. What we claim in this research is precisely the following: the teachers participating carrying out the tasks proposed have built, through their individual schemes, a collective scheme that, in turn, modified the individual schemes, entailing movement in their learning.

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