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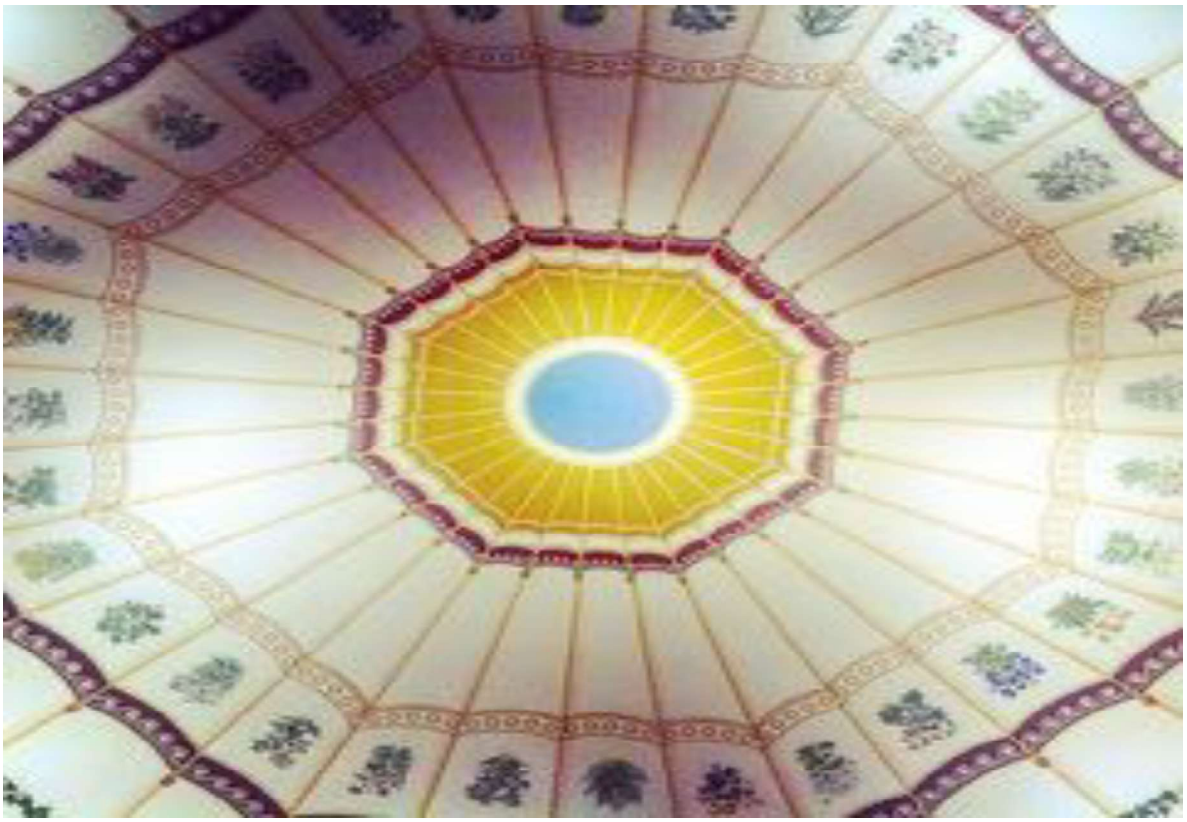

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Studying the use of digital resources in mathematics classrooms: A deeper focus on the reasons underlying teachers' choices

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In this paper, we report research on one mathematics teacher's use of digital resources in the context of a professional development project targeting inquiry in statistics. Since the teacher was an accomplished user of digital resources, it was important for us to study if and how she aligned her teaching with the project aims, the conflicts that emerged regarding mathematical activities and communication, and the reasons behind her decisions. The analysis reveals that the teacher's choices were rooted mainly in her conventional practice, which did not include analysing and connecting the affordances of digital resources with mathematical content. This led her to block students' communication and engagement in inquiry processes.

Keywords: Use of digital resources, classroom teaching practice, documentational approach, teachers' decision making.

INTRODUCTION

Digital resources (DR) have been increasingly available for mathematics teaching overt the last years primarily with the aim to promote development of inquiry processes, and support cultures of richer mathematical activity and communication in classrooms. Given the teachers' reported difficulties in achieving that goal, this paper aims to contribute in getting a deeper insight into teachers' underlying reasons for how they integrate DR in their daily practice. Research shows that integration of DR in mathematics teaching appears to be a highly complex task for teachers. This complexity relates to the fact that the introduction of DR involves the establishment of new cultural practices that requires comprehensive changes in pedagogy, if it is to facilitate student learning as envisaged (Hoyles & Lagrange, 2010). In addition to identify the potential of different DR for mathematical understanding, teachers face a number of critical issues underlying the teaching and learning process with DR. These include the nature of the designed tasks, the appropriation of the available (digital and non-digital) resources into classroom teaching as well as the need to transform dominant modes of classroom communication in more participatory directions where new forms of exploration with digital and dynamic mathematical representations are present (Ruthven & Hennessy, 2002). However, research points out that little is known about the impact of DR's actual use on teachers' work and the interrelationship between factors that influence teachers' decision making in DR settings and established norms, teaching conventions and personal background (Goos & Soury-Lavergne, 2010). To address this issue, we study how a primary teacher (Sofia) regarded as an accomplished user of DR, use these resources in her classroom teaching in the context of her participation in a large Teacher Professional Development (TPD) program

aiming to engage students in inquiry processes by use of DR. It was critical for us to study if and how she aligned her teaching with the project aims, how she drew on DR, and what conflicts emerged in her teaching with regard to mathematical activities and communication.

THEORETICAL FRAMEWORK

The *documentational approach to didactics* acknowledges the crucial role of resources for teachers' work and professional growth. Gueudet and Trouche (2011) retain a broad meaning for resources comprising material and non-material elements (such as a textbook, a discussion with colleagues etc.) while they consider that the teacher's work with and on resources constitutes a dialectic process where design and enactment are intertwined. Teachers use different kinds of resources that shape not only the mathematical content and the ways it is (re)presented, but also students' mathematical learning. Teachers adapt their appropriation and use of resources to their needs and customs. An implication of this approach is that curriculum material is not conceived as a static body of resources that guides instruction, but rather as a set of objects amenable to changes and modifications depending on the teacher's didactical design and actual use. This dynamic process of (re)-design and interpretation continues ('in use') during enactment of the resources (e.g., Pepin et al., 2013) leading to teachers' creation of *documents*. A document incorporates "practice (how to use these resources for teaching a given subject) and knowledge (on mathematics, on mathematics teaching, on students, on technology)" (Gueudet & Trouche, 2011, p. 401). On the one hand, practice entails observable parts of teachers' stable behaviour for a given class of situations called *usages*. On the other hand, teacher's knowledge about the use of the resources is often implicit, but can be inferred from the usages, i.e. the 'reasons' piloting the usages called *operational invariants*. Creation of documents is considered as unfolding through a dual process of instrumentation (the resources influence teachers' practice and knowledge) and instrumentalisation (teachers act upon these resources as they appropriate them).

Another strand of existing research indicates that integration of DR depends highly on teachers adapting and developing appropriate craft knowledge to underpin their classroom work (Ruthven, 2009). Aiming to make visible and analysable the constituent elements of this kind of practical knowledge in bearing technology integration in mathematics teaching, Ruthven developed the conceptual framework *Structuring Features of Classroom Practice (SFCP)*. It brings to the foreground five structuring features of classroom practices which shape the ways in which teachers integrate (or fall short of integrating) new technologies in their teaching: *Working environment* refers to where the lessons take place (room location, class organization etc.); *Resource system* includes the digital and material resources in use towards student activity and learning goals; *Activity structure* describes activity formats that frame the action and interaction of teacher and students during particular styles of lesson; *Curriculum script* is a loosely ordered mental model of goals, resources and actions for teaching a mathematical topic that guides lesson enactment (e.g., potential

emergent issues, alternative paths of action); *Time economy* refers to the teacher's management of the time available for class activity so as to convert it into "didactic time" for student learning.

In our study, the documentational approach offers an opportune window into Sofia's classroom work to explore if and how the project innovation was taken into account (e.g., task redesign, aligning her lesson plans with the project aims). It also allows us to address implicit and explicit knowledge, and conventions, norms, views and values that drive her choices at the level of design and enactment. SFPC allowed us to access key aspects of Sofia's classroom practices so as providing a more comprehensive interpretation of the emergent current conflicts by highlighting their connections to Sofia's teaching history in terms of long term activity structures.

METHODOLOGY

Even though the focus of the TPD project was not on teachers' classroom practices in particular, it turned out to be a useful context to study Sofia's teaching in terms of identifying conventions, norms, views and values that underlay her integration of DR. The context was especially useful, when Sofia attempted to adapt her practices in line with the project, but where it became difficult for the students to engage meaningfully in the statistical activities and communication. These instances of practice provided insights into conventional practices that seemed to contribute to complicate the intended inquiry processes. We termed such instances as critical instances of practice, much in line with Skott (2001), and used them as an analytical strategy to make visible the reasons behind her daily integration of DR.

We observed and recorded 31 classroom lessons (16 from the project, 15 before or after it) and conducted five semi-structured interviews (three during the project and two five month later). Apart from the last one, which was a focus group interview evaluating the entire project, the others were conducted face-to-face and focused on Sofia's perception and use of DR in her daily teaching as compared to her teaching carried out in the context of the project. Based on the interviews that were audio-recorded and transcribed, we constructed a narrative of Sofia focusing primarily on how she became a mathematics teacher preoccupied by DR and how she perceived mathematics teaching with/without DR. We identified critical instances of practice in the videos of the project lessons, which we analysed in terms of (a) the ways Sofia conceived and used DR, and (b) the SFCP framework. With the aim of understanding Sofia's practice and reasons behind her decisions, we compared and synthesized (triangulation) evidence from interviews and observations. For example, a verbatim transcript of the lessons (e.g., *"Write it all down. You just have to make a list [of your everyday use of statistics]"*) and an interview quote (e.g., *"I think I only teach basic skills … we never have time to do something [inquiry oriented]."*) were used to establish the presence of a specific operational invariant or activity format (e.g., Sofia tends to interact in procedural ways with students).

THE CASE OF SOFIA

Sofia has taught mathematics in grade 4-6 at the same small municipality school in a Danish village, since she graduated in 2000. She describes the mathematical part of her four years of education as an amplifier of her high school mathematics, dominated by presentations of theorems and proofs. Didactical aspects, such as how to use DR and communicate in mathematics classrooms, were only insignificant parts of her education. Inspired by her own everyday use of DR, she started early on to use them in teaching mathematics. During the last 15 years, she participated in various TPD on DR such as national projects, publisher arrangements and municipal initiatives. On the one hand, she emphasises such opportunities as important for keeping her spirits up on teaching. On the other hand, she expresses lack of real development opportunities as she experiences to be the most knowledgeable about DR: *"Each time I have that naive belief that someone can inspire me and tell me what they do and how… but no-one does"*. Hence, Sofia appears very secure and confident about her teaching and reasons for integrating DR. Her colleagues and the school management regard her as an accomplished user of DR and recently the management appointed her as DR-coach in the municipality. In her daily teaching, Sofia uses various DR such as an electronic training-database, applets (e.g., Book Creator, Explain Everything and Showbie), Microsoft Office package and dynamic geometry system (seldom). She uses such resources primarily to engage students in skill practice; check their understandings and fluency; and adapt the content to students' individual needs.

In 2013-2014, Sofia participated in the mathematical part of the national TPD project with the overall aim to support teachers in developing new teaching practices that take DR into account and are in line with the reform orientation of mathematics teaching (NCTM, 2000). A unit, called *Youngsters and ICTs,* covering 15 lessons of statistics teaching in grade 6 was its focal point. The aim of the unit was to support teachers in using DR to initiate, negotiate and establish two classroom mathematical practices: (1) to be critical towards the use of statistics, (2) to investigate and reason about patterns in data sets. To realise these aims, the unit framed and suggested ways for teachers to engage students in statistics inquiry by use of electronic surveys to aid them generate their own data, spreadsheets to support their data analysis and reasoning, and Explain Everything to support their reasoning and interpretation.

Sofia participated in three workshops and taught the unit two times (spring 2013 and winter 2014). Generally, she considers the unit as not sufficiently innovative as regards DR, while she appreciates its different teaching approach: *"I do not think there has been enough DR ... but, mathematically, it's another way of teaching than I have taught in the past"*.

A CRITICAL INSTANCE OF STATISTICS TEACHING

We present one critical incident from the second lesson of Sofia's teaching in 6th grade in 2014 where the pivot was a newspaper article using statistical methods and reasoning in inappropriate and opaque ways. By engaging students in a first critical examination

of such methods with the aid of a spreadsheet, the purpose of this lesson was to set the stage for the rest of the unit. The lesson started with Sofia introducing the article to the students and asking them to answer questions she had written in Showbie. At this phase of the unit, Sofia had adapted her activity format and curriculum script on several occasions as when she engaged students in exploring the questions through a combination of group work and whole class discussion. However, these promising adaptations concerned only parts of her teaching that did not involve DR. In comparison, the selected episode involves use of DR and it brings to the fore how Sofia's conventional practices make it hard for the students to engage meaningfully in statistical inquiry and communication.

The incident occurs when Sofia encourages a group of four engaged girls to examine critically the article's calculation of the statistical mean of children's use of ICTs given four pairs of hours and minutes for different age groups. Sofia initiates, *"Do you have a calculator, where you can try to do it?"* She carries on instructing the girls on how to convert from hours and minutes to minutes, before they realise this as a necessary step. The girls manage on their own to convert the numbers with the use of the calculator, add them and ask Sofia, *"Do we have to divide by four?"* In a long interaction (more than 2 min.), Sofia initially encourages the girls to think for themselves, but as they repeatedly type the numbers wrong, gaining odd results, the mutual frustration grows. When a girl asks, *"How can you interpret the mean?* Sofia takes over on the calculator, types the four numbers and divide them by 60, while she says*, "You have to find out. You have to make a guess"*. Sofia does not succeed in finding the mean, and together they try more or less randomly, before they realise that they need to divide by four. One girl types the addition of the four numbers, divide by 60 and then by four. When the calculator returns 7.7333, she says, *"That was close [the mean in the article is 7 hours and 48 min.] but clearly not right"*. Sofia asks, *"What does the decimal 7333 mean? How do you convert into minutes?"* As no one reacts, Sofia moves on *"We agree that it is 7 hours? We remove the 7 hours and 0.7333 remains. If you multiply by 60 then you get that part of an hour … You just have to find 73/100 out of 60"*. Clearly guessing, the girls suggest to subtract 73/100 and 60 and then to divide the two numbers. Sofia repeats her explanation and one girl says, *"You confuse me more than I was before"*. Sofia instructs the girls what to do and says, *"But you have not understood it. You just know what to do"*.

REASONS UNDERLYING SOFIA'S CHOICES

In the instance, Sofia enacts the unit but she decides on behalf of the girls to use a calculator as a DR, not a spreadsheet as suggested by the project. However, the calculator does not require the girls to develop a model or sheet that could provide them an overview of the situation and help them structure their solution. On the contrary, they have to sequence the calculations in separate parts without being able to log their calculation history or model their common thinking. They could have used paper to keep track of their calculations and provide an overview, but only using the calculator seems to complicate the activity. This example is evidence of a practice that we see

generally in Sofia's teaching: she chooses to use DR without considering how to support students' learning through their use.

In terms of the documentational approach, Sofia initiated a usage for the calculator focusing on computing the statistical mean through automatization skills. At the same time, she failed to integrate the resource use in an inquiry way as targeted by the project. We seek to make visible the underlying reasons driving Sofia's choice and use of the selected resource as well as the features of her practice that pilot her enactment of the project's unit in the classroom. Based on the narrative we deduced four reasons behind her choice and use of DR. First, Sofia has established a norm where she learns a new DR together with the students. She copes with the fact that they often learn it faster than her as a sound exchange of roles *"It is fine, that they can teach me something. It is sound for them to see that I am not able to do everything"*. Sofia developed this practice in response to the often-heard need of Danish teachers to be in full control of the resources they use in their classrooms and not dare to use an unknown or less familiar one. Second, Sofia's choice and use of DR also connect closely to her balancing her working hours. She reports seldom to have time to do a designed task with DR before teaching. She considers this unpreparedness as a necessary condition of her job: *"I haven't done any of the tasks [with a DR]. Of course, then you sometimes fail as a teacher, because you have not prepared yourself properly. That is part of being a teacher"*. This means, that Sofia is neither conscious nor prepared to handle the mathematical or technical difficulties students might encounter when they use a new DR or solve a new task. Third, she constantly balances between the time students require to learn a new DR and their expected learning outcome, i.e. the time economy. So far, this balance has tilted to the side of not introducing spreadsheets, as she considers it too complex for this class. Therefore, the range of DR that she can draw on in the activity is limited. Fourth and most crucial, when choosing to use DR Sofia predominantly steers by general pedagogical concerns such as to motivate students by variating activities during a lesson and to meet their different needs by individualizing their work. Her decisions do not rest on analysis nor reflections on the mathematical affordances of DR in relation to students' learning through their use. We deduce two operational invariants that seem to pilot her daily usages regarding DR. One is that "The use of DR generally contribute to students' learning", and the other that "The use of DR does not need to be addressed from a mathematical point of view".

Taking an overall view of the episode in terms of SFCP, we see that at the level of the resource system Sofia only uses DR familiar to students (e.g., calculator, Showbie) and at this time she chooses not to use the ones suggested by the project (e.g., spreadsheet) that facilitated a critical stance towards use of statistics. In contrast to the projects' focus on selecting resources according to their potential for supporting students' statistical learning, Sofia's underlying reasons are related to her working conditions (limited time for introducing new DR), and to handle students' low and different ability level in mathematics from general pedagogical perspectives.

In planning to teach the unit on statistics, Sofia draws primarily on her existing curriculum script built over years of experience. In particular, as she mentioned in interviews she views DR as an efficient tool to provide new, different and dynamic representations. Nevertheless, she appears to underestimate the refinements that curriculum scripts need in order to integrate a new DR. For that reason, the inquiry processes targeted by the project conflict Sofia's views on the aim of mathematics teaching, which is to provide students *"with a tool box ... The students have to be able to calculate area and circumference, to add, subtract, multiply and divide and solve an equation"*. In the episode, we see Sofia concentrating on the standard techniques (e.g., divisions, linking decimals to time units) without having responded to ways in which a DR (i.e. calculator) may help/hinder specific processes and objectives involved in learning the targeted topic (i.e. statistical mean). Here it seemed to hinder the students' engagement in the activity and their communication.

At the level of activity format, we see that in the beginning of the lesson Sofia seems to adapt her normal activity structure to include the suggested whole-class discussions and classroom activity format, when DR is not involved. However, when DR is part of the activity, Sofia interacts with students in her conventional procedural way by instructing them on what to do and asking questions that fit with her own interpretations. Based on the narrative, her underlying reasons for such procedural interactions relate partly to her view of the aim of teaching mathematics targeting basic skills as a prerequisite to processes of inquiry, through *"a lot of practice. It is important to make a lot of the same type of tasks because then you get good at it"*, and partly to her view of mathematics communication. On the one hand, she stresses communication as one of her teaching values. On the other hand, she does not consider it as one of her strengths as a teacher: *"I have never been a mathematics teacher that can talk for twenty minutes"*. Hence, her activity format encompasses short initial lesson instructions to students on what to do and interactions with one or a few students working primarily on closed tasks using DR. Only rarely does she assemble the class for joint classroom discussions. Sofia considers her role as, *"... the role of a supervisor. I think I often supervise more than I teach"*. Sofia's integration of DR have enforced both her role as supervisor and her procedural interaction format as she has to technically support and structure students' individual work on mainly closed tasks in relation to more resources.

CONCLUSION

The TDP project targeted statistical inquiry with goals, resources and actions emphasising a critical approach to statistical thinking. This required a resource system exploiting the affordances of the different resources (digital and non-digital) to support students' conceptual understandings. Although Sofia found the unit challenging from a mathematical point of view, she appears to draw mainly on resources familiar to her and her students as well as to follow her conventional ways of interacting and communicating with the students when using DR. Without recognising the need to analyse and connect the affordances of a DR with mathematical content, she finds

herself in a position that blocks students' communication and engagement in inquiry processes. A potential suggestion for teacher education targeted integration of DR in mathematics teaching can be a deeper focus on analysing potentialities of DR in relation to students' learning.

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