A CLASSIFICATION OF RESOURCES USED BY MATHEMATICS TEACHERS IN AN ENGLISH HIGH SCHOOL

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This paper provides a classification of resources used by mathematics teachers in an English high school. It is based on data analysis from ongoing PhD research exploring mathematics teachers' appropriation of digital resources and the impact on classroom practices in selected schools. This paper reports a way of making sense of the myriad curricular and digital resources that are increasingly available to the teachers in planning and enacting their teaching and assessing their students' understandings in the context of their every day practices. The classification has potential to aid understandings of teachers' appropriation of resources for teaching mathematics.

Keywords: Coding data, Mathematics, Resources, Teachers

INTRODUCTION

This paper examines the resources used by four teachers in a Mathematics department in a state school in England. It presents and discusses a way to classify resources used by teachers and explores similarities and differences in teachers' use of resources using this classification. The paper is structured as follows. We begin with a review of literature on mathematics teachers and resources and the theoretical framework which guides the PhD research. We then present the context of our research, the school and the four teachers. The methodology of the research (the means of collecting and analysing data) is then outlined which is taken a step further in the next section which present a 'logical classification' of codings obtained in data analysis. We then present the results, the resources used by the four teachers in preparing to teach and in teaching; we present these using the 'logical classification'. The paper ends with a discussion of the classification and of the resources the four teachers used.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

The literature on the importance and relevance of the use of curricular and digital resources in mathematics teaching and learning has matured over the new millennium. Our understanding of resources aligns with Adler's (2000, p. 7) reconceptualization of resources "It is possible to think about resource as the verb re-source, to source again or differently". Within educational settings, 'curricular resources' (Stylianides, 2016) or 'curriculum material' (Remillard, 2005), include all the materials (digital or physical) that teachers appropriate in and for their teaching, with the textbooks been the most dominant resource internationally. In the context of mathematics teaching and learning Pepin, Gueudet, & Trouche define "mathematics teaching resources as all the resources which are developed and used by teachers (and pupils) in their interaction with mathematics in/for teaching and learning, inside and outside the classroom" (2013, p.929). A more recent publication, Monaghan, Trouche and Borwein (2016) documents the major milestones in the studies on teachers' integration of digital technology and the ongoing research efforts focusing on the appropriation of curricular and digital resources in the context of practice. We appropriate the above views in our research and consider mathematics teaching resources as including:

- Text resources, such as curriculum materials: mathematic textbooks, teacher curricular

guides, teachers' worksheets, spreadsheet, posters and syllabi.
- ICT resources, such hardware and software: laptops, iPads, applets, e-textbooks, games, Geogebra, blogs and learning platforms.
- Other material resources, such as students' handheld white boards, manipulatives and calculators.

The above suggests that the construct *resource* is understood in the context of mathematics teaching and learning as everything that supports and facilitates teachers' practices but the practice takes place in a context and in a community that need to be considered to account for actual use (and variation in use) of resources by teachers. In the preparation for teaching, teachers select, use, combine and modify, bookmark and save a variety of resources over time into a structured set of teacher's resources, this is referred to as teacher's *resource system*. Bozkurt and Ruthven (2015) show how digital resources structure teachers' planning and classroom practices. They identify five key features in the structuring process: *working environment, resource system, activity format, curriculum script and time economy*. Our research takes into consideration this milieu in which teacher's practice with mathematics teaching resources takes place. The milieu in preparing to teach often includes people and we consider people (face-to-face and online) as resources when they support teachers' practices.

In the analysis of the data in this study we combine an activity theoretic approach (Engeström, 1987) with the more recent 'documentational approach' (Gueudet and Trouche, 2009) from the French didactics as theoretical tools for developing an understanding of the teachers' appropriation of resources in the context of planning and enacting their lessons and assessment. These provide coherent multiple interpretative perspectives to be simultaneously considered in the processes of data collection and analysis.

CONTEXT

Data for analyses presented in this paper were gathered in the context of the aforementioned PhD research exploring mathematics teachers' appropriation of digital resources in selected High schools in the UK. The unit of analysis is the teachers' nested activity contexts. The mathematics departments in the selected schools are the broad setting since teachers usually undertake their practices within that collective context. This environment consists of overlapping layers of interactions: the whole school environment, the Mathematics Department, classrooms, curricular and digital resources available for mathematics teachers for planning, for teaching and for assessment. The four teachers considered in this paper volunteered to participate in the project and each has more than 5 years of teaching experience. The overall structure of these teachers' lessons was a three-part-lesson: *Starter phase*- to engage students and bridge learning from previous lessons into the current; *main part of the lesson*- for the development and consolidation of new learning and; the *plenary*- for extension and assessment (Jones & Edwards, 2005; Beere, 2012). The school, for students aged 11-18 years, hosts one of the *maths hubs* (a collaborative national networks of schools' initiative) where the use of digital resources are encouraged and supported. The schools hosted many visitors over the data collection year including mathematics teachers from China (hence the reference to 'Chinese teacher' in Table 1 below). The students were in mixed ability classes. The classification we provide in this paper is based on these four teachers from this school though we believe it could be used more widely.

METHODOLOGY

A qualitative case study approach (Creswell, 2013) was adopted. Purposive sampling was used in selecting seven teachers from three schools based on the use of curricular and digital resources,

access, proximity and the opportunity to observe teachers' practice with mathematics teaching resources in natural settings. Data collection was undertaken during the 2015-2016 school year through periodic whole day school visits. Data were collected from a range of sources: audio-recorded semi-structured interviews; classroom observations using an adapted systematic classroom analysis notation for mathematics lessons (SCAN) (Beeby, Burkhardt & Fraser, 1979); recordings of teachers accessing digital resources, enabled by screen capture software (SnagIt, https://www.techsmith.com/snagit.html); researchers' field notes; and the collation of documents to which the teachers made reference. In this paper, the interviews are used as primary data sources, complemented by the screen capture data.

The four teachers from the school described above are the case units of analysis: Katie, James, Emily and Joe (pseudonyms). They were selected from teachers willing to be involved in the study based on their commitment to the of ethos the Mathematics department in the school. They taught in a context where a wide range of curricular and digital resources are easily available for use. Transcripts of the interviews and screen capture data were coded and thematically mapped, constantly grouped and regrouped into categories (we use the term 'category' for a set of codes).

Our classification of resources (for these four teachers)

The coding process described above produced a lot of codes/categories. There were four stages in the development from initial coding/categories to the classification in Table 1 below, these were: (i) initial coding by the first author; (ii) discussion and refinement of the initial coding by both authors; (iii) an informal inter-coder reliability session between the first author and a teacher from a non-study school which also produced a slight refinement of the coding; (iv) a second meeting of the two authors in which a 'logical classification', which we now discuss, was superimposed on the post stage iii categories.

Open coding is an interesting, and often useful, activity but it is very subjective (even when more than one coder is involved). In discussing this in stage iv we saw that the codes could be divided logically; 'human' – 'non-human' provides a partition of all resources a teacher may use. Taking this logical division further we can: partition human resources into those where there is 'physical contact' and those where there is 'not physical contact'; similarly, non-human resources can be partitioned into those which are 'electronic' and those which are 'non-electronic'. Our final division is to partition: electronic resources into 'hardware' and 'not hardware' (notice that 'hardware' and 'software' is not a logical partition); and non-electronic resources into those created by the individual teacher under consideration ('individual', e.g. Katie) and those which were not created by the individual teacher under consideration ('not individual'). Note that a worksheet created by Katie and used by Katie and James would be coded 'individual' for Katie but 'not individual' for James.

Note that further divisions are possible. For example, 'human, physical contact' could be partitioned into 'formal' (e.g. within a scheduled meeting that has an agenda) or 'informal' but we found the classification provided in Table 1 was sufficient to accommodate all of the codings developed in stage iii; it was also manageable, relatively easy for the two authors to code in an identical manner.

RESULTS

Table 1 provides a summary of resources used by the four teachers.

Human		Non-Human			
Physical contact	Not Physical Contact	Electronic		Non-Electronic	
KATIE	Podcast	Hardware	Not Hardware	Individual	Not Individual
Personnel CPD TeachMeet Chinese teacher	Social-networking Twitter	iPads IWB HWB	Resource banks Mangahigh Task-spec websites applets Gcsepod.com Resourceaholic TES.com Music	Paper-based resources Workbooks Worksheets Posters	Resource banks Paper-based resources textbook
JAMES	Podcast Facebook Twitter Blogs	iPads Laptops IWB	Resource banks Mangahigh applets Resourceaholic TES.com GeoGebra Mathspad.co.uk Desmos Coberttmaths.com	Paper -based resources Workbooks Worksheets Posters	Resource banks Paper-based resources
Personnel TeachMeet CPD					
EMILY	Twitter	Calculators iPads Laptops IWB HWB	Wordwall Ttrockstars Mathsbox.com Code buster King of Maths QR code Stopwatch	Paper -based resources Workbooks Worksheets Number line	Resource banks Paper-based resources
Personnel TA TeachMeet CPD					
JOE	Facebook Twitter	Calculators iPads Laptops IWB HWB	TES.com Socrative Mathswatch.co.uk Plickers QR codes 10ticks Virtual manipulatives	Paper -based resources Workbooks Worksheets	Resource banks Paper-based resources
Personnel TeachMeet CPD					

Table 1 Resources used by the four teachers (Katie, James, Emily and Joe)

Table 1 is structured with the columns representing the partitions we described in the previous section and the rows representing the four teachers. Many of the terms (e.g. twitter, iPad), we feel, need no explanation. Abbreviations used are: CPD – continued professional development; IWB – interactive whiteboard; HWB – handheld manual whiteboard; and TA – teaching assistant. 'TeachMeet' are informal but organised opportunities for teaching to meet to share 'good practice'. We now explain software used by teachers under five terms in common use in English schools. Endnotes provide links to websites for specific resources.

Resource Banks

There are three types of resources banks. (i) The individual mathematics teachers' resources on an iPad and flash drive (ii) The Shared resource bank of the mathematics department.)iii) Online resource banks, some of which are commercial and some are free. Online resources banks include: Gcsepod.com[i], Resourceaholic[ii], TES.com[iii], Mathspad.co.uk, Mathswatch.co.uk, 10ticks[iv] and Mathsbox.com. Here teaching resources of various sort can be accessed and used by teachers, parents and students.

Applets

These are small applications that performs specific task. They run within the scope of a dedicated widget engine and are designed to be placed on a web page as a plug-in auxiliary application. Applets used by these four teachers include Plickers, Socrative (mathematics specific) and King of Maths.

Dynamic Mathematics Software

These are open-source software that afford teachers and students dynamically linked multiple mathematical representations tools to help create models of real situations and links algebra and geometry representational systems simultaneously. In this category *Geogebra* and *Desmos*[v] were used by one of the teachers.

General Purpose software

This is often a suite of software in the form of an integrated package like MS Works incorporating spreadsheet and presentation software like power point. Wordwall belong to this class.

Data-capture Software

This are simple but powerful tools that allow the teacher capture, collate and analyse data in real-time for a whole class formative assessment. Plickers and Socrative were used for this purpose.

DISCUSSION

We first comment on our classification and then consider similarities and differences over the four teachers.

As mentioned above, open coding is often useful but it subjective. The partitioning in our classification is not subjective, it employs the law of the excluded middle: in classical mathematical logic, for any well-defined statement *A*, '*A* or *not A*' is true. Our classification of resources was not designed or used to replace the open codes generated in stage iii but as a means to present the resources contained in the open codes. We think this is a case of *having your cake and eating it*. With research on teachers' use of resources on the rise we offer this logical classification to fellow researchers as a means to present the results of our research in similar formats. We offer this as a 'malleable template'. The partitions we used in Table 1 suited, in our opinion, the data we collected

and analysed; a different set of partitions may be more suitable for a different research study. We now move on to similarities and differences that can be observed in Table 1.

In exploring the similarities and differences the classroom setting is worth considering first. The school of study has a new ultra-modern building, all the classrooms are spacious and equipped with an IWB, an adjacent chalk board, a laptop, a projector and every student is given a handheld writing board (HWB). The mathematics teachers have a growing shared bank of mathematics teaching resources where peer-reviewed resources are stored and are accessible to every member of the Mathematics department as a 'collective resources system'; this a 'go-to area' in lesson planning. There are class sets of iPads with an accessible iPad storage and charging trolley within the department for student use. This is the structuring context for understanding the similarity and differences amongst the teachers.

Similarities exist across the four teachers in their access to the CPD, teach-meet (a periodic whole school teachers' meeting to share experiences and expertise). All four teachers use social media and Twitter (see https://twitter.com/hashtag/mathschat?lang=en) in particular. The entries for this in Table 1 are for the specific purpose of planning lessons. The use of a mathematics teacher dedicated social networking media as a tool for communication, queries and sharing of resources is a regular feature among these teachers. There are many similarities with regard to non-human resources. Under *hardware*, all used iPads and IWBs. Under *not hardware* Resource banks, Mangahigh, TES.com and Resourceaholic are all used by two or more of the four teachers. With regard to *non-human & non-electronic* resources, the cells in the *individual* and *non-individual* columns of Table 1 are almost identical; this, we posit, is related to what we say above of the Mathematics department as a collective resources system.

With regard to differences between the four teachers and the resources they use we first note that the similarities far outweigh the differences. But we comment on differences with regard to 'doing mathematics' and to 'uniqueness'. With regard to 'doing mathematics', four resources that stand out to us as different to the rest are: calculators, Desmos, Geogebra and, to a lesser extent, virtual manipulatives. These are resources which students or teachers can use flexibly to explore mathematical relationships[vi] as opposed to being shown how to do mathematics by someone else. With regard to the four teachers and the two electronic columns contain these four resources we can see that: Katie uses neither; James uses non-hardware (software actually); Emily uses hardware; and Joe uses both. Are these individual differences? This leads us to 'uniqueness'.

Each of teachers has something unique in their use of other resources. For instance: only Katie has used a Chinese teacher as a source of ideas and uses GCSEpod.com; only James is recorded to have used blogs, GeoGebra, and Desmos in his lessons; only Emily makes use of Ttrockstars, code buster and King of Maths; only Joe uses Plickers, 10ticks, Socrative and virtual manipulatives. We also note with interest that the differences only exist with regard to digital electronic resources and we wonder whether this is the case in other European countries (as our perception is that 'The Mathematics Department' in English/UK high schools is a more homogeneous community of practice than it is in many European countries). Whatever the answer to our speculations, the uniqueness of each teacher seems to be related to the teacher's confidence in the use of digital resources and the use of those resources that help attend to the needs of the students in their engagement with mathematics.

NOTES

[i] https://www.gcsepod.com/
[ii] http://www.resourceaholic.com/
[iii] https://www.tes.com/teaching-resources
[iv] http://www.10ticks.co.uk/
[v] https://www.desmos.com/
[vi] Some apps allow this too.

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