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Expert and novice teachers' classroom practices in a technological environment

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This case study compares the teaching practices and craft knowledge of two secondary mathematics teachers using GeoGebra to teach the same geometrical topic. It forms part of a programme of research aimed at developing a more comprehensive understanding of technology integration in classrooms, by providing a model of key structuring features of classroom practice (Ruthven, 2009) which shape the use of technology in lessons and the kinds of professional knowledge required. In accordance with this conceptual framework, the classroom practices of an expert technology-using teacher are analysed in contrast to those of an experienced but technologically novice teacher, so shedding light on the character of expertise and the process through which it develops.

Keywords: Classroom practice, mathematics teaching, dynamic mathematics software, technology use, teacher knowledge and thinking.

INTRODUCTION

There has been considerable recent interest in issues of the integration of new technologies into ordinary classrooms in which the particular focus is on the teacher dimension. Researchers have suggested that teachers are faced with the need to consider a range of classroom management issues. They need not only to develop new types of interactions (Monaghan, 2004; Drijvers et al., 2010) but also to manage different kinds of time in their classrooms (Assude, 2005). They must establish a relationship between a technological environment and a paper and pencil environment in order to “build connections with the official mathematics outside the microworld” (Guin & Trouche, 1998, p. 200). Furthermore, some researchers (Monaghan, 2004; Lagrange, Dedeoglu, & Erdogan, 2006) have shown how technology can affect the emergent goals of the teacher during the lesson. When a teacher integrates

Dynamic Geometry Software (DGS) in order to make students engage with the task, s/he must consider not only a mathematical learning trajectory but also the instrumental aspect of this including the operation of the tool (Lagrange et al., 2006). In this light, it is not surprising that the process of orchestrating technology-integrated mathematics learning is not straightforward, in particular for teachers who are novice in technology-use, since the use of digital resources calls for “change in teachers’ professional knowledge and development” (Gueudet & Trouche, 2009, p. 199). In this respect, Tabach (2012) showed that classroom practices of teachers in relation to technology-use influence their knowledge and thinking and vice versa. Similarly, a number of studies (e.g., Monaghan, 2004; Drijvers, 2012) have shown that, over time, teachers’ practices with technology generate professional growth as teachers revise and adapt their teaching in relation to technology through feedback from their experiences. In other words, teachers build up knowledge from their reflection on their own classroom experiences and strategies they develop when, in the course of using the technological tools available, unexpected issues occur in the classroom.

Two fundamental questions, then, need to be addressed: “What aspects of classroom teaching shape the ways in which teachers integrate new technologies?” and “What kinds of professional knowledge do teachers need to teach with them?”

THEORETICAL FRAMEWORK

The recently conceived Structuring Features of Classroom Practice (SFCP) (Ruthven, 2009) was the framework chosen for this research on teachers’ classroom practices with the use of new technologies. This framework takes a naturalistic approach, focusing on constructs that are directly related to teachers’ classroom practices. Drawing from prior research

on teaching and schooling in general, it identifies five constructs which have already been developed to analyse what happens within classrooms and which bear crucially on incorporation of technology within classroom practice. These are working environment (e.g., Horne-Martin, 2002), resource system (e.g., Cohen, Raudenbush, & Ball, 2002), activity format (e.g., Burns, 1984), curriculum script (e.g., Putnam, 1987; Leinhardt, Putnam, Stein, & Baxter, 1991), and time economy (e.g., Assude, 2005).

Working Environment: Using new technologies typically requires adaptation of the working environment, either through moving teaching to a specialised computer laboratory or re-organising the ordinary classroom.

Resource System: New technologies increase the range of tools and resources available in classrooms, and pose a challenge for teachers to create a coherent resource system.

Activity Format: Technology-based lessons may require the adaptation of existing activity formats from non-technology based lessons or the development of some new format which “structures the activity and provides the organizational means by which learning tasks will be accomplished” (Burns, 1984, p. 103). Grouping arrangements, delivery system and interaction patterns define the activity format.

Curriculum Script: Mathematics teachers who are integrating new technologies in their classrooms need to develop their curriculum script in order to have a structure for planning and interpreting classroom teaching of a topic with technology. Curriculum script was developed by Putnam (1987) and defined as “a loosely ordered but well defined set of skills and concepts students were expected to learn, along with the activities and strategies for teaching this material” (p. 13).

Time Economy: Assude (2005) argues that time related issues in classrooms stem from time management difficulties in the classroom. Following Assude, Ruthven (2009) uses the concept of time economy to denote “how teachers seek to manage the ‘rate’ at which the physical time available for classroom activity is converted into a ‘didactic time’ measured in terms of the advance of knowledge” (p. 14).

The SFCP framework identifies key aspects of the craft of teaching that indicate the corresponding professional reasoning and craft knowledge that teachers must develop about these aspects in order to successfully incorporate new technologies. Ruthven (2009) explained the interaction of these aspects in teaching decisions and activities: for example, “Each of these modifications of an established activity format calls for the establishment of new classroom norms for participation, and of classroom routines to support smooth functioning” (p. 10). Employing this framework, the research reported here studies teachers’ use of technology in classrooms and the associated expertise teachers use in their everyday practice.

RESEARCH CONTEXT

This study examines classroom practices of two secondary math teachers’ use of GeoGebra (GGB) for math teaching, working within the English school system. GGB was of particular interest due to its accessibility. Although there is a lot of interest in GGB, difficulties arose when looking for suitable lessons, which indicated that in practice its use still remains quite rare. The most popular topics are concerned with graphing functions, geometrical transformations and angle properties in a circle.

After teachers agreed to participate in the research, the first author visited their schools to discuss their timetable and to find out when they were planning to make some significant use of this technology. Observations took place at a time agreed in advance with each teacher. Thus, this study involved no attempt to control or influence teachers’ lessons. In particular, the researchers did not participate in the lessons planning, although it is clearly possible that a teacher’s planning was influenced by the knowledge that a lesson would be observed. To try to forestall this, the research protocol made clear to teachers that they themselves should choose the topic, using GGB however they saw fit, and in any manner they wished.

Both teachers in this study chose to teach the topic referred to in the English curriculum as “Circle Theorems”. One (pseudonym Chris) is an Advanced Skills Teacher (a recognised grade of classroom teacher within the English school system, also taking special responsibility for leading professional development). He has around twenty years of teaching experience and is an expert technology user who utilises new

technologies in a progressive way in math instruction. He taught the topic over a series of four lessons to a top set Year 11 class. The other teacher (pseudonym Susan) also has around twenty years teaching experience, but is a novice technology user. Although Susan was experienced in teaching Circle Theorems, it was the first time she had integrated GGB into her teaching of this topic to this extent. She taught the topic over two lessons to a lower set Year 10 class.

Teacher Interviews: Semi-structured post-lesson interviews were conducted in order to clarify the professional thinking behind the observed lessons according to the SFCP framework key themes. Interview questions mainly focused on how using technology in the lesson might make it rather different to organise and run from a similar lesson without technology. These interviews were audio-recorded.

Classroom Observations: A semi-structured, non-participant observation approach was adopted for which the SFCP framework as an interpretative lens provided guidelines. In this regard, observation data aimed to provide evidence about teachers' classroom practices in relation to use of technology, with a focus on pre-specified aspects of the SFCP framework. All observed lessons were recorded and transcribed verbatim. To do this the teachers were asked to wear a microphone during lessons to capture all speech during individual teacher-student interactions.

RESULTS

The data acquired from this study are presented in detail due to space constraints. Instead some of the main findings are outlined and compared with other research.

Working environment

Chris's lessons took place in a Computer Lab where the computers for students were arranged in a U shape around the back and sidewalls, so that students working at them were facing away from the front of the room. There was also sufficient seating in the centre of the room to accommodate the entire class being taught as a group facing the front. At the front of the room there was a computer connected to a data projector for the teacher, and a Smart-board. Susan's lessons took place in a normal classroom where the seating consisted of rows of tables with chairs. There was a Smart-board as well as an ordinary whiteboard at the

front. The teacher provided students with laptops on which GGB was downloaded, which they used at their normal tables in the classroom. In order to ensure that students would have a functioning computer system she spent a considerable amount of time in preparation.

Chris was satisfied with the working environment since the layout allowed him the most convenient method of monitoring students, which in turn supported interaction between teacher and students.

I can see all of their screens. So if I stand in the middle and turn my head I can see everybody's screen which means that I know immediately if somebody isn't doing what they should.

He also appreciated the availability of software that allowed the teacher to control students' screens.

Although Susan made an active choice to use laptops because her class had too many students to fit into the available computer room, she described her ideal layout as being a bigger U-shaped computer room where she could monitor students in a more straightforward way.

I'd rather have a bigger room. My ideal would have been a big U shaped computer room with big screens that they can see and that I can walk around easily. You can position yourself to see 3 quarters of the screen to scan the room. And I suppose this is where for me I am always thinking about the classroom management issues particularly in these lessons where I'm a bit out comfort zone.

Resource system

Chris as an expert technology user had a full command of the software. He was aware of difficulties that might arise with students' use of the resource and preempted these through use of technical demo (Drijvers et al., 2010). For instance, he made sure that students all knew how to measure an angle with GGB. This was because, over the years, he had noticed that students often "measure" without clicking in the anti-clockwise order (a convention embedded in GGB).

For example measuring angles, you can click on the three points and depending on which order you click. If you click one two three, then it will

measure the interior angle (he shows on the paper). If you click them the other way round it measures the reverse angle. That was just a matter of try clicking in a different order.

However, Susan was a novice in using GGB and did not have a full knowledge of it. So she was learning some aspects of the software during the lessons. While she was doing a technical demo at the beginning of the first lesson she wanted to show how to measure an angle on GGB; however she was not aware that GGB measures anti-clock wise and she got the measure of an obtuse angle a number of times while wanting to measure an acute angle. But during students' work on laptops, a student told her about clicking in the anti-clockwise direction.

I was learning on the hoof this bit where it measures it anti clockwise; I had not really tweaked that. As I say Mike (*a student*) helped me with that one. I mean, yeah yes I did learn during the lesson. So then I could show the students. But the only way I have got now that in my head is by going through that pain and then teaching the students.

Similarly, she did not know how to set GGB to measure to the nearest whole number, which she thought created some confusion for students in this lower set since they had difficulties in seeing the relationships between angles.

Both teachers allowed students to use GGB by themselves for around half of each lesson as their aim was for students to discover some CT rules (Susan) and to explore some mathematical ideas, i.e., proof through CT (Chris). During students' use, teachers' role was to walk around and make sure that students engaged with their task. The teachers also used GGB for whole class teaching to explain or discuss problems. However, the two teachers had prepared rather different sets of tasks for students. Chris used more open-ended tasks, which aimed to encourage students to use GGB as tools or representations to help thinking. With this particular class, which is a high ability group of students, Chris pointed out that they have established this way of working over several years. His aim was to show students that there were many paths to reach the same mathematical solution; in particular he saw the topic of Circle Theorems as a vehicle for developing ideas about mathematical proof by focusing on different ways of proving. He

also thinks that students have to learn to interpret the diagrams through building them up by themselves. On the other hand, Susan asked students to set up the diagrams shown on the worksheet by using GGB and then to explore triangles inscribed into circles and try to formulate four different CT rules through using dragging techniques.

I expected them to discover the circle theorems. That was the aim of it. I wanted them to have that moment of awe and wonder, when they notice that special things happen in the diagrams. And I think the GGB lent itself to that.

During her reflections, Susan indicated that she used GGB to add 'fun' to lessons and to help students engage with more examples through using dragging techniques and to facilitate noticing the relationships between angles in circles. In comparison with undertaking the same worksheet on CT by hand, she considered that GGB assisted investigating CT through its accuracy, speed and manipulative ease.

Activity format

SFCP does not suggest specific activity formats, however Instrumental Orchestration (e.g., Drijvers et al., 2010; Drijvers, 2012), which also focuses on teachers' classroom practices in technological environments, has particularly focused on how activity structures relate to particular ways of making use of the technological component of the resource system, and has provided operational descriptions based on a combination of data- and theory-driven analysis (Ruthven, 2014). We will make use of the six activity format types identified for Instrumental Orchestration research; Technical-demo, Explain-the-screen, Discuss-the-screen, Spot-and-show, Work-and-walk-by and Sherpa-at-work (Trouche, 2004; Drijvers et al., 2010; Drijvers, 2012)

Chris' lessons broadly broke down into 3 segments. Initially the teacher introduced lessons in a whole class when he gave information about the lesson agenda and projected student work from a previous lesson to remind students what they had done and what direction to take from there. In the second segment, students went onto the computers and worked to discover for themselves in groups of at least two while the teacher walked around to monitor their progress and guide when necessary. Work-and-walk-by activity format comprised about 50% of a lesson. This for-

mat gauged students' involvement and engagement with the task, and also determined whether they had any difficulties during tasks. The teacher also guided the students to think in different ways during this format. Therefore, elements of Discuss-the-screen and Explain-the-screen were apparent in the teacher-students interaction during Work-and-walk-by. Finally, the teacher gathered the students in the middle of the room in order to discuss important points of the lesson primarily to create collective knowledge. Chris often made use of a Spot-and-show activity format during each segment of his lessons perceiving it as a means to enhance student involvement and discussion. He spotted students' examples, in particular different approaches, and showed them to the whole class in order to make pupils think of different ways of doing things. Another activity format that Chris made use of was Sherpa-at-work (Trouche, 2004): he spotted an example while circulating in the classroom, and stopped the students to project this spotted example on the IWB for whole class discussion. However the difference from the Spot-and-show format was that the teacher let the student, whose example he spotted, run the example from her computer and at the same time he was explaining/discussing the screen of what was going on. In other words, the Sherpa-student was the owner of the spotted example and she was in charge of the technology. Predict-and-test was another activity format used during the middle segment. The teacher encouraged students to make their own conjectures and then test them out on the computer.

The activity formats for Susan's lessons consisted of whole class teaching as well as student work at computers with the teacher moving around to monitor and provide support. The former was mostly to demonstrate some tool techniques, and to outline what the lesson was about. Since she was teaching this topic with GGB for the first time and most of the students had never used GGB, she spent half of the first lesson using a Technical-demo format to show some tool techniques that they could use for angle properties. She demoed briefly what she expected students to do, and to exemplify she used GGB in modelling on the IWB how to tackle the first question from the printed worksheet. During this, she showed the specific tools in GGB that students would need for constructing the shapes shown on the worksheet. Susan's activity formats were still influenced by non-technology patterns, and not fully instrumented by the technology. For instance, when she made use of Spot-and-show, rath-

er than using GGB on the IWB she would hold up a student's worksheet in order to show others how this student had done the question.

Curriculum script

Examining the tasks sequences used in these cases provided a starting point for looking at how technology featured in the curriculum scripts (CS) of the two teachers, and how these scripts were developing in response to using technology. In particular, post lesson interviews focused on aspects where teachers reported change/development in their thinking about teaching the topic and/or structuring the lesson related to using GGB. Striking contrasts appear, with the CS of the technologically expert teacher being richer and more detailed in this respect than that of the technologically novice teacher. On that note, it was much easier to elucidate information from more experienced teacher about his CS. This richness was also evidenced by the differing nature of, and the degree of emphasis on, CS against resource system. The novice teacher's focus tended not to be on the CS, but was more about developing instrumental knowledge to make it part of the resource system, first for herself personally and then also for her students. For instance, Susan's reflections on what issues came up in lessons that she did not expect focused more on her lack of knowledge of GGB such as measuring acute angles and rounding measurements. These issues have already been raised in the section on resource system and they are more about GGB not yet being part of a functioning personal resource system for the teacher. In that sense she did not have a well-developed aspect of her CS for the topic that is specific to technology, which combines content and technology knowledge. Her CS consisted of following the sequence of her worksheet (prepared for teaching this topic in a non-technological environment) and she was at the stage of learning and adapting. However, Chris, who had been teaching with GGB for many years, had layers of accumulated knowledge about how to teach this topic with GGB.

Time economy

It became clear in post lesson interviews how the use of DGS contributed to time efficiency in lessons. Both teachers indicated that GGB – in particular the angle-measuring tool and the edit/undo option – enabled students to progress faster compared to measuring/calculating angles by hand.

It will let us do lots of measuring without needing to do measuring or calculating so it will measure without us needing to do those by hand. That is a huge time saver. That saves a lot of time over drawing them out. (Chris)

This speed helped the students to produce and engage with more examples without spending as much time capital, therefore, maximised the didactic time.

The speed is that they can see lots of versions of it and all the weird versions. (Susan)

As an expert technology user, Chris's use of working environment and available resources such as control software for showing examples led to efficient use of instructional time. Also, instrumented use of Spot-and-show during students' work at computers provided 'intermediate syntheses' (Assude, 2005), which helped him save time capital. However, the fact that Susan was not aware of some tool techniques introduced some time diseconomy in her lessons.

While students worked at computers in groups, both teachers walked amongst students and guided them through making 'authoritative contributions' (Assude, 2005, p. 201) and posing leading questions in order to increase the didactic time during activity by avoiding students dissipating the limited time capital available.

CONCLUSION

As a novice technology-user, Susan believed that students need more monitoring during technology lessons, and that some room arrangements offer better scope for monitoring and interaction. Both teachers were very conscious of the degree to which GGB formed part of a functioning resource system for their class: in Susan's case, that she was just embarking on establishing such a system; in Chris's case, that he could count on such a system having already been established. In terms of activity formats, most of the orchestration types characterised in Drijvers and colleagues (2010) and Drijvers (2012) studies featured in this study but with more variants. However, an additional type of activity format, Predict-and-test, was identified in my study (resembling an activity format already noted in Ruthven, Deane, & Hennessy, 2009). The interaction becomes between the teacher, class and computer, with the students making a prediction and then testing it out on the computer

rather than teacher validating – or invalidating – it. That shifts the role of the teacher towards becoming an organizer/observer of this process. Also, this activity format appears to be specific to technology use, depending crucially on its use. Therefore, it could be said that the results of this study also contribute to extending the Instrumental Orchestration framework to some extent. There was a notable difference in the way in which teachers instrumented activity formats through the use of technology. The novice teacher tended to customize existing (and more generic) formats for implementing activity. The expert teacher believed that Sherpa-at-work was distinctive to technology use where the involvement of the computer uniquely influenced the nature of the interaction-taking place.

This study makes a threefold contribution. Firstly, it provides a further empirically-based test of the usability and usefulness of the SFPC conceptual framework (Ruthven, 2009) as a tool for advancing research on technology integration. Secondly, in focusing on the teacher dimension (Lagrange et al., 2003) this case study provides an illuminating comparison which math teachers and teacher educators engaged in professional development on the issue of the integration of technological tools could employ to build a holistic understanding of the conditions of technology in ordinary classrooms and shed light on how teachers can adapt new technologies to their teaching. Finally, there might be a third type of contribution through presenting the report of these teachers' teaching with technology in ways that could be directly accessible and useful to other teachers, by reporting practical solutions to concrete problems that a teacher commencing integrating technology into their teaching would encounter.

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