ON THE ADOPTION OF A MODEL TO INTERPRET TEACHERS' USE OF TECHNOLOGY IN MATHEMATICS LESSONS

Jean-baptiste Lagrange and John Monaghan

IUFM de Reims and University of Leeds

This paper examines why researchers adopt a theoretical model in reporting the results of their research. It describes the development of two researchers investigating teachers' use of digital technology in their lessons. The two researchers were dissatisfied in their attempts to understand the difficulties that the teachers they were researching experienced and they got round this dissatisfaction by augmenting their theoretical positions by the adoption of Saxe's four parameter model. The paper introduces Saxe's model, provides accounts of the researchers' development and ends with a discussion of issues raised.

INTRODUCTION

There has been considerable recent work on theories in mathematics education, reflecting researchers' efforts to be explicit about their theoretical assumptions and the links between different theories. CERME has been a focal point for many of these reflections. But why do researchers adopt a (particular) theoretical model in reporting the results of their research? There are many possible answers including: researchers are expected to adopt a theoretical model; a particular model may be 'in vogue'; the researchers work in a culture where a particular model is the accepted model; the model addresses central questions that the researchers seek to understand. We are two researchers, with different national backgrounds, who used Saxe's (1991) cultural framework and especially the four-parameter model to understand teachers' activities in using technology in their classrooms. We look at this model with regard to central issues we sought to understand. The paper addresses CERME Working Group 9's *call for papers* questions: *What divergences appear in the way different perspectives conceptualize empirical realities, tackle practitioners' problems? What is the influence of the different frameworks used on the research process? What is their influence on the interpretation of data?* The paper is a report of what Prediger (2008, p.285) calls 'problem solving "in the wild" of ordinary classroom practices' and considers the dual nature of this theoretical problem solving (theory and researcher). The paper first sets out Saxe's model, then describes why and how Saxe's model was used and ends by discussing issues arising.

SAXE'S MODEL

Saxe's model centres on emergent goals under the influence of four parameters: activity structures; social interactions; prior understandings; and conventions and artefacts (see Figure 1). Emergent goals are not necessarily conscious goals but are goals that arise from a problem in an activity and once the problem is solved the emergent goal usually vanishes. Saxe's model was conceived to explain mathematical practices in cultural transition (the Oksapmin tribe dealing with decimal money transactions) and is cultural-historical in its conception of artefact and interpersonal mediation in social practice. It has been applied in studies of street-sellers' practices (Saxe, 1991) and technicians' volume calculations (Magajna & Monaghan, 2003). It is, in our view, quite general in its application and particularly suited to the interpretation of innovative technology-based activity, such as teachers using digital technology due to unexpected goals emerging in this activity and the influence of cultural views regarding technology. The four parameter model is the first component of a three component theory: analysis of practice-linked goals; form-function shifts in cognitive development; the interplay of learning across contexts, i.e. Saxe's model is a construct and is part of Saxe's broader theoretical framework.

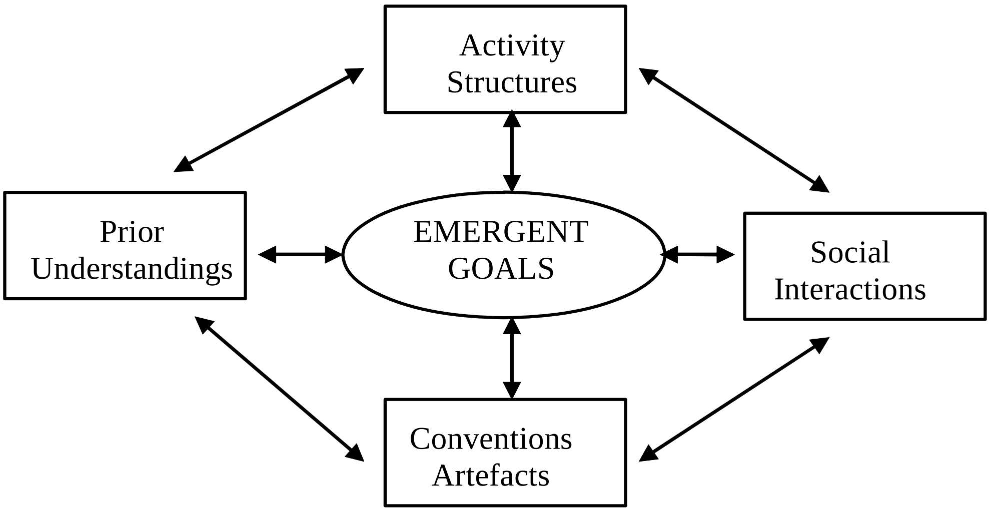

Figure 1 Saxe's four parameter model

We provide examples from Monaghan (2004) to illustrate the parameters, in the case of teachers using ICT, their interrelatedness and their impact on emergent goals.

The *activity structures* parameter "consists of the general tasks that must be accomplished in the practice- and task-linked motives" (Saxe 1991, p.17). In mathematics lessons this parameter concerns tasks that the teacher sets and the lesson structure. The tasks students engaged with in non-technology lessons were textbook exercises and the lesson structure was teacher exposition and examples followed by students doing textbook exercises. The tasks and cycles of the technology-based lessons varied considerably over the teachers and over time for each teacher.

The *social interactions* parameter concerns relationships between participants, teachers and students, in lessons and how these relationships influence participants' goals. It is very difficult to summarise differences between technology and non-technology lessons with regard to social interactions so we provide one example. Teachers spent much more time speaking to two or more students (as opposed to speaking to an individual) in technology lessons. Further to this the computer tools not only performed mathematical actions but also recorded the product of these actions and this provided a common basis for a group of students to collaborate.

The *conventions and artefacts* parameter, consists of “the cultural forms that have emerged over the course of social history” (ibid p.18). Cultural forms in mathematics lessons include techniques linked to traditional, not computer-based, tasks and tools and these can clash with new practices using new tools. A teacher using a spreadsheet planned a lesson focusing on ratio but the students’ and her emergent goals in the lesson were on getting the spreadsheet cells right, not only the correct equation but a suitable cell format. She commented after the lesson that she was unhappy with this focus on ‘cell-arithmetic’ and questioned “is this maths?”

The *prior understandings* parameter, includes teachers’ content, pedagogical and institutional knowledge, “the prior understandings that individuals bring to bear on cultural practices both constrain and enable the goals they construct in practices” (ibid p.18). The term ‘individuals’ is important because the different levels of experience participants in practice “bring to bear different (arithmetical) understandings on practice-linked problems and consequently their goals differ” (ibid., p.18). One teacher commented that with technology it was “back to being like a student teacher” because you are not prepared for any eventuality.

These parameters interact and impinge on practice-linked emergent goals. With regard to *conventions and artefacts* and *prior understandings* and the teacher who questioned whether cell arithmetic was mathematics, for example, this question was legitimate for her because her prior understanding of mathematics was formed in a public understanding of what (school) mathematics is. Further to this she voluntarily planned the task and wrote a worksheet which resulted in a focus on cell arithmetic and this discomfort only emerged in practice because her emergent goals in the lesson were shaped by the need to get the spreadsheet cells right.

HOW AND WHY WE CAME TO EMPLOY SAXE’S MODEL

We, in turn, state why we adopted Saxe’s model in our search for answers to central questions in our research.

Monaghan’s case

I have a long history of using digital technology in my own teaching and in working with other teachers who endeavoured to use it (some found it easy, others found it very difficult). In the late 1990s I ran a research project where I deliberately set out to work with teachers who had not used digital technology in their classrooms but who wished to do so. I worked closely with 13 secondary school teachers over a full school year, leading training sessions and conducting many interviews and observations. Teachers chose the technologies they would use which included computer algebra and dynamic geometry systems, graphic calculators and computer graphic packages and spreadsheets. Each teacher was video-recorded several times over the year (51 recordings in total) including one recording of a lesson at the beginning of the year where they did not use digital technology. Video-recordings were analysed using systematic classroom analysis notation (SCAN; Beeby et al., 1979). SCAN analysis involves viewing lessons as a series of activities, e.g. teacher exposition, students working, teacher-student dialogue. Each activity is viewed as a series of episodes, e.g. coaching, explaining. Events sub-divide the episodes into social and linguistic categories, e.g. managerial, confirmation. Coding consisted of categorising 30-second blocks with regard to the teacher, the students and the episode. I wrote and co-wrote a number of papers on this work but I still felt 'unsatisfied' – there were difficulties that the teachers had experienced in their practices that I could not explain in a satisfactory manner. In one paper (Monaghan, 2001), for example, based on SCAN analysis, I produced fairly strong empirical evidence that teachers using technology did not change from being 'didacticians' to 'collaborators-with-students' (as some constructivists would have it). I showed, for example, that many teachers became what I called 'techno trouble shooters' and I described the material basis for this (the set up and use of classrooms and computer-rooms) but this was not the deep understanding I was looking for.

Of the many intellectual influences on me at that time (≈2000), one that fitted with my thinking was Olson's (1992) work on teachers' routines. Olson views the study of teachers' routines as a means to interpret teachers' actions.

> Through classroom routines teachers express themselves. To understand what is being said in classrooms it is important to know what the routines are because such routines are rituals – performances involving significant symbols. These symbols belong to the tacit dimension of practice – what is said in the classroom that is not spoken directly.

As a teacher-educator who is familiar with teachers' routines these words ring true to me but as a researcher in this project with teachers using digital technology I had a problem with a focus on routine – my project teachers, who were using digital technologies in the classroom for the first time, did not have routines – they were experimenting and doing lots of different things (according to the material conditions of their classrooms). I needed another means to interpret the difficulties my project teachers experienced and the diversity of in-class practices they exhibited. I had, with Zlatan Magajna, used Saxe's model in his work on technicians' mathematical practices and I considered analysing my project teachers' practices via Saxe's model. Initial considerations looked promising. I feel it is worthy to note, for discussion at CERME WG9, that this analysis via Saxe's model was quite different to my SCAN analysis. The SCAN analysis was "local" in as much as it concerned categorising actions in specific (30 second) time intervals; further to this it was procedural and, as far as is possible in qualitative analysis, objective. The analysis via Saxe's model was "holistic" in that whole lessons and often sequences of lessons informed categorisations and took the form of confirming or not the influence of parameters in teachers' practices.

Lagrange's case

My approach is to consider theories to address an overarching question: considering the potentialities of technology and the strong emphasis that society puts on its educational uses, why are these uses so rare, and why, when they exist, are they often deceiving? In this approach, I was brought to focus on the teacher using technology and especially on his(her) classroom activity, and to search for theoretical frames that could help in that endeavour. This approach is reflected in the contributions I wrote for CERME 2, 3 and 4 and in a recent paper (Lagrange, Ozdemir-Erdogan, to appear).

In CERME2 (Lagrange, 2002) I reflected on a meta-study conducted by a group of French researchers of a comprehensive corpus of international publications about research and innovation on the integration of technology into mathematics. The study built a framework of several dimensions in order to account for trends in the corpus. A statistical analysis provided evidence that dimensions considering the impact of technology upon the learner and mathematical knowledge were addressed by a wealth of studies and theories giving account of successes of the use of digital technologies mostly in 'laboratory conditions'. The other dimensions related to the 'ecology' of technology in educational settings were poorly addressed in term of research studies as well as in terms of theoretical frameworks that could give account of successes but also of failures in 'real school conditions'. We considered a 'teacher dimension' but found very few studies addressing this dimension.

In CERME3 (Lagrange, 2004) I focused on problematising teachers using technology. Returning to the overarching question of a discrepancy between the potentialities of technology and the actual uses, my interpretation was that innovators and researchers made an implicit assumption: new technologies and the associated didactical knowledge could easily be transferred to teachers by way of professional development and training. I thought that this assumption had to be questioned because, in a country like France, uses of technologies are deceptive although efforts have been made to train teachers. In my hypothesis the existing corpus of didactical knowledge and frameworks about digital technologies use was not sufficient to really help teachers integrate technology. Thus research had to study the teacher and try to look at his(her) action in the light of new frameworks.

Analysing research (especially Kendal &Stacey, 2001 and Monaghan, 2004) about the teacher and digital technologies strengthened the idea of a difficult integration, contrasting with research centred on epistemological or cognitive aspects. Kendal and Stacey brought evidence that, even in a research project, teachers' use of technology can be very different to what was intended because of the influence of teachers' beliefs and habits on the way they use technology in the classroom. Monaghan did a thorough analysis of teachers' classroom activity showing that innovators' expectations for a more open classroom management and for more emphasis on mathematics in teacher-students interactions were not fulfilled.

These studies were a first entry into the complexity of teachers' relationship with technology use. To give account of this complexity and to think of new strategies for a better integration, I considered that an activity theory framework was needed. The reason is that, while teacher's activity in the classroom is problematic, it has its own logic and consistency. I believed that an activity theory framework would help to elucidate the difficulties encountered by teachers using technology in the classroom, while giving insight on how their activity and professional knowledge evolve during these uses.

In CERME4 (Lagrange, Dedeoglu & Erdogan, 2006) I tried out models of teachers' practices when using technology. Working with two doctoral students, observing and analysing teacher practices in two fields – teachers at lower secondary level using dynamic geometry and teachers at upper secondary level non-scientific stream using a spreadsheet, we (Lagrange, Dedeoglu & Erdogan) noted that classroom use of technology reinforces the complexity of teacher practices by introducing a number of new factors. Our aim was to understand the impact of these factors on systems of teachers' practices, and the conditions for classroom use of technology. We considered Robert and Rogalski's (2005) "dual approach" and we tried to complement this approach by using models dedicated to teacher use of technology: Ruthven and Hennessy's (2002) model addressed teachers' views of successful use, whereas Monaghan (2004) developed a model of teacher classroom activity inspired by Saxe (1991), as outlined above.

We noted in the conclusion that, combined with classroom observations, this model can help to make sense of phenomena in the classrooms that we observed. For instance, it is a general observation that teachers teaching in a computer room devote much time to technical scaffolding when they expected that technology would help their students to work alone and that they could act as a catalyst for mathematical thinking. Ruthven and Hennessy's model helped us to understand how a teacher can connect potentialities of a technology to her pedagogical needs, overlooking mathematically meaningful capabilities. The observation of two teachers using dynamic geometry showed what happens when the connection does not work: the teacher tries to re-establish the connection by becoming a technical assistant.

Saxe's model was chosen to appreciate teachers' specific positions using the parameters and to make sense of their classroom activity in similar lessons. We considered two teachers, one positively disposed towards classroom use of technology, and the other not, both of them experienced and in a context in which spreadsheet use was compulsory: a new curriculum in France for upper secondary non-scientific classes. We contrasted the two teachers through the viewpoint of Saxe's parameters and analysed their activity. In the classroom observations, we noted that teachers had to face repeatedly episodes marked by improvisation and uncertainty. The notion of emergent goals was central to analyse this flow of unexpected circumstances and questions challenging teachers' professional knowledge and parameters helped to understand how teachers react differently with regard to this flow. We also used other didactical constructs like *instrumented techniques* (Lagrange 2000) and *milieu* (Brousseau, 1997) that helped to highlight weak points in these teachers' activity: teachers seemed not to be able to open a clear dialogue with the students about why it is better to use spreadsheet techniques than usual paper pencil techniques. They also seemed to not have a clear view of the *milieu* they should establish for their teaching goals. Saxes' approach helped to understand the reasons for these weaknesses, mainly grounded in the different cultural representations between students and teachers (Lagrange & Erdogan to appear).

The analysis clearly separated the two teachers. One teacher was at an impasse. Her tendency to act on an exposition/application activity format and a teacher/student individual interaction scheme had been reinforced by the spreadsheet and consequently application was replaced by narrow spreadsheet tasks. With regard to individual parameters, the other teachers' dispositions towards technology integration were, in our opinion, excellent, but globally they conflicted and this teacher had to make real efforts to get herself out of such conflicts. Saxe's approach helped us to understand why good dispositions are not a guarantee of easy integration.

Using Saxe's model gave us more than what we expected. Because it is a cultural approach, it drew our attention to how cultural representations of the spreadsheet can differ, making it difficult for teachers to anticipate and understand what students do with the spreadsheet.

DISCUSSION

We consider issues raised above under two headings: the need for an augmented framework; how to evaluate the productivity of a theory.

The need for an augmented framework

Although we have developed as researchers in different countries we have, for many years, corresponded on matters concerned with the use of technology in the classroom. The constructs available to us, however, and in our opinions, for viewing teachers' activities in technology-based lessons were insufficient because they focused on teachers' established routines and technology messes up teachers' routines. Saxe's model, with its central emergent goals, provided us with a construct to view teachers' activities in technology-based lessons precisely because emergent goals arise from unexpected things that happen in such lessons.

A second reason for augmenting a theoretical framework lies in the gap between data analysis and data interpretation one can trust. Very often researchers conduct research with a framework that integrates methodology and theoretical approach, where data analysis leads the researcher to data interpretation. This appears very sensible unless one finds that the data analysis does not answer 'why' questions. This happened with Monaghan. SCAN analysis revealed large differences between teacher time spent (in technology and non-technology-based lessons) in teacher-whole class exposition, eliciting ideas from students, etc. (see Monaghan, 2001 for further details) but did not contribute to a deep understanding of why this was happening. Saxe's model, in Monaghan's opinion, provided a means to a deep understanding of these phenomena.

In augmenting a framework one should ensure that the augmentation is consistent with the underlying assumptions of the broader framework. In the case of Saxe and us there is a shared value of the importance of activity and mediation through artefacts and people. Further to this Saxe's model as a construct makes few assumptions. We have focused on emergent goals and parameters which interrelate with them. Emergent goals are ubiquitous in every human activity – so much so that we rarely notice them. Saxe's model has what Dawkins (2008), in discussing Darwin's theory, calls a large explanation ratio, 'what it explains, divided by what it needs to assume in order to do the explaining – is large'.

How to evaluate the productivity of a theory?

In our opinion two outcomes impinge on the usefulness of a theory or model, understanding and widening the research focus/questions. First, the theory or model should provide specific understanding with regard to the focus of the research. Comparing the contribution of Saxe's model to other frameworks helps to evaluate this specificity.

In Lagrange's national context two frameworks are dedicated to learning (Theory of Didactical Situations, Anthropological approach) and a framework is dedicated to the teacher (Robert and Rogalski's (2005) 'dual approach'). These frameworks were useful, but the conclusions we drew did not constitute sufficient progress towards understanding the situation of teachers using technology.

As said above, considering how teachers dealt with the "milieu" and the spreadsheet techniques helped to highlight weak points in their activity. But it was not our central question. The question was why it is specifically difficult, even for experienced teachers, to develop a consistent activity when using technology. Then, the question is, why are those teachers not aware of these weaknesses, or, if they are, why do they not change their activity? Saxe's framework provided a means for a deeper understanding of these weaknesses: rather than a poor didactical analysis, they reflect teachers' uncertainty, and differences between students and teachers, with regard to spreadsheet representations and the fact that it was difficult for teachers to anticipate or understand what students do with spreadsheets.

Robert and Rogalski's approach assisted a consideration of the complexity of teachers' activity. We learnt from that that we would have to consider a plurality of factors with complex links between them. We anticipated and observed that, rather than bringing solutions, technology amplifies complexity. This result is, however, too general and did not account for the uncertainty experienced by teachers using technology in the classroom. The 'dual approach' postulates that practices are complex *and* stable, that is to say that teachers' practices do not change easily because they are constructed to deal with the complexity. In contrast, teachers' practices in dealing with the complexity of classroom use of technology are far from stable and Saxe's framework assisted an analysis of this unstability as a flow of emergent goals.

A second criterion for the useful contribution of a theory or model is that it helps to widen the research questions. The main reason for choosing Saxe's model was the uncertainty of teachers' activity when using technology and the need for a holistic approach of this activity. We were attracted by the model rather than by the whole framework: goals and parameters seemed adequate to analyse teachers' classroom activity, and they actually were. But after using the model, we reflected why this model was productive. We realized that there should be something in common between our teachers and the New Guinea Oksapmin from which Saxe built the model. This should be that both had to deal with a new artefact involving deep cultural representations. In the Vygotskian perspective, Saxe was interested by the impact of culture upon cognition and he chose the Oksapmin people because in their case there was a conflict of cultures: these people have a traditional way of counting, using parts of the body as representation of numbers; some of them trade in the modern way, but their traditional way does not permit them the calculations that this trade requires. This comparison brought us to consider cultural systems involved in classroom use of technology. Students saw the spreadsheet as a means to neatly display data. It is consistent with the social representations of technological tools. People are generally not aware of the real power of the computer, which is the possibility of doing controlled automatic calculation on a data set, even when they used spreadsheet features based on this capability. In contrast, the teachers saw the spreadsheet as a mathematical tool. They were disconcerted because they were not conscious of the existence of other representations. Clearly, Saxe's approach helped us to widen our reflection about the impact of cultural views associated to computer artefacts upon classroom phenomena.

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