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'It's getting me thinking and I'm an old cynic' : exploring the relational dynamics of mathematics teacher change

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Abstract

Actor-network theory is a way of describing and understanding the complexity of social change. This article explores its relevance to understanding teacher change in mathematics education by considering a single teacher change narrative. This is centred on a veteran teacher of mathematics who participated in a teacher led, teacher-educator-supported professional development project. The project had two foci: investigating forms of school-based collaborative professional development in the context of developing a dynamic approach to teaching and learning geometry. Three conceptual tools appropriated or adapted from actor network theory are used to describe and analyse features of this teacher narrative. These are *relationality*, *translation* and *fluidity*. Some implications are considered for developing accounts of, and actions for, mathematics teacher change.

Key words: Mathematics teacher change, mathematics teacher professional development, mathematics teacher education, actor-network theory, collaborative professional development, dynamic geometry software

Introduction

This article proposes that concepts drawn from actor-network theory (Callon, 1986; de laet & Mol, 2000; Latour, 1999, 2005; Law, 2004, 2007) are useful in understanding and guiding action for teacher change. A variety of models of teacher change have been proposed. Such accounts describe the relationships between factors such as a teacher's knowledge, beliefs and attitudes, the process of

professional experimentation, the influence of the outcomes of change practice and external sources of information and stimulus. These models variously propose linear (for example, Guskey & Huberman, 1995; Guskey, 2002) or more interconnected processes, (for example, Clarke & Hollingsworth, 2002). Such models focus on change of individual teachers with other teachers being modelled as 'external sources', implying a particular - and, it is argued here, questionable - view of the nature of social reality and of individuals. The need to develop accounts of professional development that centre on relationality is particularly important when describing instances of collaborative professional development. The models cited above do not, I contend, account for all processes and phenomena that enable teacher change. Actor-network theory draws attention to the important role tools and other entities have in enabling teacher change. Such tools include both pedagogical tools and the practices used for professional development. Thus, considering teacher change and professional development in relation to actor-network theory allows for a more extensive understanding of what constitutes the situation in which change takes place and the forms of relationality that enable it and that it entails.

Actor-network theory is not the only possible way of recognising these concerns in the context of mathematics teacher learning. Perspectives such as enactivism (for example, Davis & Sumara, 1997) and activity theory (for example, Russell & Schneiderheinze, 2005) address similar concerns. However, what is distinctive and potentially useful about the actor-network approach lies in a radical ontology: an entity is its relationality. Actor-network theory starts from the view that reality is "complex, diffuse and messy" (Law 2004, p.2). It is an:

> [a]pproach to sociotechnical analysis that treats entities and materialities as enacted relational effects, and explores the configuration and reconfiguration of those relations […] Actor-network theory is widely used as a toolkit in sociotechnical analysis, though it might better be considered as a sensibility to materiality, relationality, and process. Whether it is a theory is doubtful (Law, 2004, p. 157).

As an alternative to considering it a theory, Law (2007) describes the actor network tradition as a "disparate family of material-semiotic tools, sensibilities and methods of analysis" (p. 2). In this article, I use the whole phrase 'actor-network theory', as it is the generally accepted referent for the tradition or approach I am drawing on. However, I share Law's caution and reservation about any epistemological commitments that the word 'theory' might imply. Further, Latour (1999, 2005) suggests that the word 'network' in the phrase 'actor-network' may also be misleading. An actor-network is not a static fixed entity such as, for example, a transport network that conveys goods or passengers without changing them (Latour, 1999). A defining feature of an actor-network is that the relationships between different parts of the system are dynamic. This is so in two ways. Firstly, these

relationships are not fixed but change. Secondly, it is the changing relationships between entities that create and define what those entities are. Thus the entities are also in an on-going process of change. The actor-network is, then, both the entities and relationships that simultaneously are formed and changed through the relational process. Given the way in which the term actor-network may mislead or obscure, Law has suggested that this approach might be better termed material-semiotics. The term 'material-semiotic' refers to a central concern with the interrelationship between human actors, materialities (tools and artefacts), and the production and enactment of meaning.

This article is not presented as a full actor-network account of an episode of teacher change. Rather, I appropriate three particular analytical tools or sensibilities (Law, 2007) and illustrate their potential value by using them to highlight particular features of a teacher change narrative. These three tools are *relationality*, *translation*, and *fluidity*. 'Relationality' focuses attention on the nature and quality of relationships. This includes openness to discovering what relationships may be important through enquiry rather than starting from a prior structural form or model. 'Relationality' also points to openness about the relative importance of the role of different types of relationships and entities including materialities. The term 'translation' is based on Callon's (1986) account of the way meaning and relationships are produced and transformed in a change process in relation to the purposes of the actors involved and the interplay of interests and identity commitments. I take as an example the way in which the meaning of 'collaboration' is translated through the teacher-change process. 'Fluidity' refers to the qualities of being adaptable, flexible and responsive (de Laet & Mol, 2000). This concept brings insight into why both dynamic geometry software and models of collaborative professional development are powerful tools for enabling teacher change.

Constructing an actor-network narrative

To develop and illustrate these concepts in the context of teacher change, I focus on one veteran teacher, Clive. The name is a pseudonym as are the names used to refer to his school and colleague. Here, I use the term to recognise that Clive is a teacher with 35 years of experience. During this change story, Clive was teaching at a high school, Waterfield, for students aged from 11 to 16 years old, in a small rural town in the UK. Clive was a participant in a professional development project focused on developing geometry pedagogy through a process of collaborative professional development.

In this article, I position Clive as the protagonist, the central character. However, Clive's story interweaves with other stories including my own as a teacher educator. This quality of interwoven narratives is also relevant to other aspects of the project Clive participated in. The project intentionally braided a curriculum and professional development project with research into the forms of collaborative professional development teachers enacted. An attraction of actor-network theory is that

it can allow for, and perhaps calls for, multiple narratives. In particular, it allows teacher educators to be repositioned within narratives of teacher change rather than positioning them as external agents of change.

Actor-network theory may be viewed as "an empirical version of post-structuralism" (Law, 2007, p. 6). As such it does not seek to describe a reality that "is out there to be examined" (Edwards, 2009, p. 49). Rather, it describes the creation of reality that occurs through the process of examination. The actor-network approach has analysed this process of production in both social and other sciences (Law, 2004). Although empirically rooted in a particular set of events, the article is intended as a contribution to theoretical discussion rather than a research case study. However, I do include an account of the ways in which the material presented in this article was gathered and produced when describing the professional development project itself. My aim here is to blur the boundaries between the teacher education and research aspects of this project. This reflects fluidity in my roles as project co-ordinator acting as a supporter of teacher change and researcher, who is in part a narrator (that is a constructor of narratives) of teacher change.

The boundaries of what constitutes an actor-network are necessarily open and, from an analytical perspective, always extendable. The actor-network of relationships and entities in this story of change is, then, not a set of discretely bounded objects. A relational analysis suggests the need for an infinite map (Deleuze & Guattari, 1987) to represent social processes. Given that such a map can never be completed, the process of analysis calls for a longhand tracing of associations (Latour, 2005; Perillo, 2008). The choice when to end the process of tracing is practical, pragmatic and informed by the purposes that are being enacted rather than one that attempts to mirror or describe an external reality. In the narrative that follows, I discuss those elements of the actor-network that are most relevant to the purpose of illustrating the relevance and developing an account of relationality, translation and fluidity.

Although the exploration of teacher change is analytical, the purpose is to inform, guide and support action for teacher change. The way the phrase 'teacher change' is often used implies a desired type of change - something positive or worthwhile. There are various conflicting and overlapping understandings of what is positive or worthwhile change in mathematics education. These different understandings are usually implied rather than explicitly articulated. However, the account I offer suggests that purposes are important. In this case, one of the purposes of the project Clive engaged in - to encourage reflection and thought about pedagogy - was at least partially realised.

The title of this article is from a statement by Clive:

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I was quite sarcastic when we started, I can tell you, but I just felt that it went very well and I was looking for other things to do with it, you know other areas to expand the package into. I was thinking today I was doing parallel lines with my year seven and I thought, 'mmm, I can't be doing with this, there must be a better way than this' so it's getting me thinking and I'm an old cynic.

The section that follows is a vignette that describes Clive and the professional development project. It is, in part, based on an extended interview with him. All quotations are from Clive unless otherwise stated. I refer to myself in the third person. Whilst, clearly, I am the author, one intended effect of this literary device is to also place myself as an actor within the narrative.

A story of teacher change

Mark was co-ordinating a series of school-based professional development projects that took place over the course of a calendar year. These were focused on dynamic geometry software as a focus for developing collaborative practice. The National Centre for Excellence in Teaching Mathematics (NCETM) funded these projects following a competitive bidding process. The NCETM, founded in 2006, is a relatively new organisation in the UK. It shares a similar acronym to the National Council of Teachers of Mathematics (NCTM), a membership organisation for teachers of mathematics in the US. However, in contrast, the NCETM was created and is funded by the government education department and is managed for the government by an external private company and has a directorate that has autonomy in terms of how policy is implemented. The NCETM's purpose is to support mathematics-specific continuing professional development (Hoyles, 2010). One of the ways that it does this is to offer grants for various professional development, enquiry and research projects.

Shortly after it was established, the NCETM invited bids for grants for projects that would explore 'collaborative practice' in ICT contexts. Mark and a colleague approached five schools including Waterfield to be partners in a bid for a grant for a project focused on developing a dynamic approach to teaching geometry. An aim of the project was to explore the conjecture that relatively unfamiliar mathematical environments, such as dynamic geometry software, might promote and support collaborative processes and teacher reflection. Project teams in each of the five participating schools defined both the mathematical foci and the form of collaborative professional development they wished to enact.

After the bid was successful, representatives from the five schools met to discuss and agree on the research and collaborative practice protocols. Each school then engaged in an enquiry process similar to action research following a cycle or cycles of reflection, planning and action. Alongside these school-based enquiries, Mark recorded meetings with project teams and individuals, gathered documents and conducted interviews.

Clive had taught at Waterfield nearly all his career. At a departmental meeting Clive was told about a project using dynamic geometry software by Anna, his Head of Department, who had recently joined the school. Anna asked Clive to work with her as one of two collaborative pairs which together made up a project team of four. The team meets to discuss the "kind of lessons and directions we'd like to take and how we'd like to use the [dynamic geometry] package". Anna chose to pair with Clive as she hoped to support him in "varying the style of his lessons", believing that he was resistant to experimentation.

At the start of the project Clive was a "bit cynical". The project team of four met and chose to look at circle theorems with a class aged 14 to 15 years old. The topic of 'circle theorems' is an area of the geometry curriculum in the UK. Students are expected to know and use facts about the relationship of angles in a specific set of constructions that can be drawn in circles. For Clive, the choice of circle theorems was a good one because it is "all in the exam paper" so "it's worthwhile doing and worthwhile spending time on."

Before the project Clive had taught the topic in the following way:

> I just blocked them into two blocks of three and said this is the first theorem. Then they do a load of questions on that and then this is the second theorem they did a load of questions on that and hopefully by the time they got to the third theorem they were starting to pull the first two together. It was a terrible subject to teach, I hated teaching it.

The initial work with Anna and two other colleagues meant that Clive "realised that you could actually end up deriving all the circle theorems just using the dynamic geometry package, and that was pretty good." There was a change during this planning process from scepticism to a willingness to engage with a different way of teaching.

> I thought that [to talk with colleagues] was a benefit. A benefit to me because I must admit I was a bit cynical. But I thought "well I've always taught circle theorems in this way, and it's about time [to try something different] maybe we'll give this a go".

Clive and Anna worked together to develop a series of lessons so that their students could use dynamic geometry software to "derive the circle theorems". Dynamic geometry software is a virtual environment in which objects can be connected in such a way that mathematical relationships can be specified. This allows mathematical relationships to be explored through transformations. Clive was "pretty sarcastic" about using dynamic geometry software. However, he worked with Anna to produce a series of lessons. The first two lessons developed involved "teaching" the students "how to use the package". These are then the basis for lessons in "which they discovered the theorems for themselves" and so Clive "didn't have to tell them". There is an emotional change from his previous dislike of the topic. He felt the lessons went "splendidly".

The pedagogy in the collaboratively planned lessons contrasts with his previous way of teaching circle theorems. Clive tells us that using dynamic geometry software meant that "they actually knew it". He thinks this is because "they like to see the thing moving about and actually witness things happening rather than me saying this happens and that happens". He compares this to his previous practice of

"trying to fill an empty vessel" in which he "gives the mathematics" to the students. Now students were able at times to "show me something that they'd done that I couldn't do". He reflected that:

> In a strange way it sort of helped form good relationships, somehow, because they were able to it for themselves, that gave them a feeling of like security, not security exactly, but they had developed themselves because they'd done it themselves.

For Clive an important reference point was the evaluation and test he gave at the end of the topic: "they did significantly better on the questions on the theorems they'd derived themselves. It was much more powerful than when I gave them [the theorems] to them." This is an example of practices and beliefs that were sustained whilst others changed. His discourse both about circle theorems and parallel lines continued to imply a conception of geometry that the examination syllabus supports, that is a series of disconnected topics. There were also limits to developments in his pedagogical knowledge. For example, although the dynamic geometry software "encouraged" him to "do proof", his account indicates that 'proof' here means demonstration of theorems in all possible cases rather than engaging in deductive proofs.

The change in Clive's practice occurred whilst working with Anna. This involved planning together, which led to an: "outcome [that] was much better because of the collaborative effect of talking to one another". Anna came to see Clive differently: "he is quite a perceptive sort of person really, he is certainly far more observational than I am. I think he notices things that went by me." Clive and Anna also observed each other teaching. For Clive this felt different than other experiences of being observed:

> Because I felt that when Anna was observing me, when we'd finished at the end, we were both able to comment constructively about the lesson. It was not particularly about me and how I'd pitched the lesson. It was just the lesson itself and how we felt it went. So when you got two people together talking about the same thing then you don't feel threatened at all.

Towards the end of the project, Mark met with Clive and Anna and interviewed them separately about the project. Mark also collected a variety of materials. These included a report authored by teachers in the school as well as materials developed during the project and samples of students' work.

During the interview with Clive, Mark was struck by and surprised at Clive's enthusiasm and reflections on his participation. This surprise arose from the difference between Clive's description of his experience and contribution in the interview and Mark's expectation. This expectation may have

been due to his interpretation of what Anna had told him about Clive. Anna had felt Clive was one of the teachers in her department less open to change. Alternatively, perhaps he had decided that Clive was similar to veteran mathematics teachers who were resistant to change that he had worked with when a school mathematics teacher himself. Whatever the reason, later Mark reflected that perhaps he, like Clive, had been something of a cynic. In Mark's case, the cynicism was about Clive's capacity to be co-creator of change as a veteran teacher whose style has previously included a lot of teaching by telling and student practice of examples.

Relationality

Clive's relationships with other actors changed as did his relationship to himself. His relationships to Anna and his students developed and there was a reciprocal change in their relationships to him. He began by seeing himself as a cynic and sceptical and later describes himself as someone who was now "thinking" about his practice. There are also indications of a shift in his students' relationships with mathematics as they experience "discovering it for themselves". The actor-network perspective suggests that such changes cannot be treated independently: change is a quality of the actor-network as whole. This particular narrative draws attention to three aspects of relational change: the importance of what does not change, a shared quality of change, and the need to be inclusive about what contributes to change.

Clive's trajectory from sceptic to enthusiast has a significant reference point: the importance of the syllabus and the national examination. He believes that circle theorems are a good choice of topic because they are a topic that often is included in the examination. He convinced himself of the value of the new approach by giving them "a little test". We might think a focus on examination outcomes would tend to inhibit experimentation and change. However, in the specific set of circumstances here and in relation to other features of this particular narrative, that focus supported change. More generally, a range of stabilising factors may be important in enabling change. The response and enjoyment of his students in using dynamic geometry is also important to him. Here, we see an instance in which student outcomes are a factor in supporting or leading to changes in beliefs (Guskey, 2002).

The forms of translation in an actor-network are, it is claimed, not generally homogeneous (Latour, 2005). However, in this case there does appear to be a similar quality to the changes that take place in a variety of relationships. A number of descriptors are relevant to a variety of the changed relationships described above. There is an increase in shared authority, dialogue, respect, and

security. For example, the quality of change in Clive and Anna's relationship parallels the change in relationship between Clive and his students. The actor-network perspective suggests that relationships themselves interrelate to provide the stability that confers continuity and identity. Each relationship is not independent. Clive's narrative may indicate that when one aspect of relationality changes others that are connected to it also change in similar ways.

In actor-network accounts, the concept of symmetry (Callon, 1986) is used to indicate the importance of being inclusive about what is relevant to a change process. The quality of symmetry here relates to 'sameness' of influence different actors have in change processes rather than the specific uses the term has in mathematics. Assumptions are not made in actor network accounts about what will be relevant or important when developing an account of a change process outside of or prior to the account itself (Law, 2007). As humans and other entities are all part of the actor-network the same type of explanation should be provided of their different roles (Law, 2007).

It is important, in this case, to recognise the role dynamic geometry has in the change narrative. During the early part of the project, dynamic geometry has mobilising and directing power that is not recognised by Clive until he reflects later "it encouraged us to say we'd do proof as part of the lesson", it "led the way" towards the choice of project focus, circle theorems. It also has a disciplinary power. It means that Clive knew his activity was in keeping with "your expectations". I develop this discussion of dynamic geometry below.

More generally, rather than focusing either on the teachers or 'external' instigators of change, the dynamic for change may arise from multiple features and relationships. Such features may not be spatially or temporally proximate, and the visibility of a feature may not correspond to the importance of that feature (Latour, 2005). The change in Clive's practice cannot be explained by only considering actors immediately and visibly present in the school or project he participated in.

What constitutes the system as an analytical unit is expandable both socio-culturally and in terms of the inclusion of other systemic fields of understanding. Some of the actors may appear to be peripheral and of little significance, both come to be recognised as more significant as perception and focus shifts from the local to the general or across the "scales of time" (Lemke, 2000). For example, in Clive's account the NCETM does not appear directly although what he refers to as "your expectations" in the project does. Nevertheless, the NCETM not only funds the project but significantly influences the form and focus of professional development.

Translation

Callon (1986) studied the intervention by a group of researchers' in a scallop fishing area that led to the formation of social groups with shared identities, the development of socio-economic practices and the production of knowledge. He used the term a "sociology of translation" to describe this process. Translation has four aspects. *Problemetization* happens when an issue is identified and defined that is recognised as an issue or problem for a variety of actors. This is a dynamic process that involves negotiation and contestation that creates "alliances, or associations, between entities, thereby defining their identity and what they 'want' " (p. 204). This leads to a process of *interessment* in which the identity of different actors in the process is stabilized through interaction with each other. This stabilisation allows for *enrolment* of actors in preparation or agreement to act. Enrolment then allows for a *mobilisation of allies* as the researchers come to have a position in which they are able to stand for and represent other entities in the network through a variety of discursive representations. The process of translation is one in which actors pursue interests, have purposes and intentions that can be more or less conflicting or aligned and as needed persuade, block, negotiate, resolve, and compel each other to do and be in certain ways. This illustrates Foucault's conception of power's local production (Fox, 2000). Rather than being held or possessed, power circulates through and in the changing relationships between actors.

These analytical categories are potentially useful in considering the background and context to the project; for example to describe the establishment of this National Centre for Excellence in Teaching Mathematics (NCETM) and its early history in relation to the 'problem' of mathematics teacher professional development. Similarly, the project itself arises from problemetization of the role of collaboration in professional development. The activities that followed the bidding process - the enactment of the school-based projects through to the process of reporting, including the production of this article, have correspondences to Callon's phases of translation. Other aspects of Clive's change story diverge from this process. Nevertheless, the concept of translation is particularly useful if it is understood more generally as a process of transformation and production of meaning through relationship and association in which power is present. Here, I trace one such series of translations: the meaning and enactment of 'collaboration'.

The invited focus for project bids by the NCETM was for "research pathfinders" focused on collaborative practice in an ICT context. Before the establishment of the NCETM with government funding, the group of mathematics educators who held key positions in the NCETM in its first year had established and led a series of "collaborative practice" projects. A report on this work was already published (NCETM, 2006) at the time the bid for the dynamic geometry project was written. This report described three research sources that had informed the collaborative practice model as well as reporting on how this model was used. These sources were described as "the East European model", "Japanese Lesson Study" and "Lesson Lab" (NCETM, 2006). Thus elements of these culturally situated different professional development practices are translated into a model of collaborative

practice. This in turn is enacted and together these different happenings are transformed into a report.

In this eleven page report, the term 'collaborative practice' appears twenty six times in various forms. The term 'professional development' is used three times. The term collaborative professional development is not used. The discursive construction focuses attention on collaboration centred on practice and omits the possibility that teachers might collaborate in other ways, for example on curriculum development. It appears that the concept of practice is focused on teacher actions in the classroom rather than a wider understanding of the practices of teaching or professional development entailing change in a teacher's personhood.

In constructing our bid for the project I and my colleague took account of both the published invitation and the NCETM pathfinder report. Thus the bid and project plan represented a further translation. We were not passively enrolled in an undertaking to promote "collaborative practice". We examined how it met our own purposes, both in relation to mathematics education and to a myriad of other personal and social interests. The projects in each school were to be led by a school-based project team who would determine the exact form of collaborative practice. A research question was developed: to see how schools might develop collaborative practice differently. What was emphasised in the bid was joint planning of lessons and activities as well as "team reflection". The projects would, it was stated, draw on what was "already known about collaborative professional development". Although the shift in emphasis was subtle, a process of translation took place about the meaning of professional development (one that preludes changes in the NCETM's own approach in its second year when under new leadership).

The Heads of Mathematics departments who agreed to be involved did so for their own purposes. They assessed the extent to which involvement in the project met the perceived needs of their departments. Once a Head of Department agreed to participate, they were sent a summary document outlining the project. In this the term collaborative practice did not appear but rather the phrases 'collaborative development' or 'collaborative professional development'. It is this term that was then most often used within the project by the teacher educators involved. During the project the meaning of collaborative professional development is refashioned by this (on-going) encounter with the idea of collaborative practice as initially outlined and the academic influences on it, particularly lesson study.

The project began with a half day meeting. Here different forms of collaborative professional development were discussed, including historically important UK projects that integrated curriculum and pedagogy. Documents identified a number of possible foci for collaborative professional development: curriculum, resources and activities, technology, teacher practices, lesson, and learning practices. A model of collaborative professional development was offered as a starting point based on Japanese lesson study (see Fernandez, 2002), with a discussion of the advantages of groups of

teachers working together. The schools were encouraged to further develop or adapt the model.

At Waterfield, Anna, the Head of Department, had her own particular purposes and constraints. One of the constraints was the emphasis on whole school improvement initiatives rather than subject-based professional development. She did not believe it would be worth arguing for a large number of teachers to be withdrawn from regular teaching at the same time. So, she decided to work in collaborative pairs. Because Anna is Head of Department, the process of collaboration with Clive is defined in reference to, and as different from, existing observational practice in the school, which generally happens as part of performance management. However, Anna's interpretation and translation of collaboration in the school project was not a final move. The actual form, the way she and Clive worked together, developed through the process of co-planning and observation - they reshaped their relationship through collaborating. The process of translation continued in the production of a school report, in the presentation of their project in the interviews with me and indeed here in this research text.

The above account underlines the way in which educational practices are re-interpreted and transformed as they are enacted in different contexts. The process of translation may involve contestation, negotiation, and conflicts between different purposes and intentions. Practices and entities are changed and new meanings are produced and so human actors' identities, commitments and actions are shaped in reference to their existing purposes and webs of relationships.

Fluidity

In this section, I focus on the role of dynamic geometry software in Clive's story. The term is derived from de Laet and Mol's (2000) account of of the successful development and widespread use of a water pump in Zimbabwe. This success is attributed to the pumps "fluidity, the capacity for shape changing and remaking its context" (Law 2004, p. 81). Fluid technologies are adaptable, flexible and responsive and travel well (de Laet & Mol, 2000).

Dynamic geometry software is such a technology. Indeed, the software is designed to be internally fluid. It allows for a wide variety of geometrical relationships to be explored. The process of 'clicking and dragging' geometrical objects is itself a flexible practice. Its application in a wide range of settings indicates its transportability. Dynamic geometry software is not a simple tool which can be used for only one purpose. It is widely recognised as having the potential to support pedagogy of guided discovery and pupil exploration and inquiry but also can be used in a less innovative way, for example, to support teacher presentations (Ruthven, Hennessey, & Deaney, 2008).

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Dynamic geometry software has its own narrative embedded in Clive's story. First, it is something marginal and, in Clive's classroom, unused. It is something other teachers do and he is sceptical about its benefits. It then becomes a focus for discussion and negotiation within the departmental team. It becomes something that both Clive and his students learn to use. Clive tells us that "they learned how to use the package. But they discovered the theorem for themselves". Learning how to use the package involved working together through relatively closed activities through which the skills to use the software are learnt. He contrasts this with the more active and open experimentation that follows. He appears to instigate a third alternative to the choice between guided discovery and teacher presentations: a pedagogy led by the potentialities and capabilities of software and the students' curiosity. Perhaps this is because of his own novice relationship with the software. As the students develop their relationship with the software and engage with the geometry of circle theorems, the relationship between Clive and his students changed as did the students' relationships with each other. Thus dynamic geometry is coupled not only with relationships to mathematics but also with social relationships more generally. Clive comes to recognise it as a tool that supports enjoyment for students and "good relationships". He also believes that dynamic geometry, when used to support student understanding, is a means to improved learning and to higher tests scores. Dynamic geometry becomes something that could be expanded into other areas and holds the promise of a "better way" in other areas and with other classes.

It may be that the fluidity of the technology itself supports the process of change. Let us suppose that the possibility of dynamic geometry software being used as a presentation rather than discovery tool could in someway be designed out. Would this mean it would better support teacher change? Clive's narrative indicates not. The fluidity of dynamic geometry, the fact it can be used in many different ways and for many different purposes, including as part of a more transmissive pedagogy, may be one reason why it enabled and supported teacher change. Because there are multiple ways to engage with dynamic geometry software, it allows Clive and the other Waterfield teachers to develop a relationship with it that is appropriate for them and one that can change.

Dynamic geometry software is not alone in having a quality of fluidity. Teacher educators become used to artefacts created to support a participative approach to mathematical learning being reinterpreted by prospective (and experienced) teachers to support a more transmissive approach to teaching. Similarly, artefacts that reify or support practices that appear to preclude meaningful engagement may be re-appropriated to support such engagement. In itself, the introduction of a fluid technology does not necessarily lead to a more fluid pedagogy. Here, the interrelationship of the fluidity of the dynamic geometry software with the collaborative process is important. The form of collaboration that Clive and Anna engage in allows space for the technology to be used in a variety of ways. The fluidity of technologies reminds us that entities do not necessarily have "clearcut boundaries that come with stable identity" (de Laet & Mol, 2000, p. 227). Thus dynamic geometry is

an assemblage (Deleuze & Guattari, 1987) and one that is resonant with the practices of the community of those mathematicians and educators who created it. The collaborative process allows the purposes that are implicit in these practices to manifest.

Accounting for and enabling teacher change

In this article, I have used concepts drawn from actor-network theory to draw attention to particular aspects of one teacher change narrative. This account suggests it is important to investigate, firstly, the relationship between stabilising factors, which do not change but may contribute to change and, secondly, the ways changes in different relationships themselves interrelate. The way relationships and meanings are reshaped points to an alternative to models that categorise entities through binaries of cause/effect or subject/object. Rather, as interests and purposes interplay, reciprocal roles are negotiated and contested.

Actor-network theory draws attention to the role tools have in the change process. The main tool considered here is dynamic geometry software. However, also important was the model of collaborative professional development itself. Both dynamic geometry and forms of collaborative professional development are fluid and this is important to the outcomes of the project. Just as there are many ways to engage with dynamic geometry, so there are many ways to collaborate. Dynamic geometry software is mutable and adaptable and so allows for Clive and Anna to meet as "two people talking about the same thing".

Clearly, given the limits of this study, how far these interpretations are relevant to other teacher change narratives can only conjectured. However, I suggest that they do indicate directions for actions to support teacher change. If change is a systemic property, then it is not possible to know in advance what interrelationships and actors will be important. Actors who may appear to be acting against the desired trajectory of change may actually support the change process through translation by or connection to other actors. Actions by any actor may be translated and transformed in unpredictable ways. Further actors, who are systemically present (influencing the system), may not be spatially or temporally present. It is not possible, from this perspective, to identify any particular actions or even fixed principles that are transportable to or reproducible in other situations.

Any entity or practice that is introduced to school environments is, therefore, likely to be translated and renegotiated by teachers involved in change initiatives. Given this, as part of creating opportunities for teachers to change themselves, the process and means of change should be explicitly negotiable. This calls for an approach to teacher change that allows for openness and provisionality. One means of supporting such openness is to develop and select artefacts, tools and

practices as potential change actors that have a quality of fluidity. Using fluid technologies is at least congruent with an aim of creating more fluid relationships and it may be the case that the quality of fluidity itself can be introduced to actor-networks through such technologies. It also suggests that teacher educators should seek, in turn, for qualities of adaptability, flexibility and responsiveness if they aim to support the reshaping of pedagogical relationships to be more fluid.

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