Department-initiated change aiming to improve mathematics learning

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Abstract

This paper reports the activity of three secondary school mathematics departments in England in self-initiated states of change that led to overall improvements in students’ achievements when compared to previous cohorts. This took place without intervention, and without their participation in particular projects. They provide examples of departments that can work effectively on their own development and hence their work adds to our knowledge of the potential for teacher collaboration. The departments were monitored over three years and data were analysed using a lens from activity theory. In contrast to departments in many studies, these departments worked overtly on mathematics pedagogy through the shared production and discussion of resources, shared planning and task design. Also in contrast to several other studies they developed distinct ways to handle differences of subject knowledge among the teachers in the department. Their focus changed during the study from developing resource banks to supporting students’ learning through hybrid teaching. .

**Keywords:** collaborative practice, low attaining students, changing practice, grouping, school mathematics departments, subject departments, teacher communication

Abbreviations:

HoD: Head of Department

HoDs: Heads of Department

PLAS: previously low attaining students

1. Introduction

This paper describes some aspects of how three secondary school mathematics departments made self-initiated, collaborative, efforts to raise achievement for their previously low attaining students (PLAS). We treat them as activity systems, and use this lens to identify tensions and changes in their work. The study is contextualised in England, in terms of the nature of school subject departments and norms of teaching mathematics.

The whole study was complex and multi-layered, involving three years’ use of ethnographic methods to collect regular but intermittent data representing cross-sections of activity in the three departments. Study of particular cases does not imply generalisability, but knowledge of how these departments acted when initiating their own agenda for change contributes to our understanding of professional development. For example this paper describes how talk about mathematics took place, and some shifts in the ways they thought about classroom tasks.

First we describe the initial situation and context, then present some key ideas about subject departments from the literature. We then describe our research and analysis methods. From these, we identify the rules, resources, planning work, talk and tasks that characterised their activity, and describe some of the tensions, changes and marginalisations that occurred. Finally, we draw out how these departments differed from those in the literature and suggest implications for research and professional development.

2. Background

In 2005 three mathematics departments in state-maintained secondary non-selective schools in England contacted the two researchers who wrote this paper, through professional networks, having made decisions to change their teaching so that more students, particularly PLAS, achieved higher grades in mathematics. Their reported reasons for focusing on students with low attainment were a combination of altruism, concern for social justice, and pressure on schools to raise standards. Nationally standards are ‘raised’ by focusing on students whose examination performance is at a notional pass/fail borderline at age 15/16, not on those whose expectations are much lower. In these three schools the heads of department (HoDs) took the view that improvements in learning *for all* over the longer term would bring lasting benefits for individual students and the school, rather than short-term measures focused on test achievement. Their focus was not going to be on ‘teaching to the test’ but on developing mathematical learning. The HoDs saw the changes they were making as three-year projects, starting when students were in year 7 (entry year for secondary school) and leading up to national tests in year 9. Their institutional measure for effectiveness and success would be the scores of national tests compared to those of the previous cohort.

We, the two authors, asked the three schools, SP, FH and LS, if we could research what happened. The only elements of the project that we designed were our own research methods, and we engaged with teachers and students only for research purposes. Our overarching question was: how do these departments set about trying to achieve their aim of improving mathematics learning for PLAS within mainstream teaching? Their teaching has been described in more detail in Watson and De Geest (2011) and organisational aspects of the departments have been described in Beswick, Watson and De Geest (2010). To show that it is worthwhile to learn more about what happened, we first report their test results, compared to the results of their previous cohorts, and then report on the background of the schools and the study. Our aim is to understand what they did when making self-initiated change. We are not making strong claims about causality, but it is important to know whether there were improvements in test achievement as a measure of learning, otherwise the focus on changes in their practice has no purpose.

At the end of three years improvements in schools SP and LS were significant, and in FH levels in mathematics were maintained significantly against a whole school background of a fall in results, see Table 1. Nationally the pass percentage for mathematics had risen by one percentage point from 71 to 72. Thus all three schools were unusually successful in affecting attainment of the project cohorts relative to the whole school context. Attainment for PLAS was less successful, with only SP and LS achieving significant improvements and PLAS in FH doing significantly less well. We do not have space here to analyse why FH was less successful with PLAS but have done so elsewhere (see Watson & De Geest, 2011). Table 1 also shows changes in ‘pass’ percentages for this cohort in high-stakes 16+ examinations two years after the end of the study; the project cohorts were also successful in the longer term.

Table 1: National test results for 2008 in all tested subjects: the project cohort compared to the previous cohort, and changes in high stakes passes for the same cohort two years after the end of the study.

Background features of the three schools are summarised in Table 2 to show how their socio-economic contexts varied:

Table 2: Characteristics of schools

All the schools decided to teach the entry year in heterogeneous groups in their pursuit of high expectations for everyone. A feature of secondary mathematics teaching in the UK is the general use of grouping according to prior attainment, called ‘setting’. Previous cohorts in these schools had been taught in sets. The decision to abandon setting was an early feature of their change in practice. Teaching heterogeneous groups is unusual and teachers require confidence to do so. For this reason, teaching heterogeneous groups in UK secondary schools tends to be associated either with particular projects and materials (such as the Association of Teachers of Mathematics project in Boaler (1997), or the SMILE project in Venkatakrishnan (2004)). Setted groups might be taught in a range of ways, from transmissional to exploratory, while heterogeneous groups tend to be taught either through individualised programmes, or through groupwork, explorations, problem-solving and discussion. Research about grouping effects in mathematics in the UK is hard to interpret because it is always associated with teaching-style effects, so although this change of organisation is a common feature in all three schools, it has to be viewed alongside other changes in practice in any story of teacher change.

In these three schools, all students had followed the national curriculum in their previous schools. Before this project teachers had planned their methods, resources and approaches individually within a school-based scheme of work that ensured content coverage. The schools were operating in the context of national guidelines for a statutory accountability regime which had the effect of imposing: setting; objective-led lessons; target-setting; regular testing; a ‘coverage’ approach to the curriculum; and a lesson format of three parts: starter, main teaching, and plenary evaluation against the objective. We were told that before this project the majority of lessons from the project teachers would have included demonstrations of techniques or concepts, and individual or pair work on questions as the main part. Whereas in all schools there were some more varied teaching approaches used from time to time, we were told that the norm would have been three-part lessons with defined, small scale, learning targets and, especially in SP, dependence on textbook use.

3. School mathematics departments

3.1 Collaborative aspects of departments

Teachers’ work in secondary schools in England is normally organised through subject departments. It is accepted that it is the department that most closely affects what is taught and how it is taught (Siskin, 1994). The HoD is a member of the school middle management team and is expected not only to organise the day-to-day functioning of the work of the department but also to be responsible for subject curriculum development, assessment, and quality of teaching and learning, combining organisational and curriculum roles (Melville & Wallace, 2007). Grossman, Wineburg and Woolworth (2001) make a distinction between departments as a collection of people who sit in meetings together and departments that act as communities, meaning practitioners who have “organized themselves for action around a shared sense of purpose” (Secada and Adajian, 1997). Such communities can make coordinated efforts to improve students’ learning, with collaborative professional learning and collective decision-making. Using this definition, the departments in this study were already ‘communities’ at the time we began to research them, in that they were organizing themselves around the shared purpose of raising achievement according to school accountability guidelines and appeared to have made collective decisions about change. Nickerson and Moriarty (2005), who initiated communities as part of a professional development project, found that those that lasted beyond their project were characterised by close conformity to the definition of Secada and Adajian (1997), but they also noted that leadership, relations within the institution, respect for each others’ knowledge, and expectations that every child can learn were important for continuity of their effort. The centrality of high expectations of learning emerges as a critical factor in many studies of the effects of professional development projects (Timperley, 2005; Nickerson and Moriarty, 2005; McLaughin & Talbert, 2001; Watson & De Geest, 2005). As Wiliam (2007) points out, teacher learning communities are not an end in themselves, but the means to improve learning, which is why we gave information about final test results as one measure of learning above.

In a study of 93 mathematics departments in the Netherlands, Visscher and Witziers (2004) found relations between department self-reports of practice and student achievement were hard to find and not very conclusive, but there was a positive relation between students’ achievement and the collaborative creation of policy. Effective departments typically collaborated to devise schemes of work which related mathematical ideas and teaching processes across years, had consistent policies about evaluating student achievement. In general, however, departments did not focus on the qualities of teaching, or discuss how to teach particular topics and the associated pedagogic problems. They, and others, found that departments tried to keep conflict low by avoiding criticising each other’s work or exploring differences in subject perceptions (Achinstein, 2002; Kruse & Louis, 1997; Leithwood & Louis, 1998). However, Little (2002) identifies the importance of critical work, shifting the emphasis from collaborative structures to the critical content of their interactions.

A lack of focus on mathematical content is also noted by Lachance and Confrey (2003) in the US, who suggested that using mathematical content as a focus for teachers’ interactions might aid the development of professional communities. Teachers’ personal subject knowledge and the degree of control they might have over curriculum decisions are connected (Nickerson & Moriarty, 2005) and weak subject knowledge can prevent some teachers from participating at all (Britt, Irwin & Ritchie, 2001). There is little research about mathematics departments specific for England, but our experience as teacher educators and frequent visits to a wide range of schools suggests these findings are relevant.

To summarise: high expectations for every child, good leadership and institutional relations appear to be conditions for a teaching community, but for improving learning there are the additional conditions of collaborative transformation of curriculum into schemes of work. Talking about subject content and teaching in a critical manner, including handling differences, might make important contributions to change, but is seldom seen.

Our focus for this paper is about what changed in our three departments as they tried to improve learning. As we shall see, among other things they developed a variety of ways to talk about mathematics pedagogy and learning. This study therefore provides examples of teacher collaboration that go beyond what is reported so far in research on departments and, as we see from the test results, are associated with advantages in achievement for most if not all students.

3.2 Departments as activity systems

Early in the national regime described above, Venkatakrishnan (2004) compared two departments which had differentially appropriated government guidance on the teaching of mathematics (as outlined above). For one of her departments, the guidance was interpreted as a new tool to support their work in helping students ‘cover’ the curriculum and achieve in national tests; it helped them do better what they were already disposed to do. But the guidance assumed some existing practices, in terms of lesson style, student groupings and departmental aims, which were different to what the other department already did. In the second school it was impossible to apply the guidance without disrupting their equitable, independent, exploratory approach to mathematics. The ‘guidance’ and the externally imposed implementation methods were potentially destructive in the second department. Seeing departments as activity systems revealed fundamental differences in their recognition and use of mediating tools, in their unwritten rules, their expectations, their relations with wider communities, the ways they went about their work and the object of their activity. Her study showed how new tools and expectations expose and potentially disrupt existing practices of school mathematics departments. This directed us towards Engeström’s articulation of third generation activity theory (1998, 2001) as a useful framework for our observations about change,providing tools for analysing actions and exposing the consequential tensions and contradictions that lead to changes of activity, of individual action, and of organisational structures.

We view each department as an activity system in which a defined group of teachers orientate themselves towards their object of improving their students’ learning, using a range of teaching tools still being developed at the start of the project. Each teacher also operates within their own classes, seen also as systems of activity. The departments also interacted with school management systems, and with national guidelines as imposed through inspection regimes, national school comparative systems, and advisory. We therefore saw the work of the departments as systems operating in conjunction with other systems.

4. Research design

4.1 Methods

The timescale followed one cohort of students from when they entered the school in year 7 until they took national tests at the end of year 9. Each school had an entry cohort of around 180+ students, organised into seven teaching groups. This timescale was long enough to observe several changes at the level of department activity and classroom activity, but not at the level of school structures.

Our methods were ethnographic; that is, we observed the department at work in its normal surroundings doing its normal work and used self-report of teachers, students and heads of departments through interviews, establishing good interpersonal relations with members of the departments. When we were in the schools we attended meetings and observed informal talk. We were mainly observers at these events but also participated overtly when invited, but we did not give any advice about mathematics teaching and maintained watching and listening habits throughout except when explicitly conducting interviews. We did not act as innovators. We did not give any feedback on the teaching or the functioning of the department. Our aim was to record and understand the departments, not to initiate change or influence how their practice matched the literature on good conditions for improvement.

We visited each school at least three times per year, with visits over one or two days. We interviewed those teachers who had agreed to participate in the study in each of the years in which they were teaching the relevant cohort, thus having up to three interviews per teacher. We used semi-structured interviews so ensure that every teacher had the opportunity to talk about similar aspects of their work. We observed one lesson per teacher per year where relevant. In the second and third years of the project we also video recorded these lessons. We attended and audio-recorded department meetings and department in-service training days where possible. We collected copies of relevant curriculum documentation, internally-produced schemes of work, tasks and worksheets. We also interviewed students but the data from this is not relevant for this paper. Semi-structured interview schedules and occasional brief questionnaires were developed recursively, so that what we asked was influenced by our analysis of the previous year’s data (see appendix 1 for example of instruments). Questionnaires were useful to ensure we had comments from all teachers about particular aspects of their work.

We could not observe the casual interactions of teachers very often, and we could only attend a few of their timetabled meetings, but we could compare what different teachers said about what the departments did, and triangulate individual perceptions within the data set. In this way we could get a complex picture of what happened without actually being there to observe all the time. All the anonymised and collated data were shared with all the teachers at the end of the project and then placed on a public website with their agreement, thus assuring the veracity of our analysis of data. Schools and teachers were anonymous except in a protected area of the site which contains illustrative video-clips for which full participant consent has been obtained.

A few teachers at the start of the project thought that we expected them to act in certain ways, but we made it clear that we were interested in *whatever* they did. Our research presence impacted on their work in one explicit way: we initiated three meetings between the HoDs at which they could share ideas and resources. We were also aware of implicit impact; one HoD reported that our visits to schools sometimes “keeps us going when times are tough”. By being explicit with all teachers about our intentions to watch, listen and learn we avoided anyone using our presence as a management tool, or being seen as associated with management. We overtly maintained strict confidentiality as fieldworkers, developed trusting and friendly relations with all participating staff. We approached individual teachers face-to-face to talk to them about our research to gain informed consent. A few teachers did not consent, and we probed reasons for this. Some are irrelevant to the research, but two in one school gave as a reason that they disagreed with the new aims. We made it clear that this would be important for us as researchers, and that we were acting totally confidentially and were not associated with management in any way. One then consented to be involved, the other did not. However, the latter teacher’s involvement with the cohort was small in the first year and nil afterwards.

4.2 Analysis methods

Activity theory models organisational learning and change, and can also reveal and explain how this happens by exposing tensions, and contradictions that lead to, and result from, change. We needed to make sense of complex situations and multiple sources of data, and to use these to learn more about what the teachers did. In Bakhurst’s terms: “The results of our activity stare back at us with meaning and this creates new needs and desires, engendering further activity that further transforms the world, which then confronts us with new demands and opportunities” (2009, p.203). Over the three years of our research we saw examples of such transformation. Seeing the department as an activity system focuses on the tools, mechanisms and structures of activity. Using Engeström’s third generation triangle structure (Engeström, 2001; Daniels, 2001) enabled us to categorise data usefully not only descriptively, but also in a revelatory manner. In this way, we could identify how the system was ‘learning’ where learning is characterised by changes in activity.

The data on department change comes from the semi-structured interviews with teachers and heads of department, questionnaires, and observations of meetings. Data are therefore mainly self-report, supplemented by observations of actual communicative events. The data were categorised according to two related triangular structures in a method similar to Engeström’s understanding of department change (1998). Each triangle represents a system, and the two systems, classroom and department, both share the object of improving students’ learning. In the department the subjects are the teachers, who try to achieve the object through use of tools and resources available and generated within the department. In the classroom the subjects are the learners. The top parts of these triangles encapsulate the ideas that (i) activity involving the subject is mediated through tools and (ii) that activity is orientated towards an object (which in our case is the abstract idea of improving learning). The base of each triangle describes the context in which these take place: on the right, the work, community and rules of the mathematics department; on the left, the work, community and rules of the classroom. How these three departments operated as systems, and how the actions within the system related to the internal connecting lines, is described in more detail in Beswick et al. (2010).

Figure 1: Departments and classrooms as activity systems with a shared object (after Engeström, 1998)

For each teacher, in each year, and from every event for which we had recordings or field notes, we categorised each utterance or written response according to its content. The structure of the triangles enabled us to gather content relevant for each aspect of activity, for each teacher, school and year, from different data sources. In this way, we accumulated the raw material at each node for synthesis. The syntheses are narratives in the sense of having content, time and personnel dimensions. The triangles allow multiple sources of data to be analysed together by relating their content to the same underlying structure of activity. The structure reveals, through contradictions, tensions which have to resolved through some kind of change in the system.

On A2 paper we constructed two interacting triangles as shown in Figure 1 for each teacher in each year and populated the nodes with the content of their comments. Firstly we distinguished whether they were talking (either in speech to us, in speech to others, or in questionnaire answers) about their own planning and teaching, about joint activity with other members of the department, or about department aims, policy and so on. Statements about their own classrooms went on the left triangle; statements about the department went on the right. If they were talking about general school policy matters this was categorised as ‘community’ or ‘rules’ on the right. Then we distinguished whether they were describing subjects, tools, object or work, community or rules (including norms and expectations). Anything they talked about as something to be used to achieve an aim was classified as a tool; anything they described as a ‘given’constraint’ or requirement was categorised as a rule. The triangle diagrams with data are too complex and detailed to be reproduce any here, but Table 3 shows a tabularised comparison of the abbreviated contents of one teacher’s interviews over two years (she did not teach the cohort in the third year). Changes in focus can be identified; in her case there seems to be a shift towards talk about learning and the purpose of tasks . These shifts can then be compared to other shifts identified from other teachers.

Table 3: Contents of triangle nodes for one teacher’s interviews and questionnaire in first and second year of project (from school LS)

In this way we built up longitudinal information from each teacher. The abbreviated content statements were then collated across all teachers within departments to see the variety of views within each system, since we are interested in the departments rather than individual teachers. Table 4 shows typical examples of the varied ways teachers in one school described the object which, although agreed at a general level as ‘improving the learning of all students’ was always expressed by teachers individually in terms of subgoals. Statements in year 2 are more detailed, and focused on planning and learning than in year 1, and one about number is significantly different from others.

Table 4: Statements about object from SP teachers in years 1 and 2

In these ways we compared between teachers over time, departments over time, and finally cumulatively between teachers within and across schools over the whole project. Because we used these triangles to analyse all relevant data, not just interviews, we could also enrich the analysis with the data from meetings and informal observations. The sequence of analysis can be summarised as:

1. categorise individual teacher’s comments using the nodes of the triangles, distinguishing between what they say about departments and what about their own teaching
2. compare year on year for each teacher to identify changes over time (as in Table 3)
3. construct collective descriptions for each department for each node over time, adding observational data, looking for changes and reasons given, and also for contrasts (as in Table 4)
4. compare these descriptions between schools to identify common features and contrasts (as in Table 6) [[1]](#footnote-1)
5. synthesise and report these changes and differences.

5. Department activity

In this section we focus on mathematical aspects of their activity, such as the shift indicated in tables 3 and 4 towards being more detailed about planning and learning. Activity theory focuses on how tensions and contradictions within a system relate to change. The data for this section come from the material we gathered at each node, and our search for patterns and contradictions within and between nodes. This results in the following reports about what happened in the schools, identifying changes in activity and how and why these occurred. We describe: tensions between internal and external rules and expectations; how resourcing changed; how the work of planning varied between individualistic to collaborative; and how different modes of talk, as a mediating tool, sustained activity. Then we describe connections between tasks and the object of the activity as teachers’ saw them. Finally, by comparing data on individuals, we identified people who, while being part of the department for organisational purposes, were marginalised as activity changed.

5.1 Contradictions between internally and externally generated rules

All three schools initially ignored government guidelines about setting and content coverage, such as advice to teach students in attainment groups and impose a particular pace and order on coverage (Venkatakrishnan & Brown, 2004). They focused instead on establishing mathematical ways of working, devising their own priorities for years 7, 8 and 9 as shown in Table 5. An example of a lesson in which the focus was not on coverage of recommended content but on ways of working is that Florence asked students whether they thought 0.9 recurring was less than or equal to 1, and to go to opposite sides of the room according to their view. Students could justify their decisions and persuade others to change. Mathematical details were beyond the current knowledge of many, but all were in an environment focused on listening to reasoning.

Table 5: Outline of the schools’ development priorities over three years

These internally-generated ‘rules’ needed defending against senior management pressure to conform to national guidelines. National tests consisted of a summative set of short questions that assumed a particular order and pace of topic coverage. These schools abandoned national guidelines for at least two of the three years, so changes in their national test results cannot be attributed to ‘teaching to the test’. Two of the departments suffered significant pressure to improve overall results. In one of these the HoD saw herself standing between the department and the management team to help colleagues raise achievement for all, not just for those on the borderline. Outside expectations, although agreeing with the aim of improvement, sometimes contradicted the departments’ internal guidelines. For example, one teacher was observed by a senior manager and heavily criticised for not providing fast-paced short tasks. The departments had to be vigilant to maintain control over decisions concerning mathematics.

5.2 Resourcing the curriculum: tasks as tools

A dominant observable activity during the first year was resource-production, and without the associated talk about pedagogy and classrooms it could have been possible to deduce that resource-production was itself the object of the department activity rather than being a subgoal towards improving learning for all.

Initially, all three schools saw the problems of teaching heterogeneous groups as problems of finding the right tasks. All departments started by collecting resource banks of tasks. They found published tasks which were accessible by all students, addressed core mathematical ideas, and allowed a variety of learning outcomes, including mathematical challenge[[2]](#footnote-2).

In SP the HoD had past experience of open-ended tasks and materials from a variety of sources[[3]](#footnote-3). She collated some of these into modules addressing broad topic areas. The department started working together at the end of the term before the project began with a workshop in which they all did mathematics together using some of the tasks she had collected. The purpose of the tasks was to develop students’ mathematical thinking rather than to focus on particular content, an aim compatible with improving learning processes rather than test achievement. For example, sequential spatial pattern tasks were to be focused towards the exploratory activity rather than a final formula. Another example was: to draw polygons to populate a two-dimensional grid which classified according to order of rotational symmetry one to five and also according to reflective symmetry in one to five lines. Students worked in mixed groups to complete the grid. The aim was as much about access and participation as about geometric reasoning. She wanted the department to talk about the pedagogy rather than seek for resources. She intended that other teachers would add ideas to the file, but there would be a basic collection which held enough for everyone to use.

In FH the decision to teach in all-attainment groups was made close to the start of the school year with no time to plan jointly, so one teacher prepared a file of ideas and resources during the summer vacation. He had experience of problem-based teaching in heterogeneous groups and his sources were similar to those in SP. The intention was that teachers would find other resources themselves and add them to this file regularly, but neither in FH nor SP did this happen systematically.

5.3 The work of planning

In LS the whole department worked extensively before the project to produce content-focused materials, each teacher being responsible for preparing a few weeks' worth of tasks about particular mathematical ideas. These were presented and discussed at department preparation meetings. Extra weekly early morning meetings were instituted for planning discussions. In all, about 20 hours were spent with the whole team together for planning on top of many more hours of individual and paired work. In meetings teachers presented tasks, supplemented with comments about the order of tasks, and students' possible alternative conceptualisations.

The full team planning in LS was very time-consuming, but avoided a problem which arose in SP and FH where provision by individuals meant that others did not know their way around the central resource bank. Instead, teachers at SO and FH relied on informal sharing in brief moments, indeed teachers reported that informal talk was the main support for individual planning. Many teachers made time to plan together, discuss associated pedagogy, and sometimes managed to debrief together after lessons. One HoD said that having a lot of informal talk improved the whole planning approach. A core group of teachers in all schools expected to spend time together at the end of the day, interacting informally with each other and sharing ideas but this did not lead to an accumulation of plans for the whole department. Eventually SP and FH adopted a more formal method, like LS, in which teachers each had a defined planning role and time to share their ideas with the team. This led to 'less planning but richer planning' one teacher said.

In LS they not only all used the same tasks, but also made decisions about how technical language would be introduced, what informal language would be used (e.g. 'balance' for equations; 'follow a rule' for loci) and so on. There was a day-long review at the end of the first year in which teachers' experiences with the tasks were discussed at a detailed level including language use, order of teaching, example use, images and diagrams, what was given by the teacher, what was elicited from students, what and how questions had been set and so on. The discussion was structured around students’ performance on a test, and differences in test performance were explored critically by teachers describing how they had taught the relevant topics. There was open discussion about how some ways of teaching may have contributed towards students being able, or unable, to do certain test questions. For example, for contextualised questions one teacher reported that she had explicitly ‘trained’ students to imagine the context before doing anything while another said that she had assumed they would do that automatically. For a spatial question one teacher said that she herself found visualisation hard so used symbols from preference, and another was surprised that anyone could find visualisation difficult.

5.4 Teacher learning through formal and informal talk as a mediating tool

As we have just illustrated, talk between teachers about students’ mathematics can be a medium for learning more about mathematics pedagogy. All schools eventually gave formal time to doing mathematics together, either working on some ideas presented by individuals, or by working through tasks proposed by planning teams. One HoD said that subject knowledge might be a weakness for some colleagues and hence 'we need to do mathematics together'. For example, in LS people gave their reasons for, and limitations of, using particular images, metaphors and language, so the subject knowledge of all could be enhanced through this kind of discussion. In FH teachers discussed how particular tasks offered the opportunity for a range of outcomes in relation to the mathematical idea; it was often repeated in meetings and in interviews that some universal mathematical ideas (such as ratio or linearity) arise in different ways at different levels of student work. One idea we observed being treated in this way was the introduction of algebraic representation through area models of the distributive law. The HoD’s intention, stated to us, was that discussion helped non-specialist teachers to see algebra as more than a series of manipulation procedures.

In the early days of the project one HoD gave the team tasks designed for their professional development rather than tasks designed for the classroom. For example, in a discussion about proof they were all given cards asking them to construct verbal, symbolic, graphical or materials-based ‘proofs’ that the sum of two odd numbers is always even. This approach appeared to us, as observers, to silence teachers rather than stimulate them to participate and we know, from teachers’ private comments to us, that some experienced teachers resented this kind of leadership. Meetings in which the same teachers discussed their classrooms and their practice, led to more people talking about, and doing, mathematics.

In SP a way was found to incorporate personal mathematical learning into the professional context. Teachers worked in pairs to explore a particular area of mathematics and produce a task sequence. The sequence was presented at a team meeting, and others had to do the tasks and discuss what learning might be expected, and how they might organise them pedagogically. For example, two teachers who had not studied logic devised a logic module to support the development of deductive reasoning within mathematics.

In all schools mathematical ideas were discussed, and this appeared to work best when the context was about classroom tasks, rather than a direct focus on individual knowledge, and many teachers could contribute. The explicit attention given to subject knowledge through discussion of mathematical content in the context of classroom tasks was in contrast to some research about school departments (Lachance & Confrey, 2003), and it was interesting that this arose from all three departments and was not the result of imposed change or structured forms of professional development.

Individual mathematical knowledge weaknesses at the planning stage were handled implicitly in all schools, but could also be handled explicitly in SP. We observed occasions in all schools in which the mathematical knowledge of individuals was exposed as being rather weak; in LS and FH incorrect mathematical statements were followed with a short period of uncomfortable silence rather than any discussion, whereas in SP they were energetically discussed. In SP the ‘respect for each other’s knowledge’ described by Nickerson and Moriarty (2005) did not lead to ignoring wrong mathematics. SP had developed an atmosphere in which a shared respect for mathematics held sway and allowed people to speak up at the planning stage, where in LS the review meeting had allowed differences to be dealt with through their effects on students’ work. We conjecture that SP managed weakness overtly because the HoD was open about areas of mathematics and pedagogy where she was insecure.

Teachers frequently referred to colleagues’ knowledge and experience in interviews as if it was a tool, a resource, for their own learning as well as a tool for the departments’ work. They also all valued informal talk. The substance of any informal talk about mathematics we observed during or after the school day was usually of mathematics pedagogy rather than knowledge, but in all schools there were private opportunities taken up for one teacher to ‘show’ another some mathematics at the upper end of the curriculum.

5.5 The relation between tasks and the object of improving learning

Discussions between teachers, and with us, became more focused on the relationships between tasks, pedagogy and mathematical learning as the project proceeded. In terms of the activity systems, the tools for communication in the department were often also the tools for mediating learning in classrooms. At first, talk was about resources at the organisational level, as if getting the right task was all that was required. Some teachers talked positively to us in the first year of 'tasks going anywhere' as if this was desirable. For example, students being introduced to methods of geometrical construction could then create their own patterns. Later teachers became more concerned about whether students were learning new ideas than whether the tasks generated a range of possible outcomes. A teacher in Table 4 expresses this as ‘more structured learning outcomes’. Their initial interpretation of the resources was conflicting with having certain content expectations for all. Towards the end of the first project year and the start of the second the focus of meetings changed from exchanging tasks to discussing: the learning afforded; what to focus on; how language might be used; and in what order things could be done. This change first appeared in the LS review meeting, when they agreed there had not been enough focus on learning particular mathematical concepts. This shift of focus could be described as being from tasks as objects to be produced to tasks as mediating tools, alongside others, between the students and the object of improving learning through teaching.

Task provision, selection and production were emphasised in year 1. The focus then shifted towards use, adaptation and sequencing - how tasks are used to promote learning. Tasks played a major role in classrooms as tools for teaching, but also as tools to mediate department activity and even as a proxy object of the activity. Task production had implications for labour among the teams, and also for the development of substantive mathematical and pedagogic knowledge among individuals and the teams. In SP some teachers were being secretive (but talking to us) about teaching ‘basics’ (meaning arithmetic and place value) and then, when they had a planning role, being more overt.

Table 6 shows the range of task-types described in interviews, discussed in meetings, and observed during the second and third years. Teachers were more articulate about tasks during these years, probably because they talked about them regularly with colleagues.

Table 6: Range of mathematical learning purposes, associated tasks, and issues about their use

Most teachers who had started out with enthusiasm for open-ended exploration were less satisfied with tasks which 'could go anywhere' by the end of the first year and instead looked for tasks and teaching approaches which had a clear learning purpose, such as exploring a central idea in a complex, extended manner.

Teachers became less likely to accept superficial comments such as 'it worked' and more likely to question each others' ideas in discussions. In the second year there was more open discussion about need for fluency of certain skills, and opening up this issue accompanied the shift away from focusing on tasks and towards thinking about learning. All teachers ended up including exercises and games approaches to fluency alongside richer, extended, tasks. In this development of hybrid teaching many teachers reported developing a pack of varied tasks alongside a repertoire of strategies. Many reported that they were 'better at questioning': for example, one said: ‘I make much more use of 'thinking' questions’. In our final interviews, most said their teaching for all groups had changed since the start of the project, with a stronger sense of purpose about the use of long tasks, for example: ‘I am more structured in the way I use 'rich' tasks than before, but less structured than my previous teaching’. The only aspect in which there is not a clear distinction between most teachers and a few is in the final category of tasks for basic skills and memory.

Most impressively, some teachers said they had abandoned their own past teaching approaches in order to have coherence throughout the school. In general there were two changes made which we could trace in our data about public talk, and also in the teacher interviews: the first was at the start of the project *from content coverage to developing ways of working* through exploratory tasks; the second was *to focus on learning and use hybrid methods* to develop both ways of working and appropriate knowledge and fluency. For example, in one lesson three triangles had to be compared to describe each of them as the ‘odd one out’ in relation to three different criteria. In this lesson students learn that comparing and making distinctions is a method of mathematical enquiry, alongside learning more about the characteristics of triangles, and all students had to engage with this. These shifts were made by nearly all the teachers over three years. The first shift was associated with discussions about the pedagogy accompanying tasks; the second was evidenced in a general change from talk about resources to talk about opportunities for students to learn.

5.6 Marginalisation

Every department had a core of enthusiasts and one or two marginalised colleagues. These did not join in informal discussions, volunteer to develop materials, or agree with the basic aims. Some part-time teachers reported missing significant discussions or information. By seeing who came to meetings, who ‘hung out’ in the team rooms, from self-report about co-planning, and from lesson observations we identified three sources of marginalisation (which may overlap):

* *Epistemological*: teachers with different experiences of learning mathematics. They may use shared resources but adapt them towards different purposes.
* *Institutional*: teachers who have other roles in school, or who join late. They use the department resources but often missed the associated pedagogic discussions.
* *Ideological*: teachers who voice different beliefs; they may not enact department policy nor use the shared resources.

6. Summary of departmental change

Our aim was to understand the practice of the three departments and how this changed, by looking for tensions and contradictions by viewing their work as activity systems. Improvements in achievement took place in two of the schools, and overall achievement was maintained against a school background of falling results in the third , so looking at their changes in practice is worthwhile. We cannot claim directly that their changes *caused* improvement, since FH, while it improved relative to the rest of their school and its practice was similar to that of SP and LS as described above, did not succeed in improving test achievement for PLAS. Nevertheless we do make the looser claim that these changes in practice are associated with overall improvements in learning.

These departments initiated change by engaging collaboratively in transforming national requirements into schemes of work that reflected their own priorities. Initially they developed new practices in contradiction to national expectations, moving away from setting and pace of content coverage. Internally, production of resources became a dominant activity, but only in one school was this collaborative at first. Contribution to resources became the work of all teachers only when formalised into systematic planning, and acted as the object of department activity during the early stages.

In contrast to the generic literature about the behaviour of subject departments, all three discussed mathematics content and pedagogy explicitly; this took place through the shared development of tasks and hybrid teaching methods. This discussion shifted emphasis from collecting resources to understanding children’s learning, and from a focus on mathematical ways of working to adopting hybrid teaching methods with multiple purposes. Teacher talk eventually became orientated around tasks as tools in the classroom, and the pedagogy associated with them, where at first it had been about production and organisation of resources.

All three departments established a team approach to discussions about learning mathematics, and worked critically together to organise, teach and plan. Differences in personal subject knowledge and approach were handled implicitly and also, contrary to general findings in the literature, explicitly through detailed discussions about tasks and learning.

# 7. Conclusion

Viewing departments as activity systems was a powerful way to analyse the complexities of their activity over time, and identify tensions within the systems, and from outside, that influenced change. This lens and the associated analytical methods and syntheses allowed us to understand how these self-motivated professionals developed their collaborative practices towards their aim of improving learning.

These departments exhibit the general features of effective departments summarised earlier in the paper, such as the commitment to raising achievement, but they also exemplify self-initiated engagement with mathematical knowledge and pedagogy through joint activity. Their work suggests that some departments do not need intervention, nor engagement in outside projects, to make significant change that is associated with improved learning, and that overt discussion about mathematics tasks and their use can be a self-generating engine for improvement. The school-centred systematic shared planning, and inclusive discussion of students’ learning through joint work on tasks, are features in common with more formalized methods of improvement such as lesson study,If these are the critical factors, the question is what qualities and opportunities did these teachers have that enabled them to self-generate these changes. These three departments go beyond the findings of current literature about effective departments, and about collaborative mathematics teacher change. The implication for our field is that studies of mathematics teachers’ self-initiated collaborative behaviour in improving learning might be valuable sources of information for development strategies.

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Appendix 1

Example of research instrument used in year 2 influenced by our analysis of year 7

Interview questions for CMTP teachers year 2006-7 (year 8 cohort)

1. What are the department aims for year 8 this year?
2. Describe the year 8 group you are teaching this year
3. What are your aims for this group?
4. How do you know if you are being successful?
5. In what ways would you like them to be more mathematical?
6. What sort of task and questions do you give them to help them become more mathematical?
7. What other types of task and question do you give and for what purpose?
8. Where do you get ideas, resources, materials for year 8?
9. Have there been any changes this year in your teaching generally; your teaching for year 8? Compare your teaching for year 7 last year and year 8 this year

Teachers’ questionnaire

**Statements about the department**

As a team we discuss how to …………………………

We work as a team to ……………………………….

We work individually to ……………………………….

Please tell us about something you do which you think is contrary to what the department as a whole has agreed to do.

Please give the following statements a mark out of 5, where 5 means high agreement and 0 means no agreement.

|  |  |
| --- | --- |
| We all teach year 8 in similar ways |  |
| We all teach year 8 in different ways |  |
| We are concerned about basics |  |
| We are concerned about mathematical thinking |  |
| We are concerned about behaviour |  |
| We are concerned about parents’ attitudes |  |
| We are concerned about informal/formative assessment |  |
| We are concerned about formal/summative assessment  |  |
| We do maths together |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Nodes** | **1st year: department** | **2nd year: department** | **1st year: classroom** | **2nd: classroom** | **Changes of focus** |
| **Object** | (nothing said by this teacher at this stage) | To build stronger connections between teachers.  | To learn as much maths as possible and enjoy it | More questioning; more whole class work. Build engagement, fun, and resilience. Always have a learning aim, not a topic aim. | From behaviour of students to their learning |
| **Tools** | Scheme of work is frustrating, slow paceImportance of ‘really talking’ | Scheme allows ‘sensible’ time on topics. Early morning meetings about experiences of using tasks and future plans. Talk is important about how to interpret tasks. | Accessible tasks; open ended exploratory tasks | Tasks to reveal understanding; memory aids; physical joining -in tasks.  | More time on topics More talk of shared planning of purposeful tasks. |
| **Rules** | Use accessible tasks; mixed attainment groupings; teach big chunks of maths | Start with what you want students to learn rather than ideas from somewhere.  | Participate | Balance metaphor for equations: ask why and when it doesn’t work? | More focus on students showing what they can do |
| **Commu-nity** | Not enough time to evaluate and review; legislative pressure to do things a certain way. Headteacher is supportive. | Develop the use of learning support assistants |  | One class I did not want to take but am now very positive | From ‘outside’ influences to own sphere of influence |
| **Division of labour** | Collaborative planning; other people’s ideas prompt me to think more | Need to talk through how others see links with learning | More time to think about individuals as planning is already done | I use assessment strategies more | From planning to learning |

1. Our first task was to report what the departments did for a professional audience so we exploited the possibilities of multi-layered text on a website to report data summaries in fine detail (www.cmtp.co.uk). [↑](#footnote-ref-1)
2. See Watson and De Geest (2010) for more information about tasks. [↑](#footnote-ref-2)
3. For example: Association of Teachers of Mathematics ([www.atm.org.uk](http://www.atm.org.uk)); SMILE (www.nationalstemcentre.org.uk/elibrary/collection/44/smile); Cognitive Acceleration in Mathematics (www.cognitiveacceleration.co.uk/) [↑](#footnote-ref-3)