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Characterising secondary school teacher imperatives as subject (signature) pedagogies:
A Pedagogy of Support in maths and a Pedagogy of Engagement in science

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Abstract

The ideas of Lee Shulman have played a major role in reconceptualising pedagogical description. In 2005, Shulman described a construct called “signature pedagogies” in order to describe recognisable and distinctive pedagogies used to prepare future practitioners for their profession. As a broader application of Shulman’s ideas, this paper asks, what is the efficacy of describing pedagogies that have become entrenched in secondary school subjects as signature pedagogies? Approached from a cultural perspective these questions are examined by comparing the subject cultures of junior school maths and science as experienced by, and represented in the classrooms of, a small number of teachers from two secondary schools in Victoria, Australia. In this research, subject culture is underpinned by shared basic assumptions that govern the dominance of certain “subject paradigms” (what should be taught) and “subject pedagogies” (how this should be taught) (Ball & Lacey, 1980). In this secondary school setting, the term signature pedagogies can be equated to the term subject pedagogies on the basis that both aim to characterise practice across the subject, or discipline, based on what was perceived as central to the task of teaching and learning. The paper draws on classroom observation and teacher interview data to show how six teachers positioned two aspects of their teaching in relation to what they believed was central in shaping their maths and science teaching: the effect of the arrangement of curriculum content on teachers’ conceptualisations of the teaching task; and a pedagogical imperative to engage students through activity-based learning experiences. The cultural expectations surrounding these two aspects of teaching appear to have a strong influence on practice, and in some senses teachers’ pedagogical responses were clear. These common responses are what I am calling “subject pedagogies” (see Ball & Lacey, 1980) because there was general agreement about what was central to the teaching task. Two subject pedagogies were seen to represent strong discourses occurring in both subjects: a “Pedagogy of Support” in maths, and “Pedagogy of Engagement” in science. Their established and shared character resembled Shulman’s posited “signature pedagogies” (Shulman, 2005). The data shows that by evaluating cultural practices that teachers have in common, and assumptions underpinning these, there is potential for highlighting imbalances, strengths and weaknesses, and connections and disconnections, associated with prevailing subject pedagogies.

In the 1980s, the ideas of Lee Shulman played a major role in reconceptualising pedagogical description by re-instituting disciplinary knowledge as an important factor in shaping pedagogical description. Today, his classification of teacher knowledge, such as pedagogical content knowledge (Shulman, 1986, 1987), provides the theoretical basis for many research and professional agenda. In 2005, Shulman again provided a framework for re-conceptualising pedagogy, this time in relation to professional education through a construct called “signature pedagogies” (Shulman, 2005). These are characteristic forms of teaching and learning that “organize the fundamental ways in which future practitioners are educated for their new professions” (p.52). Such pedagogies are characterised as routine. Rules of engagement dictate the behaviour of teacher and student and the type of curriculum, that is, what counts as knowledge and such how knowledge becomes known. As a broader application of Shulman’s ideas, this paper considers the question, what is the efficacy of describing pedagogies that have become entrenched in secondary school subjects as signature pedagogies?

I approach these questions from a cultural perspective on the basis that any practice that is deemed to be characteristically and exclusively associated with a particular discipline might be considered cultural, or even “tribal”, in nature. Becher’s (1989) theory of academic tribes depicts groupings of different sections of academic communities as being associated, in a tribalistic way, with an epistemology and the appropriate systems, behaviours and practices that accompany that epistemology. The tribalistic nature of these communities is manifested through idols, defining artefacts, and language. Becher states that
disciplinary discourse highlights the cultural features that are characteristic of a discipline and its various related knowledge domains and is crucial in establishing cultural identity. Signature pedagogies, as pedagogies specific to the professional education associated with that academic tribe, I posit, could also be deemed to develop and distinguish one tribe, or culture, from another.

Such tribal characteristics are reflected in schools (Siskin, 1994). Siskin equates academic tribes to the compartmentalisation of subjects in schools that express knowledge as distinct fields, “each specialised discipline with its own ‘territory’, and populated by its own ‘tribe’” (Siskin, 1994, p. 4). Generally across the secondary school system, school subjects act as the locus around which teachers organise themselves, and they are inherently distinguishable by their traditions of practice, knowledge, and purposes. Siskin’s (1994) research and research by others (Grossman & Stodolsky, 1995; Grossman, Stodolsky, & Knapp, 2004; Stodolsky, 1988; Stodolsky & Grossman, 1995), consistently reveal differences in discursive patterns and dominant themes in subjects as teachers talk about their work. Siskin states that these dominant themes are worth exploring because they “translate into systematically different conceptions of the tasks of teaching and learning” (p. 162). Little research exists that investigates how teachers internalise and deal with such assumptions in their daily teaching.

In this paper I use the term “subject culture” to refer to the traditions of practice, beliefs, purposes and behaviours associated with a subject. Schwab (1969) states that a complex culture, such as a subject culture, requires both diversity and unity when conceiving of the tasks of teaching and learning. Unity as common goals amongst teachers within the subject area is important in establishing “shared traditions, shared experience, shared problems, values and idiom” (p. 198). This unity makes the subject identifiable. Drawing from Organisational Theory, subject culture is underpinned by patterns of “shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration” (Schein, 1992, p. 12). Basic assumptions are derived from the previous experiences of the individual, and consist of perceptions of the nature of people and objects in the work environment. According to Schein (1992), the essence of a group’s culture is its pattern of shared taken-for-granted basic assumptions. Schein likens these basic assumptions to Argyris and Schön’s (1974) theories-in-use that prescribe how to act, think, and feel about things, and that operate as “unwritten scripts” for members of the group. These scripts internalise a routinised approach to performance on the job: “Potential courses of action are evaluated in terms of internalized socially constructed theories-in-use” (Schein, 1992). Like theories-in-use, basic assumptions are internalised perceptions of the world, objects, ideas, and how to relate with others.

In the teaching context, enculturation involves a lifetime of experiences of learning, practising and teaching the subject. If the “group” refers to all science and maths teachers across all schools, then subject culture refers to those shared basic assumptions that govern the dominance of certain “subject paradigms” (what should be taught) and “subject pedagogies” (how this should be taught) (Ball & Lacey, 1980). These basic assumptions act as signposts and guidelines for teaching and learning the subject.

Whilst signature pedagogies were intended to distinguish between pedagogies used in professional education, they could also used to explore those established and shared conceptions of teaching within subject cultures by focusing on the common, but complex, purposes of the subject. Used in this way and in this educational context, signature pedagogies are comparable to Ball and Lacey’s (1980) ideas about dominant “subject pedagogies” which govern how content should be taught.

The purpose of this paper is to reinterpret the findings from an empirical study exploring the subject cultural traditions that shape teachers and their science and maths pedagogy (Darby, 2010) from the perspective of signature pedagogies. Shulman described signature pedagogies as having a number of dimensions:

- **Surface structure**: the concrete, operational acts of teaching and learning.
- **Deep structure**: set of assumptions about how best to impart knowledge and know-how
- **Implicit structure**: moral dimension, comprises set of beliefs and professional attitudes, values and dispositions
- **What is missing**: the absence of which delineates what the pedagogy does not impart or exemplify from what it does.

This paper therefore explores how the practices of a group of junior secondary science and maths teachers may be re-interpreted through the lens of these dimensions of “signature pedagogies”. The following section describes the research study, and how the ensuing analysis addresses each of the dimensions of signature pedagogies.
The study – researching subject cultures and pedagogies

The analysis reported in this paper formed part of an Australian Research Council Linkage project involving Deakin University and the Victorian Department of Education and Training, the *Improving Middle Years Mathematics and Science* (IMYMS) Project, investigating teacher change processes in maths and science. My study formed one component of the larger project, investigating the relationship between teachers’ pedagogies and their experiences of maths and science subject cultures. I employed a constructivist paradigm methodological approach by Guba and Lincoln (Egon G. Guba & Lincoln, 1989; 1994) to investigate this relationship from the teachers’ perspective, drawing on teachers’ experiences and classroom practice. The research focused on how maths and science teachers constructed their pedagogy while operating within and in response to their social setting. Data generation centred on the teaching strategies employed in the classroom, and teachers’ commentary on what influenced their practices. I looked particularly for evidence of teachers’ experiences of the traditions, expectations and assumptions associated with teaching the subject.

Two secondary schools participating in the IMYMS project were invited to participate, School A and School B. School A is a co-educational Government school in a provincial city in regional Victoria, offering Years 7 to 12 to about 1,300 students. Four teachers participated from School A: Rose, Donna, Pauline and Simon. School B is located in an eastern suburb of Melbourne. It is a co-educational Year 7 to 12 Government secondary school with over 900 students from neighbouring suburbs. Data from three teachers, Ian, James and Marg, were included in the analysis.

The schools selected teachers on the basis that they had a teaching allotment that included maths and science classes, or multiple maths or science classes in Years 7 to 10. For each teacher, data generation focused on two maths classes, or two science classes, or a science class and a maths class. Table 1 summarises the teachers and their involvement in the research.

Table 1. *Teachers and Their Classes Represented in the Research*

<table>
<thead>
<tr>
<th>School</th>
<th>Teacher</th>
<th>Involvement in the research</th>
<th>Length of teaching career</th>
<th>Teaching allotment</th>
<th>Teaching preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Rose</td>
<td>2 x Maths classes</td>
<td>&gt;20 years</td>
<td>Snr &amp; Jnr Maths</td>
<td>Maths</td>
</tr>
<tr>
<td></td>
<td>Donna</td>
<td>2 x Science classes</td>
<td>4-5 years</td>
<td>Jnr &amp; Srn Science</td>
<td>Science (Biology)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Jnr Maths</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Simon</td>
<td>1 x Science class</td>
<td>3-4 years</td>
<td>Jnr &amp; Srn Maths</td>
<td>Maths</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 x Maths class</td>
<td></td>
<td>Jnr Science</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pauline</td>
<td>1 x Science class</td>
<td>2-3 years</td>
<td>Jnr &amp; Srn Science</td>
<td>Science (Physics)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 x Maths class</td>
<td></td>
<td>Jnr &amp; Srn Maths</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>James</td>
<td>2 x Science classes</td>
<td>&gt;20 years</td>
<td>Jnr &amp; Srn Science</td>
<td>Science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Jnr Maths</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ian</td>
<td>1 x Science class</td>
<td>&gt;20 years</td>
<td>Jnr &amp; Srn Science</td>
<td>Science &amp; Maths</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 x Maths class</td>
<td></td>
<td>Jnr Maths</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marg</td>
<td>2 x Maths classes</td>
<td>&gt;20 years</td>
<td>Jnr &amp; Srn Maths</td>
<td>Maths</td>
</tr>
</tbody>
</table>

Various qualitative methods were involved. Classroom observation formed the basis for directly experiencing the school setting, the classroom and teachers’ practices (Carspecken, 1996; Goetz & LeCompte, 1984). One lesson in each lesson sequence was video-recorded. A total of 52 lessons were observed, 23 of these were video-recorded. I conducted a reflective interview with each teacher after they had viewed their videos privately. A focus group discussion involving four of the teachers was also used to explore emerging themes.

Analysis was iterative, on-going, and incorporated categorical and thematic analysis techniques (van Manen, 1990). The focus of analysis was the teacher, and their reflections on their classroom practice.
Classroom observations enabled me to refer to particular classroom events during interviews. Categorical and thematic analyses of the transcripts in order to drew out commonalities and diversity in how teachers experienced the subject cultures of maths and science. See Darby (2010) for further description of the data generation strategy and analysis processes. The analysis, of which only part is represented in this paper, fore grounded the demands associated with subject cultures, identifying constraints that were common to many (represented here as Signature pedagogies), but also emphasising that teachers’ construction of a “subject culture” is shaped by a teacher’s mediating personal lens, which acts as the “interpretive backdrop” to a teacher’s practice (Darby, 2010).

Two themes speak particularly to the different ways in which the subject cultures of mathematics and science shape the practices of these teachers. The first theme compares the effect of the arrangement of mathematics and science curriculum content on teachers’ conceptualisations of the teaching task. The second theme explores how the focus of instruction shapes teachers’ conceptualisation of practical learning experiences in the subject. The essence of the emerging practices were described in Darby (2010) as Subject pedagogies and re-interpreted in this paper as Signature pedagogies.

The remainder of this paper applies the four dimensions of Signature pedagogy to this analysis of subject pedagogies in the following way. The surface structure, or concrete operational actions of teaching and learning, focuses on elements of teaching that were seen to be central to either maths or science. Excerpts from interviews and classroom observations, and description of their practices and pedagogical reasoning are used to illustrate trends in the data relating to the pedagogical responses of teachers’ to their experience of curriculum content organisation, and their use of hands on activities. The cultural nature of these practices is demonstrated in the description of how subject culture shapes practice.

The deep structure, or set of assumptions about how to best impart knowledge and know-how, is described as basic assumptions evident these two themes.

The implicit structure, or moral dimension, is described as the pedagogical imperatives driving practice, underpinned by the basic assumptions, and resulting in the subject (signature) pedagogies of these maths and science teachers.

What is missing from these practices distinguishes these pedagogies from each other and from what is possible. I describe what is missing in terms of how the pedagogy is situated in, and may be moved forward by, a broader reforming subject culture represented in science and maths education literature.

1. Surface Structures: Teachers’ Practice

The ensuing analysis draws on teachers’ reflections of their practices to identify two elements of classroom teaching that were particularly powerful in foregrounding what was central to the practice of these teacher in maths as compared with science. Two areas distinguished science and maths: the focused attention on the strict organisation of curriculum in maths, and the heavy reliance on practical activity in science. Below, teachers explain how such emphases shaped their pedagogical practices, thus acting as drivers for the perpetuation of the surface features of their practice.

Curriculum Content Organisation...

... in Maths

In maths, all teachers recognised the tight sequencing of the maths curriculum content. In reflecting on why she directed a struggling student to complete problems further back in the textbook, Rose stated,

ROSE:  Tom couldn’t do, he really wasn’t up to that, so I just put him back. And I will often do that, make them go back or give them some examples that are at their stage rather than what we are up to. Because there are about four of them that struggle with a lot of the content... if they haven’t got these down here, they can’t do this. [S2AR:38,39]

Rose’s actions and commentary suggests a curriculum content that is sequential and hierarchical in nature, building on previous concepts and skills, and dependent on students grasping each step to enable them to move successfully through the curriculum. This depiction is consistent with Siskin’s characterisation of maths knowledge as “ordered progression from place to place through a sequence of
steps” and level. Such sequencing places demands on teaching and learning, as was illustrated by Rose: when asked about how she saw her role as a teacher of maths, she stated, “I want them to enjoy maths. Because maths is a threatening subject, it is so threatening because it is so sequential” [S2AR:62]. Her response was to meet students at their level: “And often it is just going back to their level, to fill in the gaps, but sometimes you can’t fill in the gaps, there are just too many gaps to fill” [S2AR:279].

Simon’s view supported that of Rose. The school’s syllabus was considered an important guide for teachers in moving their students along the trajectory: “That is why the syllabus is so important. We rewrote it just on Monday, just to make sure what you have done in Year 7 and 8 [leads into Year 9 so that it] flows” [Simon, S2AS:158,160]. Rose’s pedagogical response in maths is reflected in Simon’s aim to ensure students have enough of “those concepts in their heads ready to go and to build on next year, and build on those for the next year and follow that process the whole way through” [Simon, S2AS:239].

… in Science

Donna explained that a recent restructure of the science course at Years 9 and 10 had implications for the Year 7 and 8 courses, for example, some parts of the Year 8 course were moved to Year 9. Despite the textbook remaining the basis for unit content, teachers made decisions about “what level to do it in Year 8” to limit repetition of content covered in the Year 9 subject, Standard Biology.

DONNA: At Year 8 we do basic classification in a short unit of two weeks. It looks at why we classify using the button or lolly activity that we did. Definitely the kingdoms then basic keys. Then in Year 9 we take it to another level and we talk about living and non-living things. A little about cells as the basis of all living things, then get into the five kingdoms, get the kids to think about what fits where and why... There is some overlap just because you can’t expect kids to remember it. “Remember when we did this last year?” and they go “No.” So there is definite overlap. And some kids will not pick Standard Biology in Year 9 ... So you try to cover some sort of chemistry, physics and biology so they've got some idea of what’s on offer at Year 9 and 10.

Donna described curriculum content as being sequential within topics or disciplines (that is, chemistry, biology or physics) and building on students’ ideas from their prior studies. This is consistent with Siskin’s (1994) description of the science curriculum as progression through disciplinary routes. Students are introduced to different areas of content that they are likely to encounter and use during higher year level studies. Donna also implied that the subject matter increases in complexity over the years, explaining that she was comfortable teaching light to Year 8, but would struggle at Year 10 due to the greater degree of difficulty and abstraction: “at Year 9 [explaining light] can get really tricky, like I wouldn’t want to teach physics at Year 10 or Year 11, to explain it even more than that would be, unless you are physics trained, I think it would be really hard” [S2AD:69]. The sequential nature appears at first to mirror the nature of increasing complexity in maths, but the difference lies in there being less of an imperative in science to prepare students as thoroughly for future studies as in maths. Pauline captured this perspective when comparing maths and science: “They’re skills, numeracy and literacy are skills that spread throughout the curriculum, whereas science is a content based subject and its not as essential” [Pauline, FGD:48]. In the above quote, Donna accepted that students tend not to remember ideas from the previous year so that some overlap of content is required. Conceptual knowledge is the focus here, where the distribution of various parts of the topic across the year levels is based on the premise that concepts can be understood at varying degrees of complexity.

Curriculum content organisation shaping pedagogical responses

The experiences of teachers highlight certain pedagogical responses, or surface features, arising out of the organisation of curriculum content. Teachers compared the need for a variety of supportive practices in maths and science.

The metaphor of filling the gaps that Rose used highlights the “continuous” nature of the maths curriculum content. Learning builds upon, and relies on, prior learning and, therefore, requires “catching up” when a student has been absent. The potential of missing content makes a subject “threatening” for learners if the content requires keeping on top of what is taught. This experience of maths has been described in research. For example, one of the challenges facing the teaching and learning of numeracy, according to Siemon et al. (2001) is the significant number of students that experience failure or a sense of
disconnectedness, and, consequently develop into “reluctant learners” (p. 7). The Education and Training Committee (2006, p. 165) found similarly that “maths anxiety” is a common response by maths learners due to a fear of maths and a lack of confidence resulting from gaps in student understanding. Such anxiety and reluctance can ultimately lead to student disengagement. Because of the sequential nature of the maths curriculum content, and the demand that this places on student learning, the need for student support became central for these maths teachers. Support came in the form of:

- **An assessment regime that monitored student understanding:** considered more important in maths than in science by Pauline to ensure that students do not fall behind:

  *Pauline:* in science I’ve been known to say to a kid who has been away, ‘I won’t test you in that topic’, or just give them an assignment and use that as their assessment rather than the full test. But with maths I feel the need to make sure they have understood that topic because they’ll need it further down the track. [FGD:32]

- **Individualised student support:** allowed teachers in my study to attend to students’ needs at their level so that students could achieve success, as well as be more optimistic about their own abilities: “there are all different levels, and if you can help them at their level then you are building up their self-esteem and they will feel better about it and therefore they enjoy it more” [Rose, S2AR:64].

- **Close attention to student difficulties:** considered more important in maths than in science. James compared student difficulties in maths and science: “like so many kids, when it comes down to thinking maths, it just doesn’t click” [S2BJ:126]; and “students cotton onto science pretty readily because of the tangible nature of much of the science that students study in junior science” [S2BJ:128].

- **Non-threatening classroom environment:** where students feel safe to take risks in exposing their limited knowledge or make mistakes. Mentioned in relation to both subject, particularly maths:

  *Rose:* I have set the environment, I hope to make it non-threatening because maths is such a threatening subject... And I hope the kids will have the confidence to ask and that no-one gets left out because if you don’t know things, there will be other kids in the class who don’t know. [S2AR:249, 251]

Subject matter differences are manifested as pedagogical differences in the above examples. Generally, teachers accorded a much higher demand for support to maths. At the centre of each of the above pedagogical choices in maths was the need to support students as they build firm foundations and extend their existing knowledge. In science, the need for support was evident, but was mentioned less in interviews. The message from this research is that, when compared with the support needs in maths, those in science are lessened.

In summary, a number of issues were raised by teachers in relation to the structure of the curriculum content in both subjects. Stodolsky (Stodolsky, 1988; Stodolsky & Grossman, 1995) asserts that the nature of the subject matter and its organisation is unique to any subject and likely to determine teaching practices. While this assertion is supported by my data, also evident in the data was a difference in the degree to which student support is a central pedagogical imperative. Curriculum content organisation was seen to play an immediate and critical role in shaping the practices of the maths teacher because of the demand that the nature of the content, and the progressive nature of student learning, placed on student learning. The shaping effect of the curriculum organisation appeared less central in the minds of the science teachers, who were guided by an imperative to plan units “that work”, that is, units that are age appropriate and that provide opportunities for students to engage with science concepts at various levels. This comparison arises out of differences in the degree of specificity and sequencing of the subject matter—maths to a higher degree than in science.

**Hands on Practical Work…**

… **in Maths**

Practical experiences in maths were discussed in the interviews much less than in science, partly due to the limited number of occurrences in the lessons that I observed and video recorded. Teachers recognised such experiences to be valuable in maths but felt that they were peripheral to the main aim of maths instruction. A tradition of instruction based on a commitment to a skills-based curriculum that prepares students for
senior studies perhaps detracts from time that might be spent doing more time-consuming tasks like engaging with concrete representations of abstract concepts, such as “fraction walls” that Donna referred to briefly. Time constraints and an over-crowded curriculum were blamed for constraining the emphasis placed on these valued yet seemingly dispensable experiences. For James, getting through the syllabus overrides his desire to include more “realistic” activities: “there’s always this time pressure or tension between having activities which are realistic based on reality but don’t cover all the syllabus and doing stuff from the textbook which tends to cover everything in the syllabus” [S2BJ:102].

Ian also felt the pressure of time. In the following response, Ian demonstrated how his personal commitment to using activities to reinforce students’ understanding of concepts was thwarted by time constraints. This excerpt was a response to a question about the difficulties that non-maths trained teachers might face when teaching maths:

IAN: There’s actually a lot more resources out there than most teachers are aware of that are available for reinforcing these kinds of concepts. But the way education is, you really never get a chance to look at all these done properly in the right way. Even some teachers don’t seem to twig to what some of these activities are trying to do. [S2BI:41]

… in Science

I identified three broad purposes of practical work that teachers referred to when providing commentary on, or justification for, using practical experiences in science. These views emanate from both schools, and represent a collective account of the various beliefs about the purposes of practical activity.

One belief was based on the idea that practical activities motivate students at both emotional and cognitive levels, recognising that both levels were required for students to learn. For example, Donna believed that “fun” experiences were important for motivating students to learn. She mentioned that including practical activities reduced the intimidation that students experienced in science by making the subject “fun” and “interesting”, and “not scary” [S2AD:59]. Also: “It’s making sure they’re having fun because they won’t learn it as well otherwise” [S3AD:34]; and “it’s a fun way to learn and it reinforces all the theory” [S3AD:58].

A second belief was that practical work enabled students to participate in the processes of science, thereby enhancing students’ skills and scientific thinking. For example, I saw a strong emphasis in Ian’s separating mixtures lessons (lessons I1, I2 and I3) on science processes, particularly fair testing. This type of activity, Ian believes, both engages students and gives students a glimpse at the core of the scientific endeavour:

IAN: designing their own experiments is the one thing that really works ... that’s the thing that makes it science. It’s not the content so much as the thought behind it or the scientific process. What makes an experiment? What’s a valid experiment? What can you draw out of this data? And if you can manage to put the two together you’re doing really well? [S2BI:59, 63]

A third common belief was that practical work assists in student understanding of science concepts. To achieve this depth of understanding, Pauline believed that students needed opportunities to develop explanatory understandings from their practical experiences. Observing natural phenomena and explaining them was a natural part of Pauline’s approach to her own learning: “I like to spend, and I do spend at least fifty percent of my time doing prac work because I am into observing things and then talking about them” [S2AP:36].

Actors involved in perpetuating practice

Students, teachers and school contexts were actors in perpetuating practices, or surface features.

James explained that students expected to be actively involved in science through experiments:

JAMES: They come into the classroom with the perception that maths is, sit down, copy the examples from the board, answer the problems on the left hand side, that’s sort of built in. They come in with the expectation of a science classroom that they’re going to do chemistry, and they’re going to see videos. They’re going to have discussions. They can talk a bit more. [S2BJ:116]
In both maths and science, teachers either enabled or inhibited opportunities for students to engage in more practical experiences. For example, Donna positioned herself less of an expert in maths because of her limited experience and knowledge:

DONNA: I don’t have a big maths background, so I have to spend a bit of time thinking about what could be available and what I could do, whereas with a science background, I think of things just because I’m experienced in that area. So I suppose it might depend on how much maths you’ve done or what resources you’ve been exposed to. [FGD:91]

Context was seen to play the following roles in perpetuating these traditions:

- **Privileges of funding**: funding for resources, supportive infrastructure (laboratories, preparation and storage rooms), and personnel (laboratory technicians) that science has traditionally enjoyed remain largely out of reach for maths departments. Swan (2001) found similarly that lack of funding for the purchase of, and training in the use of, manipulatives is a significant impediment to their use.

- **Lack of suitable learning environments for maths lessons**: James complained that maths is timetabled in any room, including needle craft rooms, such that mathematical equipment and artefacts are not visible to mathematical learners, nor readily accessible for maths teachers: “until that sort of idea percolates to the administrators in schools so that people like our head of department are able to implement the ideas that they really want to, it’s going to be very hard to do practical activities in the classroom” [S2BJ:190].

- **Strong and well-informed leadership**: Teachers at School B were under strong direction from the maths head of department to employ more activity oriented teaching approaches. Ian described the situation in this way: “he has been encouraging us to use the standard discovery learning things like RIME and a few others of those because they’ve been well tried methods of expanding kids out of the textbook” [S2Bl:27]. As a result, the maths lessons I observed at School B contained a greater proportion of activities and open-ended problem solving than those at School A.

Whether a teacher incorporates practical or activity-based experiences in maths and science is not simply a matter of having a filing cabinet full of activities, but requires an awareness of the purpose and nature of the types of activities appropriate for the subject. It also requires a particular epistemological stance, which is underpinned by a web of beliefs, knowledge, and experiences that provides some logic to the pedagogical decisions that are made by a teacher.

In summary, curriculum content organisation played an immediate and critical role in shaping the practices of the maths teacher because of the demand that the nature of the content, and the sequential nature of student learning and teaching. In comparison, this strict organisation was less central in the minds of the science teachers, who were guided by an imperative to plan units “that work”, that is, units that are age appropriate and that provide opportunities for students to engage with science concepts at various levels.

Practical activity was more central in the minds of science teachers who relied on hands-on activities to provide motivation for and to facilitate learning, but less central in the minds of teachers who rely on less hands-on teaching approaches that are successful in preparing students for future maths learning.

2. **Deep Structure: Teachers’ basic assumptions**

Some basic assumptions are evident from these teachers’ descriptions of teaching in school science and maths. I use Schwab’s (1969) commonplaces of schooling—subject matter, student, teacher and milieu—as the framework for constructing these basic assumptions.

### Teachers’ basic assumptions relating to curriculum content organisation

The basic assumptions listed in Table 2 represent the on-ground experience of these teachers: the enacted curriculum as it emerges out of the interface of the students’ learning needs in the classroom, teachers’ beliefs about what needs to be learned and how this is best made available for students, the imposition of a school system and its expectations and demands associated with different subjects, and the nature of the school version of the disciplinary knowledge.
The basic assumptions in Table 3 represent teachers’ experiences of using hands-on activities when teaching maths and science: demands imposed by the subject matter, teachers acting within a context that enables or constrains the use of hands-on activities, and expectations of students and teachers to incorporate such activities in supporting conceptual development.

Not obvious in these assumptions are the subject cultural shifts that I saw at School B where teachers reported on a directive from the Head of the maths department to embrace more engaging and meaningful pedagogies in the middle years. The assumptions in Table 3 tend to reflect what might be considered a traditional position on what it means to teach and learn.

### 3. Implicit Structure: Subject pedagogies arising out of central pedagogical imperatives

The cultural expectations captured through the basic assumptions above appear to have a strong influence on practice, and in some senses teachers’ pedagogical responses are clear. These common responses are what I am calling “subject pedagogies” (see Ball & Lacey, 1980) because there was general agreement about what was central to the teaching task. The basic assumptions underpin what I have called a “Pedagogy of Support” in maths, and a “Pedagogy of Engagement” in science. They represent strong
discourses that I saw characterising the pedagogical imperatives of these teachers. Their established and shared nature resemble signature pedagogies: they are recognisable as particular pedagogical practices, underpinned by certain assumptions, and as I will show below, they have a moral dimension in that they are driven by certain pedagogical imperatives that elevate particular beliefs about what constitutes subject teaching above others.

Their established and shared nature resemble Signature pedagogies because they:
- are recognisable as particular pedagogical practices (Surface Structure),
- underpinned by certain assumptions (Deep Structure),
- have a moral dimension in that they are driven by certain pedagogical imperatives that elevate particular beliefs about what constitutes subject teaching above others (Implicit Structure).

“Pedagogy of Support” in Maths
Evident in the data is a commitment to giving the students the best opportunity to be successful in the subject, therefore, support for learning dominated these teachers’ approach to teaching and learning. If the aim of teachers is to move students through a sequential curriculum and the mastery of increasingly complex and abstract key ideas and skills, then student support becomes paramount, hence the “Pedagogy of Support”. The student-teacher relationship is fundamental to this support. See for example, Williams’ Engaged to Learn model (Williams, 2005); and Noddings’ Care perspective (Noddings, 1992). For example, for Rose, a sense of care was central to her approach to student learning, with many of her reflections demonstrating her commitment to meeting the student learning needs. A teacher-student relationship based on trust enabled her to approach students openly, at their level, and with the knowledge that she can move them forward in their understanding. Support is therefore, a central pedagogical imperative in maths.

“Pedagogy of Engagement” in Science
In science, the analysis points to a reliance on a Pedagogy of Engagement where the artefacts of science and natural phenomena are used to engage students with science ideas and ways of thinking. The science teachers at School A in particular claimed to rely on students experiencing the practical work to draw students into the subject, to promote interest in science ideas, and to make students’ science experiences both meaningful and understandable. Evident is a strong reliance on engaging students through the artefacts of science and natural phenomena. Teachers believed that practical experiences provided students with positive experiences that are both cognitive and affective. The science teachers at School A in particular claimed to rely on students experiencing the practical work to draw students into the subject, to promote interest in science ideas, and to make students’ science experiences both meaningful and understandable. Teachers recognised the aesthetic dimension (Wickman, 2006) of practical activity and the positive effect they can have on engaging students in the processes of science. Donna talked about practical work as fun and enjoyable. Simon considered it as the key to boosting student interest and enrolment in senior science courses. And Ian saw it as an important tool for promoting reasoning about science ideas. Engaging students is therefore, a central pedagogical imperative in science.

4. What is missing?
Comparing maths and science enabled “what is missing” in each Subject pedagogy to be seen in sharper relief. Looking at what is missing by comparing these dominant pedagogies to reform agendas coming from the literature can give insight into how to move forward from these Subject pedagogies.

What is missing from the Pedagogy of Support in maths?
This characterization of the Pedagogy of Support has the potential to prioritize conceptual and skill development in order to “maximise outcomes obtained by emphasising standard sets of mathematical procedures” (Stacey, 2003, p. 122) at the expense of deep exploration and inquiry. This represents a traditional agenda in maths education. The reform agenda involves a commitment by teachers to allow students to “investigate and discover for themselves and have the freedom to ‘pave’ their own ways” (Krainer, 1993, p. 66). Stacey states that regardless of whether the traditional or reform agenda is the predominating approach, “greater emphasis on explicit mathematical reasoning, deduction, connections and higher-order thinking” (p. 122) is needed.
School B appeared to be moving towards the Reform agenda. Activity-based approaches that focused on problem solving and mathematical reasoning were part of the reform agenda of the head of maths department. While Ian and James saw this direction admirable and important, they nonetheless felt the pull of the demands of the senior years so that movement away from the tight sequencing of content was not without challenge.

School A most strongly represented the Traditional Agenda. Activity-based approaches provided an alternative to the textbook, but in a way that made them optional or in addition to the main focus provided by the textbook. While Rose was seen as an agent for change, there appeared to be no common agreement or comprehensive reform agenda with which teachers could align.

Moving forward therefore means shifting the pedagogical imperative from preparing students adequately for the next level of abstraction and complexity, to engaging students in the reasoning, reflection and creativity of mathematical inquiry.

What is missing from the Pedagogy of Engagement in science?
A Pedagogy of Engagement remained largely unquestioned by these teachers (with the exception of Ian perhaps), with practical experiences being regarded as aesthetically compelling and motivating, and providing real opportunities to actively engage at kinaesthetic and multi-sensory levels with science ideas. While practical work has the potential to do these things, the taken-for-granted links between practical experiences and theory, the affective opportunities often associated with science, and the authenticity of the practical experience are questioned in the literature (see, for example, Wallace & Louden, 2002). Lemke (2002), for example, questions the purported links between practical experiences and theory, and suggests instead that theory is “a realm of imagination where we can leap ahead of all possible experiments and generate impossible possibilities” (Lemke, 2002, p. 30). By omitting such a view of theory, Lemke believes that the affective dimension of human learning – that of “joy and desire, imagination and caring” (p. 31) – is removed from children’s learning experiences.

Another direction from the literature comes out of an imperative to develop curriculum content that is more relevant to students’ lives, a dimension of curriculum development that was not evident at either school. Some research has shown that some schools are moving away from topic-bound teaching (for example, states of matter), towards more thematic approaches to curriculum development (see, for example, Crawford, Krajcik, & Marx, 1999; Tytler, 2007).

Moving forward therefore means using practical experience to promote wonder; a shift from a taken for granted acceptance of practical work as the tool to engage to a focus on the mysteries of science and questions that students have that can spark deep interest; and finding opportunities for engaging with a science that more authentically represents science in community, both in terms of science ideas and science practices.

Conclusions
Based on these two aspects of the subject culture I developed two subject (or signature) pedagogies that arose from the fundamental assumptions guiding these teachers’ practices. They represent, at least with respect to these teachers, what is central and specific to teaching the subject. These perspectives do not necessarily reflect what researchers, policy makers and educators understand as “effective” teaching, but the reality of maths and science teaching as it was enacted and experienced by these teachers. These subject pedagogies make the subject teaching identifiably maths or science.

Teachers in this study talked about strong traditions of practice in each subject. In science, an expectation that practical work is part of a teacher’s repertoire is apparent. But the teacher will determine whether practical work is used effectivley by creating an environment that fosters deeper levels of engagement, or alternatively rely on the activity to “hook” students and focus purely on an affective response in the hope that students will be engaged and retain a positive disposition towards school science.

In mathematics, there is an expectation to support learning in order to prepare students for future learning success. A danger is that this imperative may be interpreted in a way that restricts the learning experiences to skills and processes as laid out in textbooks. Another danger is that teaching focuses on coverage rather than depth of understanding, resulting in superficial student learning, difficulties in
translating mathematics to real-life contexts, and poor attitudes and self concept in relation to mathematics.

Applying the dimensions of signature pedagogies enabled analysis of the traditions around prevailing pedagogies (Subject pedagogies). Pedagogical description even on this small scale enabled subject culture at the local level to be characterised in order to identify directions for teacher and school change. Exploring “what is missing” from Signature pedagogies is perhaps the most powerful part of the analysis because it provides space for critique and an entry point for reform. Without such analysis, pedagogical description may only be useful for practitioners content with perpetuating traditional approaches, rather than empowering teachers to be agents of change.

While there is some flexibility within the traditions to accommodate variation, breaking away from those traditions to embrace emerging traditions emanating from the research literature requires an appreciation of what is possible within the epistemological and pedagogical constraints of the subject. A number of factors, such as teaching backgrounds, subject commitments, and beliefs about teaching and learning, mediate a teacher’s capacity to determine “what is missing” from these traditions, as well as the degree of autonomy a teacher has to challenge or move forward from those traditions.

References


