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Translating a "Relevance Imperative" into Junior Secondary Mathematics and Science Pedagogy

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Inquiries into the state of mathematics and science education in Australia express the need to make curriculum and teaching practices more relevant and meaningful to students' lives. This vision requires that teachers understand how relevance can enter the classroom in meaningful, appropriate, and subject-specific ways. In this paper I use interview data and classroom excerpts to explore junior secondary teachers' responses to what I call a "relevance imperative". The data shows that relevance is a multi-faceted construct that is constructed differently by teachers depending on their socio-historical experience with the subject culture. Implications for teachers teaching out-of-field and how we conceive of teachers as subject specialists are discussed, and suggestions for future research are given.

Keywords: Science Education, Mathematics Education, Curriculum, Relevance, Subject Culture, Teacher Beliefs

INTRODUCTION

In recent years, there has been a push to reframe curriculum and pedagogy in ways that ensure that students' experiences at school are meaningful and relevant to their lives and perceived needs. This reframing of a "relevance imperative" ensures that the curriculum and the school experience as a whole is relevant to the lives of students. This paper explores how "relevance", as an imperative coming from the wider educational setting, is translated into the pedagogy of mathematics and science teachers, and the difficulties that can arise for teachers as they come to understand, appreciate and teach the subject. Teachers must understand how subject culture differences lead to subtle differences in what can be promoted as relevant in a subject, as well as how relevance may be meaningfully and appropriately achieved. Clarity in these areas is important for all teachers, particularly those who move into unfamiliar or changing subject cultures.

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The development of a "relevance imperative" in Australia

While relevance is a long standing imperative in education, the meaning of what might be considered relevant is not without debate. According to Newtown's discussion on the meaning of relevance in science education, "relevance requires a relationship in the presence of some need, aspiration or expectation" (1988, p. 8). He distinguishes between "external relevance" and "internal relevance". External relevance is outward looking and refers to science that is relevant to life in some way. Internal relevance is inward looking and presents knowledge as a neat, structured, coherent and unified assemblage; pattern and unity is more attractive and the content easier to acquire.

In both mathematics and science, a history of curriculum reform has resulted in movement towards emphasis on external relevance. This raises questions about what might be considered relevant to students' lives and interests. The Relevance of Science Education (ROSE) Project (Schreiner & Sjøberg, 2004) is an international comparative study that is gathering and analysing important data from 15 year olds about their attitudes to science and technology, and their

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motivations to learn about science and technology. For example, boys in England were found to be most interested in "destructive technologies and events", while girls were interested in "health related issues" (Jenkins & Pell, 2006). Osborne and Collins (2001) found that students were most interested in science topics that were perceived as relevant to their lives. While this research provides insight into what students consider to be relevant, further research is needed into pedagogies that make for relevant teaching and learning.

In Australia, debates surrounding the relevance of education have drawn partly from US discussions about the purposes of schooling, and from Australian based research that focused particularly on the middle years of education, which is typically for students between the ages of 11 and 14 years. This includes the junior secondary school levels on which this research focuses. A concern with the middle years in the 1990s prompted research into the needs of young people (Eyres, 1992). Research revealed that a curriculum that fails to recognise the personal and social lives of young adolescents results in student alienation and disengagement (Australian Curriculum Studies Association, 1996; Eyres, 1997). Some educators claimed that part of the problem is the fragmentation of the curriculum into distinct "subjects". In the US, Beane (1995) argued for an integrated curriculum more representative of students' life experiences. In Australia, the Queensland New Basics (Education Queensland, 2001) was developed to blur boundaries between traditional subjects. "Rich tasks" are used to integrate problem based learning experiences that tackle real life multi-disciplinary issues and problems. Rich tasks are informed by educational theory, including Dewey's emphasis on "integrated, community-based tasks and activities [that] engage learners in forms of pragmatic action that have real life value in the world" (p. 4); and Freire's emphasis on the solving of problems that have "relevance to the immediate worlds of students" (p. 4).

Concern with the relevance of education is a response to declining student interest in mathematics and science. Despite reforms since the late 1980s the disparity between the science and mathematics being offered and the needs and interests of students continues to be of concern. Recent inquiries into the state of school science and mathematics in Australia (Department of Education Science & Training, 2003; Education & Training Committee, 2006; Goodrum, Hackling, & Rennie, 2001) report on falling enrolments in post-compulsory science and mathematics, and student disenchantment with curriculum they often consider irrelevant. The Education and Training Committee (2006) found that a major factor contributing to student disengagement in secondary mathematics is the lack of connectivity between students' lives and mathematical problems. Similarly in science, the Committee recognised a need for curriculum approaches focused on, among other things, relevance to students' lives, as well as making strong links between future education and career pathways.

This research has informed curriculum development in Victoria. In 2006, the Victorian Department of Education and Training introduced the new Victorian Essential Learning Standards (VELS) as the guiding curriculum document. Relevance to students' lives features as one of the premises of the "Discipline-based learning strand": "students develop deeper understanding of discipline-based concepts when they are encouraged to reflect on their learning, take personal responsibility for it and relate it to their own world" (Victorian Curriculum & Assessment Authority, 2005, p. 3).

While this imperative exists, teachers' ability to respond will depend on them understanding how relevance can be incorporated into mathematics and science classrooms in meaningful ways.

This paper draws on interview data and critical incidents from classroom practice to explore how three teachers made the subject matter meaningful for their students by representing a humanised and relevant subject. Questions addressed in this paper are:

How does the subject and its associated pedagogies shape how a teacher can make links between subject matter and students' lifeworlds?; and

What issues relating to relevance arise for teachers as they move between mathematics and science?

Participating Schools and Teachers

The analysis reported in this paper formed part of a larger project aimed at improving the teaching and learning of middle years mathematics and science through the development of a school improvement process based on ction planning, which involves teachers evaluating their classroom practice. Four school clusters[1] were involved in the Improving Middle Years Mathematics and Science (IMYMS) project. Two of these clusters were invited to participate in my research on the basis of proximity to the researcher. Two secondary schools were selected, School A and School B.

School A was a co-educational Government school in a provincial city in regional Victoria, offering Years 7 to 12 to about 1,300 students. School A became the main research school due to teacher availability and proximity. Most of the data generated by the study came from four teachers: Rose, Donna, Pauline and Simon.

School B was located in an eastern suburb of Melbourne. It was 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.

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

Research design

The research involved observing and video recording teachers' mathematics and science lessons, then interviewing them about their practice, their views of school mathematics and science, and how they see themselves in relation to these subjects. Various data generation methods were involved (see Darby, 2009, for more detail).

Classroom observations allowed me to directly experience the school setting, the classroom and the teachers' practices (Carspecken, 1996; Goetz & LeCompte, 1984). Observation notes were generated for all observed lessons. The focus of the classroom observations changed depending on the purpose of the lesson and the opportunities that the lesson provided. One lesson in each lesson sequence was video-recorded. A total of 52 lessons were observed, 23 of these were video-recorded.

A sequence of modified video-stimulated recall and reflective interview occurred on two occasions. Normally video-stimulated recall (also called "video reflection", see Senger, 1998) involves video recording an event, followed by an interview between the participant and the researcher where the video is replayed to stimulate and lead discussion. In my research, I gave a copy of the two video-recorded lessons to each teacher. Teachers were asked to view the videos privately and reflect on a set of questions focusing on intentions for classroom actions, and beliefs about teaching, learning and the mathematics and science subjects. I called this a "modified video-stimulated recall" technique because the video served as a stimulus for reflection, which teachers would then discuss in a reflective interview. A trial of this process was conducted with a trial teacher who was not a participant in the IMYMS project (see Darby, 2004).

This sequence of videoing, reflection and interviewing occurred twice for teachers at School A (once for Pauline), and once for teachers at School B (none for Marg). During the first sequence, a set of directions and reflective questions were given to each teacher to reflect on while they watched the video. During the reflective interview that followed teachers were encouraged to:

- *talk generally about their approach to mathematics and/or science teaching, including background in, commitments to, and beliefs about each;*
- *respond to the reflective questions asking teachers to break up the lessons into phases and consider their intentions, evidence of subject culture expectations and practices in the lessons; and*
- *respond to questions relating to lines of inquiry that emerged from preliminary analyses of classroom observations or prior interviews.*

During the second sequence, teachers were asked to view their video-recorded lessons and use an annotated lesson plan I developed to record "things" they considered to be important in their teaching. During the interview, the teacher discussed their notes.

A focus group discussion involving the four teachers from School A followed the first round of data collection, with discussion based around three statements arising from a preliminary data analysis. Each statement was accompanied by excerpts from their reflective interviews that contributed to the development of the statement, and supportive experts from literature that expand on or correlate with the teachers' ideas. The statements related to the demands that school mathematics and science place on teachers and students; the translation of practices across mathematics and science; and influences on teachers' treatment of content in their teaching, and their attitude to the subject.

Informal discussions were used to gather demographic data, such as teacher background, and information about the units within which the video recorded lessons were included. They ranged from unstructured to semi-structured, and occurred prior to or following a lesson.

Data generation took place over four school semesters. The research was divided into "Data Sequences" that focussed on different dimensions of pedagogy in order to build up a rich picture of what the teacher was doing, and reasoning behind teachers' actions. Artefacts were collected on an opportunistic basis at all stages of the research, and included planning documents and classroom resources. Table 2 summarises the various data events within each Data Sequence.

An on-going preliminary analysis of observation notes and researcher reflections generated preliminary lines of inquiry and questions for further investigation. Part way through the research, a categorical analysis of the interview transcripts produced a list of emergent codes. Flexible lines of inquiry, or themes developed at this time. After all of the data was generated, the emergent codes were used during a thematic analysis (van Manen, 1990) of the interview transcripts, focusing on various themes and other areas of interest relating to teacher practice and subject culture (Darby, 2009).

Table 1. Teachers and Their Classes Represented in the Research

SCHOOL	TEACHER	INVOLVEMENT	TEACHING CAREER	TEACHING ALLOTMENT*	TEACHING PREFERENCE
SCHOOL A	Rose	2 x Maths classes	>20 years	Snr & Jnr Maths	Maths
	Donna	2 x Science classes	4-5 years	Jnr & Snr Science Jnr Maths	Science (Biology)
	Simon	1 x Science class 1 x Maths class	3-4 years	Jnr & Snr Maths Jnr Science	Maths
	Pauline	1 x Science class 1 x Maths class	2-3 years	Jnr & Snr Science Jnr & Snr Maths	Science (Physics)
SCHOOL B	James	2 x Science classes	>20 years	Jnr & Snr Science Jnr Maths	Science
	Ian	1 x Science class 1 x Maths class	>20 years	Jnr & Snr Science Jnr Maths	Science & Maths
	Marg	2 x Maths classes	>20 years	Jnr & Snr Maths	Maths

* Mathematics and science allotments only.

Table 2. Data Events in Each Data Sequence

DATA SEQUENCE	DATA EVENT	DESCRIPTION
Data Sequence 1 (S1)	Data Event 1	Familiarisation with the classroom, teachers, and schools through classroom observation and informal discussions with teachers
	Data Event 2	Modified VSR trial
Data Sequence 2 (S2)	Data Event 3	Classroom observations, video recording
	Data Event 4	Modified VSR and Reflective Interviews based on discussion questions
Data Sequence 3 (S3)	Data Event 5	Comparing ideas about what it means to teach the subject through a Focus Group Discussion
	Data Event 6	Classroom observations, video recording
	Data Event 7	Individual informal discussions to place the video recorded lessons into the context of the broader unit
	Data Event 8	Modified VSR and Reflective Interviews based on annotated lesson plans

One of four themes, translating relevance into mathematics and science, emerged from a common imperative of these teachers to make the subject meaningful by relating the subject to students' lives and interests. The theme interrogates how teachers translated the rhetoric of "relevance" as a generic pedagogical imperative into their conceptions of the subject, teaching and learning, and into their teaching practice. One part of this theme focusing on teacher's personal experiences with understanding and translating the relevance imperative into their pedagogy is represented in this paper. Another aspect of this research, the development of a classification of types of stories, is published elsewhere (Darby, 2007, 2009).

The following analysis begins with a narrative of how story and relevance emerged during the research process, followed by snapshots of the responses of three School A teachers (Donna, Pauline and Rose) to the relevance imperative, and issues that arose for two of these teachers as they negotiated subject boundaries between mathematics and science. These teachers demonstrate how differences in teacher background, beliefs and knowledge lead to a variety of pedagogical responses to the relevance imperative.

Finding links to students' lives in the classroom

During classroom observations I became interested in how teachers and students used stories to situate themselves or their personal experiences within the content-related dialogue. In science these stories were commonly introduced by either teachers or students and they appeared to have the purpose of situating the subject matter, and sometimes the scientific endeavour, into students' lives. In mathematics, fewer stories were used to explicitly connect students' lives to the subject matter. This raised the question as to whether stories in mathematics took different forms, possibly suggesting a different dynamic of engagement in mathematics and science.

I questioned teachers about the nature of, and potential for, telling stories in mathematics and science. Teachers recognised that stories were used, and were important in both subjects, but that science generally had more opportunities for story telling. Also, teachers and students had different roles to play in contributing stories. Simon stated that "there is no spectrum for [using stories in mathematics], whereas in Science you can do anything like that" [S2AS: 209]. On prompting, Simon was able to offer situations where he could use real-life applications of either science or mathematics. In mathematics, however, his experience was that, "most kids can't do that, like I have to lead that" [S2AS:211]. When asked whether stories were as common in mathematics as in science, Dona said "Probably not, no" [S2AD: 140], but she related this more to her limited mathematics background. Pauline believed that there are fewer stories in mathematics than science because "This is our world, this is what we live in, and explaining it, the science is all about explaining it. You just don't get stories like that in Maths, do you?" [S2AP: 44]. These differences suggest that stories play a different role in mathematics and science.

My attention turned to the pedagogical assumptions underpinning the use of stories: teachers referred to an imperative to link the subject matter to students' lives. By broadening the notion of "story" to include the notions of meaning-making, relevance and connectivity to students' lives, there was greater scope to explore in the data the various ways that teachers made the subject matter meaningful for students. The analysis presented in this paper targeted meaning-making. The notion of "story" is, therefore, referred to in a *typical narrative sense*, where stories about people, objects and experiences are "told" and become part of the teaching and learning experience, and in a *metaphoric sense*, where the lifeworld experiences of the teacher or student, and the subject matter, are not necessarily woven into a narrative but are linked in order to demonstrate the cultural and human dimensions of mathematics and science. Storying the subject reveals something of the "teller's" understanding of how the subject can link with human experience.

Snapshots of three teachers' approaches to making the subject relevant

ll teachers involved in the research said that relating the subject matter to students' lives was important; however, what they chose to relate, and how they did this, differed. In this section I present snapshots of three teachers—Pauline, Donna, and Rose—to show these differences. The snapshots illustrate how they made the subject matter meaningful by making it relevant to students' lives. The snapshots emphasise teaching strategies and approaches, and teachers' personal experiences of the subjects and disciplines.

Pauline

Pauline was in her second and third year of teaching during the study, having completed a three-year Bachelor of Science majoring in physics, then a two-year primary and secondary teaching degree. Her methods were general science and senior physics, and mathematics as her "fallback method".

Pauline demonstrated an appreciation for the human side of both mathematics and science as she talked about the effect of mathematics and science on students' lives, their prevalence in society and the impact on decision making. In particular, Pauline placed a strong emphasis on humanising science:

> *Science [provides an] understanding of how your world works and I find my knowledge of science extends to everything. It extends to when I go to the Doctor and I talk about my health … Everything I do is informed by my science knowledge, and I just think that scientific literacy is so important for kids to get the most out of themselves, out of their world… I just think scientific literacy informs everything that we do, personally, and the way we interact with the world and being more responsible. [S2AP:80]*

In this quote, science is made part of what it means to be human and a global citizen through a scientific literacy imperative. Science is constructed by people in an attempt to understand the world we live in, and to take some control over the decisions we make.

Pauline valued stories as a part of her own learning, and expressed these in the classroom where possible. In the following quote she explained that, when she was a learner, a science teacher had stirred in her an interest in science through his stories. She reflected on the role of stories in her developing interests and in her teaching:

> *I like collecting [stories]. I don't think I have enough. I like telling stories and getting the kids' stories out as well. And I have found that when I studied science they were the things that got me excited when a teacher told me a really interesting story and I don't know if mine are interesting or not, but I know that they were the sort of things that got my interest going in science and why I wanted to do more. It is unfortunate but it is true that sometimes it is the teacher's personality rather than the content that they are teaching that gets kids engaged … like I had a fantastic Year 10 teacher who revved us girls into doing physics and chemistry in Year 11 and Year12 and that was more his personality, the way he told stories, his passion for science, that got us into it. [S2AP:48]*

The way Pauline became interested in science is evident. The teacher's personality, rather than content, had been instrumental in shaping her perception of science as personally interesting and worthy of

attention. The teacher's "passion for science" that was transferred to students through engaging stories resonated with Pauline. A subsequent interest in science led Pauline to a career in physics and a commitment to science as a way of thinking about the world and informing life's choices.

Stories were a major component of Pauline's teaching repertoire. She was able to convey through story her commitment to science, passion, her experiences and her appreciation for what science offers. An example was her introduction of the theory surrounding static electricity with the story of Benjamin Franklin's discovery of electrical charge during one of her Year 8 science lessons:

> *PAULINE:I want to talk about what we did see. Now, Benjamin Franklin conducted a lot of experiments with electricity, his most famous one of course, flying a kite in a thunderstorm with a key attached to the string and having lightening strike that string and then come out of the key. Now he was really lucky that it hadn't rained yet and that the string he was holding wasn't wet because another scientist tried to replicate that experiment only a couple of months later and was killed because of the large amount of electricity going down the string. Benjamin Franklin was really really lucky. So Benjamin Franklin postulated, he came up with this idea, a model, that these, he'd done these types of experiments as well, that there was something that he called an electrical fluid that you could put onto substances and that if you took it away from substances that had one type of charge, and if you added it, it had a positive charge, if you took it away it had a negative charge. We can pretty much say we experienced that charge. Something, the most spectacular thing we did with the van de Graff when we did the discharge rods, what did we see?*
>
> *STUDENT: Sparks!*
>
> *PAULINE: Sparks. I always thought that sparks were the most impressive evidence of static electricity… We've got evidence for it. Benjamin Franklin postulated that there were two types, positive and negative. [Lesson P2]*

Here Pauline represents a scientist's search for understanding natural phenomena. She represents part of the scientific process—Benjamin Franklin postulated, developed a model, experimented, and another scientist replicated. She also provides a positive aesthetic response to the phenomenon of static electricity by using such terms as "spectacular" and "impressive", thereby modelling a fascination with science.

Pauline was confident that her style of teaching was effective and suitable for the science classroom. She used illustrations to link the subject matter to students' lives, as well as humanising stories to bring the subject to life; stories about people and events, the development of ideas, and connections with her own and students' lives.

Pauline professed that she was less confident in mathematics than science because she knew less about engaging students in mathematics, even though her teaching allotment had always included both mathematic and science. Pauline was frustrated that she struggled to translate this personal approach to mathematics, and felt disempowered by her lack of stories in mathematics.

Donna

Donna was in her fourth and fifth years of teaching. Donna had intended to becoming a veterinarian, but decided to explore her interests in zoology and ecology through a Bachelor of Science. Prior to doing a Graduate Diploma of Education, Donna worked at a tourism park as an education officer, taking tour groups on possum prowls and conducting other environmental activities. She also worked at a horse-riding park, and was involved in dolphin research. She recognised that these experiences impacted on her teaching practice by providing examples and stories of science-related ideas, experiences and phenomena.

Donna referred to her use of stories to provide contexts for investigations in order to make the subject matter relevant. She selected learning experiences that would be meaningful for students, focusing particularly on making connections between science and students' interests:

> *If you've got an idea of where your kids' interests are you can use things they like, because in that Year 8 class there's a lot of girls into horses so you can use different examples where that's relevant. And the boys: football or cricket. [S3AD: 149]*
>
> *If you've got an idea of where your kids' interests are you can use things like, because in that Year 8 class there's a lot of girls into horses so you can use different examples where that's relevant. And the boys: football or cricket. [S3AD: 149]*

Donna also referred to her use of phenomena that students would be familiar with that could act as contexts for student investigations. She replaced "regurgitating questions" with student generated questions; for example, exploring refraction by investigating "the distance that light comes out of a lighthouse in terms of where the boats are coming, how they work out where to put the lighthouse, does the light run out at a certain point?" [S2AD:126]. Lighthouses were familiar to these coastal students. In both mathematics and science, such stories were regarded by Donna as "favourite topics" [S2AD:140].

As a result of her involvement in Year 9 and 10 subject selections, Donna was aware that students often felt intimidated by science and mathematics. Donna appreciated that students would find the subjects less intimidating if they had a coherent and connected understanding of the subject matter. Therefore, many of her pedagogical choices were based on providing

students with a set of experiences with which they could relate. The way she constructed a narrative around the conceptual ideas testify to her commitment to providing a science experience meaningful to students' lives.

Rose

Rose had been a mathematics teacher for more than 20 years. At the commencement of this research, Rose had been teaching at School A for eight years, teaching mathematics at all year levels. Although qualified to teach science she chose early on in her teaching career to teach only mathematics. In the second year of the research, Rose assumed the role of Head of Junior Mathematics.

Rose made pedagogical choices based on what she believed students needed in order to be successful in mathematics, and in preparation for future mathematics studies. She used stories that provided meaningful applications of mathematics processes and concepts, such as buying a present for a colleague and using percentages to work out value for money. She used familiar objects, or more realistic representations of otherwise abstract mathematical ideas, in order to improve students' opportunity to engage with the mathematics meaningfully. For example, she drew chocolate blocks to illustrate fractions. Also, Rose expressed the personal meaning that mathematics offers. She humanised mathematics by modelling her enjoyment of mathematics. "I tell them I love maths" [S2AR:64] was echoed throughout the interviews. "It appeals to my logical brain" [FGD:108].

Rose conveyed her strong commitment to getting students to a point of understanding mathematical concepts and mastering skills and processes. Her experience with teaching across all year levels gave her an understanding of the difficulties students experienced and how to present the mathematics in meaningful ways. She appreciated the connection between student confidence and student success. Her attempts to situate the subject in students' lives were aimed at supporting skill development and conceptual understanding.

Rose's care for her students was played out in a particular way in mathematics classes. She wanted students to enjoy mathematics, to be comfortable with mathematics, and to recognise that it is preparation for senior mathematics and "preparation for life" [S2AR:54]. Such beliefs and attitudes stem from her personal success and experiences with mathematics, and her years of teaching experience. Rose regarded herself as being "mathematics-trained", which means having some degree of training that appropriately prepared her for mathematics teaching. She had no other career that involved mathematics, so her personal interest in mathematics, use of mathematics in the "real world", success as a learner, and university education provided the basis for her teaching career in mathematics. Unlike Donna, who had work experiences to draw stories from, Rose's examples emanated from her experiences of mathematics in life, learning and teaching. Such stories illustrate her commitment to ensuring students have a strong foundation in mathematics, both for life and to support future mathematics learning.

Different pedagogical approaches to making the subject meaningful

The above snapshots give a sense of how these three teachers emphasised the relevance of the subject. Their approaches reflect the teachers' beliefs about the purpose of the subject and the value that the subject can have in students' lives. For Pauline, stories were important in capturing students' interest through the use of *humanising stories of historical figures* that represent the human dimension of scientific discovery, thereby making the subject worthy of attention. The subject is made relevant through intriguing stories of the activities and attitudes of scientists and mathematicians. For Donna, investigations of *contexts* were pivotal in making connections between ideas. The subject is made relevant by using contexts that are built around students' interests or generative of new interests. Rose made direct links to students' lives by *illustrating* how the mathematics can be used. These illustrations make spontaneous, relevant and purposeful links between students' lives in order to make the subject matter more meaningful. Rose also expressed her love for mathematics as a way of thinking, thereby modelling the *human response* of appreciating the subject. The subject is made relevant because these stories demonstrate what it means to be passionate and committed to the subject, they empower students by demonstrating how ideas and modes of inquiry can be used, and they illustrate discipline-specific ways of thinking and operating that are accessible, engaging and appealing. These stories serve the purpose of situating the subject matter historically, culturally, socially and personally. In Darby (2007) I refer to these story types as Categories of Meaning Making.

The diversity of ideas represented by Donna, Pauline and Rose raises not only the question about the nature of relevance in mathematics and science teaching, but also why relevance is interpreted differently by teachers of the same subject, and differently across subjects. Understanding subject differences requires a teacher to interpret and understand the subtleties of what the subject has to offer their students. For teachers learning to appreciate, understand and teach mathematics and science, knowing the stories of the subject is vital to their response to the relevance imperative.

Knowing the stories of mathematics and science

Teachers' stories reflect something about themselves. Stories are "gathered" and "constructed" through their socio-historical interactions with science and mathematics. Teachers' backgrounds and experience with the discipline or subject provide the sum of their "lived experiences" (van Manen, 1990) from which teachers can draw. In their research into professional identity, Connelly and Clandinin (1999) refer to this as a person's "professional landscape" on their professional lives, metaphorically described as a "storied landscape". The landscape comprises multiple stories, "stories to live by". As a knowledge base, this landscape can include knowledge of events, processes or conceptual understandings, feelings, attitudes and values that stem from their experiences. Kerby (1991) states that a sense of self is generated through stories. The stories teachers tell are based on their experiences and the actual telling of stories shapes the self. For example, Ritchie, Kidman and Vaughan (2007) explore the importance of telling stories of science during teacher education in order to bring identities relating to both science and teaching to the foreground. Teachers' histories are evident in the stories that they tell. In the snapshots of Pauline, Donna and Rose, the influence of the discipline is evident as they share their experiences of learning at university, working in the field, personal experiences, or their personal orientation to particular ways of thinking. Their personal histories predispose them to particular ways of talking about the world.

For example, Donna's work experiences provided her with stories that she could bring into the classroom. Pauline's view of the subject had developed over years of studying science and enculturation into certain ontological and epistemological positions, including an appreciation of the use of stories and the problems this creates as she moved into mathematics teaching. Rose had spent most of her working life in the school environment, but she too had particular experiences as a learner and teacher that led her to develop positions ontologically and epistemologically.

It is clear that the schooling imperative reshapes teachers' experiences. When teachers enter the teaching profession stories and experiences become pedagogical tools. This knowledge base could be considered more complex than "content knowledge", or even "pedagogical content knowledge", as described by Shulman (1986) because their knowledge is impregnated with beliefs about teaching and learning, the subject, and the aesthetic dimensions of what it means to personally engage with the subject and discipline.

But what happens when teachers have few positive experiences with the subject or do not understand how their lived experiences can enhance learning opportunities for their students? Both Pauline and Donna valued stories but lamented having fewer stories to tell in mathematics because of their inexperience as

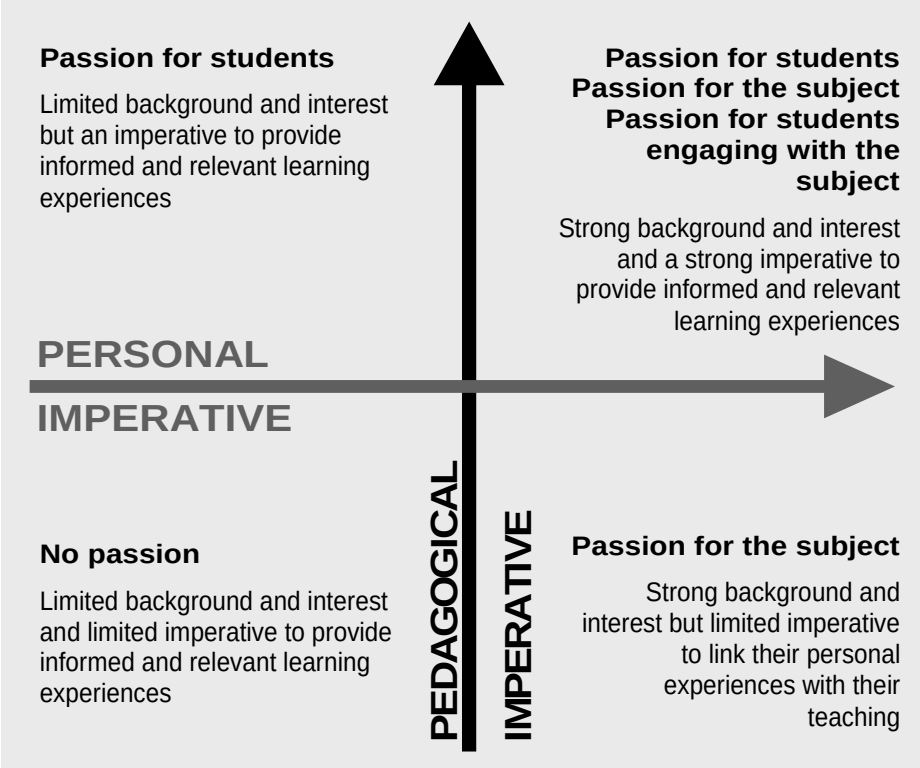

Figure 1. Relationships between personal and pedagogical imperatives

mathematics teachers. This restricted the way they connected the subject matter to students' lives. Donna explains this:

> *Probably not, no, and again I think that would probably be where I would find that, I'm predominantly a science teacher, and until I started here I hadn't taught maths before, so I am new at maths teaching, which means I try and do it where I can and I am still trying to learn where I could actually, what topics I can do that in. Because sometimes I think "algebra, how am I going to—" Whereas then you actually hear what other people are doing or you go and research a bit and you go "oh, yeah I wouldn't think of that". So now I know from last year what I can actually do with algebra, or different concepts this year. [S2AD:140]*

Clearly, Donna is relatively new to teaching and is building up a repertoire of stories as examples and conexts. Donna finds her students' lives and interests a wealthy source of contexts that she can draw on. Ideas also come from other teachers. Collegial sharing was referred to in every interview with the teachers as being valuable for curriculum development and broadening the teachers' pool of activities and resources.

The teaching imperative, therefore, motivates teachers to seek out stories. The discussion between Pauline and Donna below emphasises this teaching imperative. The discussion begins with a reflection on how they tend to be attentive to stories in the media relating to their disciplinary knowledge and research, and how these stories feed into their teaching:

> *DONNA: I'd watch a dolphin documentary before I'd watch the new latest technology in optics. I could talk about what dolphins do in their prides and family groups because I've done dolphin research, like a report to the Council. Whereas if I'd walked in cold to an optics or lenses lesson I would probably have to use what I know, what I've already researched myself or what I've taught in the past. I couldn't just go off and give them examples from industry, or this is how the newest camera works, there's this great new lens.*
>
> *PAULINE: Yeah, its an interesting thing isn't it. I'm doing optics at the moment, and I said to the kid, Did you know that the Hubble Telescope is about to be decommissioned? I think you should go off and research that. Because it is, it's our interest. And I think, if you're a biology person, then you go and watch a doco, actually I would watch a doco on dolphins too because I love dolphins, but if you're a physicist your ears might prick up when there's a story on, if you're skimming through the paper you'd go, what's this about the latest theory on how the earth was created, or whatever. And these things stick in your mind and you use them later when you're talking to kids.*
>
> *DONNA: But if I was teaching a unit on that, I would probably watch it. Because you'd help yourself out, you've got to know your stuff when you walk in class. But apart from that, with it not being an interest area, and you don't necessarily have a need for it. [Focus Group Discussion:102-104]*

These stories are different from those mentioned by Donna in the earlier quote where she used stories from the students' lives to enhance her teaching. The above discussion focuses on stories that emerge from the teachers' lived experiences with the discipline that they think the students might identify with. These stories from the discipline represent for teachers (and potentially for students) something about the nature of the knowledge and the nature of the scientific endeavour itself. They represent the subject as being a part of the larger science culture because they draw on the same body of knowledge, and that science can influence society through technology or social action. The teachers immerse themselves in these stories. These are personal stories that have interest for the teacher, and come from the teachers' historical interaction with the discipline rather than emerging out of a pedagogical imperative. Pauline indicates that these stories find their way into the classroom because of their usefulness to teaching.

There are two imperatives operating here: one is an expectation to prepare oneself for teaching, a "pedagogical imperative"; and the other is the role that a person's background and interests play in making a teacher sensitive to experiences and ideas, a "personal imperative". These two imperatives drive practice, that is, they indicate where a teacher's passions lie. Drawing from van Manen's (1999) description of pedagogy, a pedagogical imperative is when a teacher is concerned with what is and is not appropriate for their students; they are passionate about their students. A personal imperative is when the teacher is driven by their commitment to and appreciation for the subject, its bodies of knowledge and modes of inquiry; they are passionate about the subject. When a teacher recognises that their subject is of value to their students, they are passionate about students engaging with the subject. The model in Figure 1 represents the relationship between the pedagogical and personal imperatives as intersecting axes, and the passions that drive teachers' practice. This relationship is significant in driving teachers to make meaningful links between the content and students' lives. It also identifies problems that can arise when teachers are lacking commitments to the subject, or to their students.

Teachers located in the top right quadrant display a strong personal imperative, resulting in teacher confidence in content knowledge and personal interest in the subject. The teacher also displays a strong pedagogical imperative to ensure these experiences inform teaching and learning because of a personal commitment to sharing the subject with students. Donna believed that her biology teaching is more enthusiastic and informed because she can draw on her

experiences of working in the area. She is committed to making such stories available to her students in order to make the subject more meaningful.

Teachers located in the top left quadrant display a weaker personal imperative. They are less informed about the subject because of limited background in the discipline, resulting in a lower level of personal interest and commitment to the subject, and confidence in content knowledge. However, these teachers have a strong pedagogical imperative to improve their understanding of the content in order to be well prepared for teaching the content. Donna referred to paying attention to programs on television because they relate to her teaching, not because she is interested in them. Teachers teaching out-of-field who have a strong commitment to their students may fit into this quadrant because they have a strong pedagogical imperative to ensure students are engaged, but lack the stories of the subject to make relevant links to students' lives.

Teachers located in the bottom right quadrant display a strong personal interest in the discipline. However, these teachers see little relevance of these experiences, or perhaps lack the opportunity to draw these experiences and knowledge into their teaching. Pauline expressed an interest in problem solving with her senior mathematics students, but found little opportunity to do so, nor did she have the pedagogical content knowledge of how to do it. Alternatively, a teacher may be extremely passionate about the subject but not distinguish between what is and is not appropriate for their students as may occur in the case of an over-zealous teacher who ignores students' learning needs.

Teachers located in the bottom left quadrant have neither the personal interest in the subject, nor the commitment to make their representation of the subject interesting. Rose was trained to teach science but decided early in her teaching career that she did not like teaching science and became a mathematics-devoted teacher. Teachers who teach subjects out-of-field may fall into this category if they lack a personal commitment to the subject as well as the stories to bring the subject alive.

A strength of this model is that it is not discrete. The same teacher can be situated in different quadrants depending on their level of confidence and knowledge of the subject. This is demonstrated by Donna who is situated in two of the quadrants. The model is, therefore, privileging subject matter knowledge as a key determinant of teacher practice.

Negotiating subject boundaries

What stories of the discipline does a teacher need when they cross the subject divide into unfamiliar territory? Teaching "out-of-field" is a reality in many secondary schools. For example, research has shown that the future junior mathematics teacher in Australia is likely to be a female biology graduate (Harris & Jensz, 2006). A new teacher or a teacher teaching out-of-field is in danger of lacking or not knowing how to use common or previous experiences to enhance the teaching sequence. They may attempt to bring in a style appropriate for a different subject with a different set of demands. As Pauline experienced, pedagogy suitable for one subject will not automatically translate to another subject. For Pauline, movement across the boundary from science into mathematics was hampered by her lack of stories, as well as a limited understanding of how to use stories to make connections between the mathematical ideas and students' lives. While she was fluent in explaining the presence of science in students' lives, the impact of mathematics on students' lives was more difficult for her to explain. Pauline's response suggests that crossing the boundaries between subjects can be seen as a cultural border crossing for teachers in the same way as it is for their students (Aikenhead, 2001; Aikenhead & Jegede, 1999). Negotiating the boundary can be difficult for the teacher who has limited background and aesthetic understanding of teaching the subject.

Subject culture, school culture imperatives, and the individual teacher

The culture of school imposes certain imperatives for teaching, such as engagement, support and relevance, which teachers must translate into their subject teaching. A number of influences eminating from within and outside the subject culture were evident in teachers' respondes to the school imperative of relevance.

Teachers recognised that an imperative to make the subject relevant was in opposition to more traditional approaches that de-contextualised the content. This refers to long standing traditions of practice that teachers were socialised into through their historical encounters with the subject.

In addition to this traditional subject culture, teacher's pedagogical responses can be shaped by the local subject culture, that is the culture of teaching at the school that is developed through dialogue and sharing of practice with colleagues within their subject department. The provision of structures to support curriculum development requires space, resources, and a loosened hold on traditional curricula structures focused on canonical content and the textbook.

These experiences contribute to a teacher's view of the subject. Other experiences may include work experiences and training that a teacher can draw on to tell stories about what it means to be or think like a scientist or mathematician. Background in other subject

areas may assist with forging productive links with the knowledge and skills from other subject areas, thereby situating the subject within the student's broader school experience. General pedagogical experiences and beliefs developed as a learner might prompt a teacher to reject their own experiences of a disconnected subject matter and ensure vigorous attention to relevance and connectedness between the content and the lives of their students. Personal life experiences, such as a teacher's hobbies provide examples of how the subject knowledge, processes and skills of the subject can impact on one's personal and daily life.

A teacher's orientation to relevance depends on what the teacher knows, believes and values about the subject and what the subject can mean for their students and themselves. This is ultimately a personal response. Hipkin's (2006) investigation of science teachers' approaches to the teaching of the nature of science found that teachers tended to replace formal accounts of the way science knowledge is generated with more impassioned accounts based on the practices and objects of their own scientific inquiries. She found that some teachers' narratives revealed passion for their personal learning, as well as an ethical concern for their students' learning to care for the natural world and for science as a means of investigating the natural world. In the context of my research, this emphasises an aesthetic dimension to the way teachers approached their interpretation of cultural beliefs and practices, and therefore, teaching of a subject.

CONCLUSIONS, IMPLICATIONS, AND FUTURE RESEARCH

This research demonstrates that expecting teachers to make the curriculum relevant is not necessarily unproblematic because the meaning of relevance is not collectively understood, nor is it the same for mathematics and science. For teachers moving between mathematics and science teaching, especially when moving into a subject where they have limited appreciation or experience, understanding how the subject can be made relevant for their students, and themselves, is an important aspect of their pedagogical content knowledge.

Elbaz-Luwisch (2002) describes the practice of teaching as being constructed when teachers tell and live out particular stories. While the teachers recognised the importance of humanising a subject in order to give it some level of significance in the lives of their students, how the teachers embraced and responded to this challenge depended on each teacher's personal commitments to, and historical interaction with, the subjects and the subject cultures. Therefore, "having stories to tell" was not simply a cognitive issue, but also required a personal response from the teacher. It is likely that evaluative judgements about what might be of interest in the subject shape the teacher's pedagogical choices; judgements arising from what the teacher knows and values, which are aesthetic in nature.

Stodolsky and Grossman (1995) claim that subject content provides the context for the secondary teacher, not just in terms of the subject matter to be taught, but in the ways teachers think about learning, assessment, and their roles as teachers (see also Grossman & Stodolsky, 1995; Siskin, 1994; Stodolsky, 1988). My research has shown that, for these teachers, the content as context placed demands on their interpretation and response to a "generic" imperative to make schooling relevant. Teachers' beliefs about the value of the subject were bound up in the perceived potential purposes that the content could have for students and themselves. Their response to this generic "relevance" imperative was, therefore, subject-specific because of the subject matter context, but also because their teaching was based on their historical interactions with the subject. Pedagogical and personal imperatives ultimately drive teachers' response to the relevance imperative.

The data suggests that having a background in a discipline is likely to equip teachers with the disciplinary knowledge to draw on in their teaching and an appreciation and enthusiasm for the subject that can be transmitted to students, qualities that are often used to define effective teachers (Darby, 2005) and potentially lacking for teachers teaching out-of-field (Ingvarson, Beavis, Bishop, Peck, & Elsworth, 2004). Other research shows that, while a teacher's practice is dependent on the experiences that the teacher has had with the subject or discipline, these experiences are not necessarily related to exposure at university level. For example, other factors, such as career trajectory (Siskin, 1994) and professional development (Tytler, Smith, Grover, & Brown, 1999), have been found to be cogent in determining how teachers approach teaching and learning. These research outcomes highlight the importance of paying attention to teachers' experiences of the subject they are teaching. Evident also is an assumption that teachers are inducted into the culture of a subject through their experiences, and that, with further training, teachers can improve their competence and confidence in teaching a subject in which they have previously had limited background. Further research is needed that problematizes the assumption that disciplinary training automatically and alone leads to effective teaching. Such research could explore those experiences that teachers teaching out-of-field believe are instrumental in developing confidence and competence in their teaching. Further research is also needed to develop rich descriptions of those knowledge, skills and attitudes that teachers bring into their out-of-field teaching from their in-field subjects, particularly in

terms of how the demands of the subject come to bear on their translation for teaching in the out-of-field subject.

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