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Chapter-08

NEGOTIATING MATHEMATICS AND SCIENCE SCHOOL SUBJECT BOUNDARIES: THE ROLE OF AESTHETIC UNDERSTANDING

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ABSTRACT

A tradition of subject specialisation at the secondary level has resulted in the promotion of pedagogy appropriate for specific areas of content. This chapter explores how the culture of the subject, including traditions of practice, beliefs and basic assumptions, influences teachers as they teach across school mathematics and science. Such negotiation of subject boundaries requires that a teacher understand the language, epistemology and traditions of the subject, and how these things govern what is appropriate for teaching and learning.

This research gains insight into relationships between subject culture and pedagogy by examining both teaching practice in the classroom and interrogating teachers' constructions of what it means to teach and learn mathematics and science. Teachers' level of confidence with, and commitment to, both the discipline's subject matter and the pedagogical practices required to present that subject matter is juxtaposed with their views of themselves as teachers operating within different subject cultures. Six teachers from two secondary schools were interviewed and observed over a period of eighteen months. The research involved observing and videoing the teachers' mathematics and/or science lessons, then interviewing them about their practice and views about school mathematics and science.

The focus of this chapter is on the role of the aesthetic, specifically "aesthetic understanding," in the ways science and mathematics teachers experience, situate themselves within, and negotiate boundaries between the subject cultures of mathematics and science. The chapter outlines teachers' commitments to the discipline, subject and teaching by exploring three elements of aesthetic understanding: the compelling and dramatic nature of understanding (teachers' motivations and passions); understanding that brings unification or coherence (relationships between disciplinary commitments and knowing how to teach); and perceived transformation of the person (teacher identity and positioning). This research has shown that problems arise for teachers when they lack such aesthetic understanding, and this has implications for teachers who teach subjects for which they have limited background and training.

INTRODUCTION

Science and mathematics are often closely associated during discussions about teaching and learning. This is reflected in the common expectation that teachers trained in either junior secondary mathematics or science will teach both at some time in their career. This suggests an assumption that mathematics and science have elements in common, such as common ways of thinking. This, in turn, implies assumptions about what might be common in terms of pedagogies appropriate for the two subjects (see, for example, Beane, 1995; Berlin & White, 1995). Little research, however, investigates how teachers internalize and deal with these assumptions.

As disciplines, mathematics and science are distinguishable epistemologically and methodologically, and these differences are represented in the subject matter, pedagogies and purposes associated with their respective school versions. These differences place demands on teachers as they make decisions about what needs to be taught, the methods used, and the value that the subjects might have for students. The subjects are recognizably different; as are the ways students and teachers have been traditionally perceived in relation to those subjects. The distinctive nature of school subjects is described by Goodson (1993, p.31), who explaining how the organisational structure of the subject influences the ways teachers relate to the subjects and their students:

> [the] "subject" is the major reference point in the work of the contemporary secondary school: the information and knowledge transmitted in schools is formally selected and organised through subjects. The teacher is identified by the pupils and relates to them mainly through her or his subject specialisation.

Research is needed to understand how teachers experience the different demands that school mathematics and science place on teaching and learning. Of particular interest is how teachers construct for themselves these two subjects, and factors that influence the way teachers negotiate the boundaries that exists within the secondary school context.

The research reported in this chapter explores how teachers' experiences with the subjects influence them as they teach across mathematics and science. Negotiating subject boundaries requires that a teacher understand the language, epistemology and traditions of the subject, and how these things govern what is appropriate for teaching and learning. Teachers are, in a sense, inducted into the culture of the subjects by way of their own experiences of doing, using, learning and teaching mathematics and science. This research gains insight into the subject cultures of secondary mathematics and science from the perspective of the teacher and his/her classroom practice, focusing on the personal aspects of teaching, including how teachers see themselves as teachers, learners and participants with respect to mathematics and science. Teachers' level of confidence with, and commitment to, both the discipline's subject matter and the pedagogical moves required to present that subject matter is juxtaposed with their views of themselves as teachers operating within different subject cultures.

This chapter begins by comparing mathematics and science as forms of education. The differences and similarities between the two subjects are explored so as to describe the cultural traditions that the teachers participating in this research are likely to have been exposed to. A section follows that explores the relationship between the individual and culture in the context of education. This leads into a discussion of the role that aesthetics (in the tradition of Dewey) has played in education. Theory surrounding the notions of aesthetic experience and aesthetic understanding is discussed in terms of student learning, but I open these discussions to include questions about the role of aesthetics in the relationship between subject culture and pedagogy. The research and my findings follow, using the framework of aesthetic understanding.

COMPARING MATHEMATICS AND SCIENCE AS SECONDARY SCHOOL SUBJECTS

The academic disciplines of mathematics and science are represented as school subjects; however, the nature of these school versions do not, and perhaps cannot, necessarily mirror the academic versions. The foundational knowledge of mathematics and science are translated and organised for the purpose of meeting educational outcomes.

In schools, mathematics is often presented as a requirement for adult life where students recognise the utility of mathematics. Crockcroft states that mathematics should also be presented as a subject to enjoy through the use of mathematics puzzles and problems that students can engage with. In addition, mathematics education takes on a role of developing "the powers of 'abstraction' and 'generalization' and their expression in algebraic form on which higher level mathematics depends… [All] students should have opportunity to gain insight, however slight, into the generalised nature of mathematics and the logical process on which it depends" (Crockcroft, 1982, p.67).

Where work in science is about relating scientific evidence to scientific theory (Board of Studies, 2000a), science education allows students to be exposed to scientific ideas through participating in processes employed by scientists (cf Gunstone & White, 2000). Through learning and applying science, students are empowered as members of society: "Science education contributes to developing scientifically and technologically literate citizens who will be able to make more informed decisions about their lifestyle and the kind of society in which they wish to live" (Board of Studies, 2000b, p.5).

Like mathematics education, science education serves a mechanistic purpose in the lifelong learning of students. Despite this apparent similarly in the purpose of the two subjects, Siskin's (1994) research revealed 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).

How, then do mathematics and science compare? An initial point of comparison draws on the assumption of Siskin (1994) that mathematics is a single discipline, whereas science is a cluster of disciplines, that is chemistry, biology, physics, geology. This difference has a number of implications for teaching.

Where mathematics is characterised by an “ordered progression from place to place through a sequence of steps” and different levels (Siskin, 1994, p.170), science is characterised by a progression through disciplinary routes.

Subsequently, in mathematics, Siskin (1994) claims that teachers develop general agreement about “what counts as knowledge, and how it is organised and produced” (p.170). Counter to these claims of general agreement, Schoenfeld (2004) states that, as with other subject areas, controversies exist about the epistemological foundations of the mathematics discipline, particularly “what constitutes ‘thinking mathematically’, which is presumably the goal of mathematics instruction” (p.243). Despite these controversies, mathematics has often been and continues to be characterised by incremental learning, “a slow systematic and progressive movement from the simple to the complex” (Hargreaves, 1994, p.139). Mathematics activities are, therefore, often seen as “a sequential progression through a series of topics, each of which is a prerequisite to what follows” (Sherin, Mendez, & Louis, 2004, p.208), p.208). The hierarchical nature of the way the mathematical curriculum is organised makes mathematics difficult to teach and learn (Crockcroft, 1982). With this as a teaching model, Siskin claims that “mathematics teachers value testing, placement, and tracking as the means of assigning students to the right rungs during their progress up the ladder” (p.170). Tracking is presented as a point of difference between mathematics and teachers of other subjects: where tracking is viewed by mathematics teachers as a means of meeting student learning needs, tracking is viewed by teachers from other subjects as simply “convoluted” and extraneous.

One of the consequences of having widespread agreement on the content and sequence – what Siskin (1994) calls “the tight paradigm of mathematics” – is that teachers are able to learn the routines, and thereby follow the same curriculum. Homogeneity across the subject often results, Siskin asserts, such that mathematics instruction in a department can be somewhat similar. This view of homogeneity is observed by Reys (2001) who notes that in America at least there exists a generally agreed upon core body of basic knowledge such that mathematics texts from different publishers are almost indistinguishable. The best sellers are emulated by other publishers – deviation from the “norm” (best seller) results in low book sales, thereby limiting motivation to change textbooks dramatically to address the reformed American Standards-based curriculum. In 1986, Dorfler and McLone were of an opinion congruent with Reys and Siskin stating that “the material content of school mathematics is to a high degree internationally standardised. Deviations from this standard are only minor and depend on the educational system, local traditions and influences and perhaps special local demands” (p.58). This view predominates accounts of how subject matter is organised in school mathematics.

On the other hand, according to Siskin (1994), the multi-disciplinary nature of school science “brings together not different ways of knowing the same content, but the same scientific method used to know different topics” (p.174). It is beyond the scope of this chapter to explore the debate surrounding either the nature of science as represented in schools, or how representative the “scientific method” is of the way scientists operate. Suffice to say that, according to Schoenfeld (2004), claims to a scientific method that permeates all the scientific disciplines is overstated, suggesting that different disciplines of science, such as physics and biology are more disparate in both theory and method than are anthropology and sociology.

Many writers in science education prefer to focus on the nature of science as the underlying thread of school science curriculum and pedagogy, recognising the disciplines of science as adopting many methods but being subject to some basic tenets of science, although the question of what these tenets should be are still unresolved, (see for example Longbottom & Butler, 1999; MacDonald, 1996). Studies have investigated how the nature of science is represented, with more recent research promoting the importance of explicit instruction of and participation in the nature of science in science classrooms (Hart, Mulhall, Berry, Loughran, & Gunstone, 2000). Such learning experiences can be achieved by providing authentic science experiences (Rahm, Miller, Hartley, & Moore, 2003; Roth & McGinn, 1998) where students are considered as nonscientists participating in the scientific community of practice by engaging in "habits of thought" cognisant with scientific thinking (Trumbull, Bonney, Bascom, & Cabral, 2000, p.1).

A second area of comparison relates to the nature of the knowledge underpinning the subjects of mathematics and science. Science is characterised by Siskin (1994) as being less abstract and more activist than mathematics. The Victorian *Mathematics Curriculum and Standards Frameworks II* (Board of Studies, 2000a) states that "[b]ecause mathematical knowledge is about *relationships* between things, it is inherently an abstract discipline. This abstractness makes it applicable in a wide variety of situations, but present particular challenges to teachers and learners" (p.5, emphasis in the original). However, application in mathematics has an important place in applying concepts and skills in the process of problem solving, where problems are contextualised for students in both familiar and unfamiliar everyday situations (Crockcroft, 1982).

By comparison the *Science Curriculum and Standards Frameworks II* (Board of Studies, 2000) talks about application of scientific knowledge and making connections between the science community and society. For example, where mathematics patterns are taken out of context, such as tile patterns on a bathroom wall, patterns in science are dealt with in real life contexts. Scientists then "do something with it" that places the theory into practice, what Siskin (1994) calls "activist" and "making a difference". This can be linked to the application of scientific principles to real life contexts: "science knowledge is characterised by a complexity of application of conceptions to the real world, and to classroom activities" (Tyler *et al.*, 1999, p.211). With the variety of disciplines and the phenomena associated with those disciplines comes a "rich conceptual base" that adds complexity to planning in science (p.211). This can be contrasted with the contestable notion of an agreed conceptual sequence associated with mathematics curriculum. The National Council of Teachers of Mathematics (2000) identified that one of the call marks of an effective mathematics teacher is having an understanding of the "big ideas of mathematics and [being] able to represent mathematics as a coherent and connected enterprise" (p.17).

Rico and Shulman (2004) mention the long-standing dispute over the way science should be represented, arguing for a divergence from the entrenched and much criticised "science-as-facts" model towards "science as 'doing', investigating, conducting research, actively seeking solutions to yet-solved problems" (p.162). Rico and Shulman state that these poor models are unfortunately perpetuated by commercially produced materials that "emphasise facts, formulae, demonstration, and vocabulary" (p.162). Processes of science are seen to be add-ons rather than necessary for learning science content. Studies of science textbooks show that often only the basic facts are covered and that they introduce more new vocabulary than foreign language textbooks. Van den Berg (2000) claims that American textbooks tend to have little educational value partly because the experiments are dictated by tradition, and utilize largely recipe style procedures.

Traditional modes of instruction in mathematics have also been criticised and researched. Siskin's (1994) analysis of how mathematics teachers expressed their knowledge of their discipline demonstrated above reinforces a content driven focus in school mathematics. In 1988, the Victorian Ministry of Education launched a curriculum framework that dealt with the pervading problem of classroom approaches that failed to encourage students in their mathematical learnings: "the type of mathematics that has tended to be offered to students in the past has become abstract at too early a stage" (p.11). Underlying their recommendations was the need to broaden students experience of mathematics so as to develop skills, concepts, applications and processes which allow meaningful participation in society" (p.12). Schoenfeld (2004) and Sherin et al. (2004) reiterate this paradigmatic shift in current mathematics curriculum where both content and process are essential for mathematical understanding. A teacher participating in Sherin et al.'s research on *Fostering a Community of Learners* (FCL) reported that when he began to rethink mathematics as content *and* process, the classroom discourse was transformed with greater emphasis given to students sharing and responding to each other's ideas. This emphasis on teacher instruction is indicative of the general movement in mathematics education reform where effective mathematics instruction is reconceptualized as "a human construction based on historical efforts to solve particular problems, accepted modes of discourse and validation that are essentially social in nature" (Tytler, et al., 1999). In 1988 the Crockcroft Report described six elements of successful mathematics teaching: exposition, discussion, practical work, practice, problem solving and investigational work. Clearly, this seemingly new emphasis on content *and* process has been evident in the literature but maybe not so apparent in the classroom.

In many ways science and mathematics can be differentiated. In addition to the arguments presented thus far, mathematics and science can be further characterised by their degree of reliance on equipment ("materials of the trade"), and by the type of clientele they attract, for example, science has a somewhat contestable masculine image as evident by a seemingly lack of female science teachers and students electing to continue with science beyond the post-compulsory years (Siskin, 1994).

However, the fact remains that teachers, educators and researcher often closely align science and mathematics because they apparently share "linear ways of approaching things, step-by-step procedures, quantitative methods, and a mature paradigm" (Siskin, 1994, p.174). While research exists that explores how teachers represent their disciplines through classroom practices, there has been very little research that takes a trans-disciplinary approach to such exploration. The question remains, what is it about the subjects that affords and constrains particular teaching and learning practices? And from the persepective of the teacher, how do teachers' experience of these cultural traditions shape their sense of themselves, their students and their practice? This type of information is valuable, especially at a time when the traditional boundaries between subjects are being challenged.

RELATIONSHIP BETWEEN SUBJECT CULTURE AND THE INDIVIDUAL

I am approaching this relationship between subject culture and pedagogy from the individual teacher's perspective, recognising that, although there may be a (or a number of) subject culture(s) that these teachers are operating within and contributing to, the teachers respond to this in their own way dependent on the sum of their personal beliefs, experiences, knowledge etc. Borrowing from cultural theory relating to cultural organization and leadership, I am framing subject culture as those patterns of "shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration" (Schein, 1992). These assumptions work well enough to be considered valid and are taught to new members during enculturation. In the teaching context, enculturation involves a lifetime of experiences of learning, practicing and teaching the subject. If the "group" here refers to all science 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.

Paechter (1991) prefers to use the term "subject subculture" to recognise that every school is likely to have their own consensual view about the nature of the subject, the way it should be taught, the role of the teacher, and what might be expected of the students. Schwab (1969) refers to this consensus as unity, which he sees as important in providing opportunities for group action (see also Ball and Lacey, 1980). Schwab also impresses the importance of diversity of practice and beliefs amongst teachers. This view acknowledges that teachers will bring with them their own interpretation of teaching the subject. Similarly, Goodson (1985) argues that teachers have a personalised concept of a subject and what constitutes the practice of teaching.

This perspective on subject culture supports the assumption that a teacher's construction of the subject (including what and how it is taught) and the role of the teacher and learner, is mediated by a teacher's lens of personal beliefs, knowledge and experiences. It makes sense then, that the effect of the subject culture on shaping pedagogy is mediated by a lens of personal beliefs about what constitutes the subject, teaching and learning. Consequently, decisions about teaching and learning are likely to be based on experiences of the subject cultures and from life. Such experiences are likely to evoke in the teacher a response that is not only cognitive, but also affective.

THE AESTHETIC IN EDUCATION

The aesthetic became important to my explorations of subject culture and pedagogy when I became attentive to how teachers constructed themselves in relation to the subject. Teachers recognised that their interest in the topic under instruction had a strong bearing on how they taught. Subsequently, my interests turned to exploring the idea that teaching and knowing how to teach involves both cognitive and affective dimensions. Zembylas (2005b) recognises that emotion and cognition are inextricably linked in the process of student learning. I assert that the same can be said for teachers in their development as mathematics or science teachers.

Increasing attention is being given to the affective domain as researchers explore its centrality in the learning of mathematics (Bishop, 1991; Sinclair, 2004), learning of science

(Alsop, Ibrahim, & Kurucz, 2006; Chandrasekhar, 1990; Zembylas, 2005b) and learning in general (Beijaard, Meijer, & Verloop, 2004; Ivie, 1999; Pajares, 1992; Schwab, 1978; Zembylas, 2005a). The affective domain is often separated from cognition (Sinclair, 2004). Aesthetics is part of the affective domain, as are beliefs, values, attitudes, emotions and feelings, self-concept and identity (Schuck & Grootenboer, 2004).

Educational research into the nature and importance of the aesthetic has centred predominantly on its role in learning (Gadanidis & Hoogland, 2002; Girod, Rau, & Schepige, 2003; Wickman, 2006). Other research focuses on the role of the aesthetic in the activity, psychology and affective response of scientists and mathematicians to their discipline, often with the intent of informing mathematics and science teaching of that which provokes an aesthetic response (Burton, 2002, 2004; Sinclair, 2004). For example, Sinclair (2004) explains that the aesthetic has long been claimed to play a central role in developing and appreciating mathematics. Recognition of the beauty of mathematics stems from the Ancient Greeks who believed in the affinity between mathematics and beauty based on its order, symmetry, harmony and elegance. This is often called the aesthetic of mathematics, but such an aesthetic is often removed from the mathematics curriculum (Doxiadis, 2003) and the mathematics story is shortened to a sequence of steps that can result in students failing to experience the pleasure of the process (Gadanidis & Hoogland, 2002).

In science also, the words beauty, inspiring, artful and passion are often used by scientists to describe their work (Girod, Rau & Schepige, 2003). "The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful…intellectual beauty is what makes intelligence sure and strong" (Poincare, 1946, quoted in Girod et al., 2003, p. 575). Science educators draw from the discipline of science the important ideas, behaviours and dispositions that should be presented to students. If science is characterised as being analytic, logical, objective and methodical, this is then translated in classrooms as requiring students to be removed critical observers of objects, events and the world. By comparison, Girod et al. (2003) make the point that some scientists "portray science with an opposing personality—one that draws us in, begs our curiosity, passion, and emotion" (p.575), which, if translated to the classroom, they claim can improve the quality of the learning experience.

These portrayals of science and mathematics as eliciting an affective response such as curiosity and the pleasure of the process are in contrast to the objects of science and mathematics that "are amenable to a rational and cognitive inquiry" (Wickman, 2006, xii). Understanding these contrasting positions comes from Dewey's theory of aesthetic experience. Dewey breaks down false binaries such as objective and subjective, logic and intuition, thought and feeling, mind and heart, and think and feel. Wickman explains that in an aesthetic experience the inner emotional world is continuous with the outer world, meaning that one cannot think of one without the other. The cognitive (factual, what is the case) cannot be conceived of without the normative (values, what ought to be) in an aesthetic experience (which is evaluative). In keeping with this epistemology, Girod et al. (2003) claim that "from the perspective of aesthetic understanding, science learning is something to be swept-up in, yielded to, and experienced. Learning in this way joins cognition, affect, and action in productive and powerful ways" (p.575-576).

Limited research seeks to clarify the role of the aesthetic in teachers' work (see Ivie, 1999), however, teaching is often referred to as an artistry (see, for example, Rubin, 1985). This chapter focuses on the role of the aesthetic, specifically aesthetic understanding, in the relationship between subject culture and pedagogy. I frame this in terms of not so much what and how the teachers learn, but how their aesthetic understanding relating to teaching mathematics and science can give insight into how teachers negotiate boundaries between the subjects of mathematics and science and their enacted subject cultures. In particular, the aims of the chapter are to:

- Focus on how teachers construct themselves as teachers of a subject for which they have a level of commitment and about which they hold beliefs and values; and
- Explore the degree to which and in what manner the teacher has an aesthetic response, as part of their personal response to the subject cultures within which they teach.

To do this, I use the framework of aesthetic understanding from Girod et al. (2003) to explore how the teachers' construction of the subject and teaching is not simply cognitive but has an aesthetic dimension. "Aesthetic understanding is a rich network of conceptual knowledge combined with a deep appreciation for the beauty and power of ideas that literally transform one's experiences and perceptions of the world" (p.578).

METHODOLOGY

Past experience in qualitative research (see, for example, Darby, 2005b) led me to a methodology consistent with the belief that we construct meaning through interaction with our social setting. Consequently, the meaning gained from this research is considered to be a co-construction between the participants and myself as researcher.

Such an emphasis on research refers to "qualitative research," an umbrella term used by Merriam (1998) relating to orientations to inquiry focussing on understanding and explaining the meaning of social phenomena. Qualitative inquiry evolved out of recognition that human beings are chasms of complexity that could not be understood through the positivistic process of scientific experimentation that simply tests scientific theory. The positivist approach demands an adherence to procedures that are reproducible, based on refutable knowledge claims, and controlled for researcher errors or bias (Gall *et al.,*1999). Cohen and others (2000) describe positivism as being "characterised by its claim that science provides us with the clearest possible ideal of knowledge" (p.9). It is objective and quantifiable. Reality is considered to be stable, observable and measurable (Merriam, 1998). Used within the social sciences, the methodological procedures used to investigate social phenomena mirror those used in the natural sciences, and the end-product is expressed as laws or law-like generalisations akin to those established for the description of natural phenomena (Cohen, et al., 2000).

Bogdan and Bilken broaden the scope of what qualifies as research to reflect a paradigmatic shift from positivism towards qualitative research, also referred to as post-positivism, or "anti-positivism", and that Cohen and others (2000) consider to be naturalistic. Bogdan and Bilken's (1992) qualitative research mode emphasises "description, induction, grounded theory, and the study of people's understanding" (p.ix). In this view, there is a rejection of the positivist view of an objective observer of phenomena on the basis that the behaviour of individuals "can only be understood by the researcher sharing their frame of reference: understanding the world around them has to come from the inside, not the outside" (p.19). A key philosophical assumption underlying this form of inquiry is that "reality is constructed by individuals interacting with their social worlds" (Merriam, 1998, p.6).

It is these constructions of reality, or meaning perspectives of individuals, that my research into teacher pedagogy was interested in accessing and understanding. This research explores the complex ways that teachers construct for themselves their ideas about teaching and learning, and the factors involved in the way these constructions may appear to be manifested within the classroom setting. The qualitative paradigm qualifies this subjective knowledge of teachers, the *emic*[1] or insiders' perspective, as worthy of investigation, useful and informing of educative practice, and provides a vehicle for understanding the complexity of the social setting within which the teachers are situated. What's more, qualitative research has the potential to provide rich and meaningful information to the body of educational research as it characteristically builds abstractions, concepts, hypotheses or theories through an inductive process rather than simply testing existing theory (Merriam, 1998).

Such a view is consistent with a constructivist approach to research as described by Guba and Lincoln (such as 1998, 1981). The research reported in this chapter uses the discourse of the classroom and interviews to understand how teachers have constructed for themselves knowledge about teaching and learning, and the various factors that are brought to bear on both the development of their knowledge and beliefs and the manifestation of such beliefs in the classroom. My research is most suitably called constructivist as I have attempted to understand and reconstruct the constructions held by both the participants and the researcher.

Constructivists operate according to the premise that knowledge and truth is constructed, not discovered by the mind; and that reality is both expressed in a variety of symbols and language systems, and "stretched and shaped to fit purposeful acts of intentional human agents" (Schwandt, 2000, p.236). Constructivist inquiry, Guba and Lincoln claim, "denotes an alternative paradigm whose breakaway assumption is to move from ontological realism to ontological relativism" (p.203). According to Guba and Lincoln (1998) a relativist ontology claims that "[r]ealities are apprehensible in the form of multiple, intangible mental constructions, socially and experientially based, local and specific in nature (although elements are often shared among many individuals and even across cultures), and dependent for their form and content on the individual person or groups holding the construction" (p.206). Constructions are considered to be "more or less informed and/or sophisticated" (p.206), rather than absolutely "true." Furthermore, constructions and the realities associated with them are subject to change as the constructors are more informed and sophisticated. This results in the potential for multiple and sometimes conflicting social realities of the human intellect.

My research focuses on how the mathematics and science teachers are constructing for themselves pedagogy while operating within and in response to the social setting of mathematics and/or science education, making the constructivist paradigm suitable. Although the research is focused more closely on the individual teacher's constructions, I used my interactions with the teachers, the setting, and the literature to assist me in constructing a broader picture of the teachers' cultural setting. These act as the social setting for the

[1] as distinct from and preferred over the *etic* or outsiders' perspective.

research, a setting cushioned in a socially mediated subjective language that, through this act of research, for me has meaning through my experience of it.

Research Methods

The research reported in this chapter forms part of a doctoral study associated with a Deakin University ARC Linkage Project with the Victorian Department of Education and Training called *Improving Middle Years Mathematics and Science* (IMYMS)[2]. Six teachers of mathematics and/or science from two schools (School A and School B), teaching across Years 7 to 10, participated in a dialogue with me and each other over a period of about one year in order to understand differences between the subject cultures of mathematics and science. A variety of qualitative methods were selected that would support and feed into this dialogue. These methods are outlined below.

Two sequences of lessons in mathematics and/or science were observed for each teacher in order to gain some insight into the general practice of the teachers.

Two of these lessons on two separate occasions were videoed, one mathematics and one science lesson for three teacher (Simon*, Pauline*, Ian^), two science lessons for two teachers (Donna*, James^), and two mathematics lessons for one teacher (Rose*). (* indicates teachers from School A; ^ indicates teachers from School B.)

The video footage of both lessons on both occasions were returned to each teacher for personal viewing with a set of questions to guide their attention and reflection (a modified video stimulated recall process).

A "reflective interview" with each teacher followed the private viewing on both occasions. The first interview explored teacher's response to the video and the questions, and explored teacher background with, commitments to, and beliefs about the subjects, as well as exploring any lines of inquiry that were emerging from preliminary analyses of classroom observations or prior interviews (involved all teachers) (see Darby, 2004, for an explanation of the reflective interview and modified stimulated recall process). The second interview was preceded by an informal discussion with the teacher about the aims and big ideas represented in the unit of which the videoed lessons were a part, then the reflective interview asked teachers to explain how this lesson fitted within the unit sequence (involved only Simon, Donna and Rose; Pauline participated in the informal discussion but not the second reflective interview).

A focus group discussion involving the four teachers from School A followed the first round of videoing and reflective interviewing, with discussion based around three statements arising from data analysis. Each statement was accompanied by feedback to each teacher that included excerpts from their reflective interviews that contributed to the development of the statement, and supportive experpts from literature that expand on or correlate with the teachers' ideas. The statements were:

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[2] The IMYMS Project is being undertaken by Russell Tytler and Susie Groves of Deakin University, and Annette Gough of RMIT and funded by an Australian Research Council Linkage Grant, and linkage partner, Victorian Department of Education and Training. Funding was granted in 2003. My Ph. D. is one of two Australian Postgraduate Awards (Industry) associated with this grant.

Statement 1: Mathematics and science place different demands on teachers and students. For example, a student absent from mathematics for an extended period of time is at a greater disadvantage than a student absent from science for an equal amount of time. Is this necessarily the case? Are there parts of learning and teaching in mathematics and in science for which this is not really true?

Statement 2: a. There are some practices that are translated readily from mathematics to science and vice versa. b. There are some practices in science that really should be used more often in mathematics, and vice versa. c. There are some practices that cannot be translated because the subjects are very different. What are your views on this?

Statement 3: The influences on teachers' treatment of content in their teaching, and their attitude to the subject, are in the following order: 1. school, personal and work experiences in relation to subject interests; 2. their undergraduate degree experience; 3. conversations and interaction with other teachers; 4. experiences of teaching the subject; 5. curriculum documents and direction by the subject department; and 6. professional development. To what extent is this true for you?

Teacher Profiles

This chapter draws on data from three of the teachers from School A: Donna, Pauline and Rose. School A is a co-education school offering Years 7-12 in a provincial city in Victoria. These teachers were selected by the Head of Science to participate in this “video study.”

Donna

Donna was in her fourth and fifth year of teaching during the project. Donna originally went through high school with the intention of becoming a veterinarian but then decided to explore her interests in zoology and ecology through a Bachelor of Science. Prior to doing a Graduate Diploma of Education in 1999, Donna had been working 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 place and managed school and other groups, and has been involved in dolphin research. School A is Donna’s second school. Throughout her teaching career, she has taught junior science at all year levels, Year 11 and 12 Biology, and some junior mathematics.

Pauline

Pauline was in her second and third year of teaching during the project. She completed a three-year Bachelor of Science majoring in physics, then enrolled in a two year teaching degree that prepared her to teach Prep to Year 12. Her methods were general science and senior physics, but she was also qualified to teach mathematics to Year 12. Pauline chose the combination of science and mathematics due to the demand for science and mathematics teachers. School A was the second school she has taught at. At both schools she has been teaching junior mathematics and science, and Year 11 and 12 Further Mathematics and Physics.

Rose

Rose has been a mathematics teacher for about 15 years. Rose went to university to complete a Science Education degree, where she studied mathematics, statistics, chemistry and physics. She had no interest in the science, however, only doing it because she thought she had to. Although she has taught science, she chose fairly early in her career to teach only mathematics. Since completing her training, Rose has taught at various schools. During the project, Rose assumed the role of Head of Junior Mathematics. She taught mathematics at all year levels.

LOOKING FOR THE AESTHETIC IN THE RELATIONSHIP BETWEEN SUBJECT CULTURE AND PEDAGOGY

Girod et al. (2003) describe aesthetic understanding as being "transformative," "unifying" and "compelling and dramatic" (p.578). These three aspects of aesthetic understanding are described below using excerpts from the interviews of Pauline, Donna and Rose. I use the teachers' reflections to explore, firstly, how the subject culture frames the development of these three components of aesthetic understanding, and how the teachers' aesthetic understanding of the subject guides how they teach. I then explore how the application of this framework helps to understand the relationship between *pedagogy*, which is underpinned by theoretical and perspectival frameworks in relation to teaching and learning (van Manen, 1990), and *cultural practices* of the subject, which the teachers participate in and contribute to.

Compelling and Dramatic Nature of Understanding

This aspect of aesthetic understanding recognises that aesthetic experiences are steeped in emotion. Aesthetic experience "…quickens us from the slackness of routine and enables us to forget ourselves in the delight of experiencing the world about us in its varied qualities and forms" (Dewey, 1934/1980, quoted in Girod et al., 2003). In such experiences, emotion, cognition and action are fused.

So when Rose says to her students at the beginning of the year "I love mathematics and by the end of the year I want you to really like mathematics too" she is demonstrating her passion for mathematics, that there is something about mathematics that compels her into further engagement with it. It is this that she wants to share with the students so that they can appreciate mathematics in the same way. Rose explains that she is interested in mathematics because it is logical and "it appeals to my logical brain." A passion for the subject is evident here, a passion for the content matter, but also for teaching the content.

In the focus group discussion I asked the teachers what passion is and what it looks like in mathematics compared to science. Rose shared with me during the focus group discussion an experience she had during a lesson where she and a small group of students were working together on a different task to the rest of the class. "And I was so engrossed," Rose exclaimed, "I didn't realise the class had finished! And I turned around and they were all sitting back in their chairs, but my kids were so engrossed in what they were doing and really happy." Donna replied, "That's what passionate looks like in mathematics!" Rose's passion for promoting student engagement with the subject is recognisably an experience of "flow" where, simply put, a person is so engrossed in a task that they lose all sense of time (Csikszentmihalyi, 1997).

During the focus group discussion, various teachers explained how passion for the subject (or discipline) as distinct ways of knowing and bodies of knowledge are evidential in the classroom: "You're interested in it. Enjoy it. If you enjoy something then you're going to impart that enjoyment onto your students" (Rose); and "You can see that [teachers] know their stuff and are passionate about mathematics" (Donna).

Teachers' lack of passion about the subject was also considered to be evident to students: "I think kids pick up on it when you don't enjoy it. If you're teaching something you don't particularly enjoy, it seems like they muck up more. I dunno, maybe we're all suffering together!" (Pauline). Many authors assert the importance of students seeing that teachers are passionate about their subject (see, for example, Darby, 2005b; Education Training Committee, 2006; Lane, 2006; Palmer, 1998).

During the focus group discussion I asked teachers: if passion for the subject is so important what happens when teachers teach outside of their subject area? Donna explained that in these instances, a general passion for teaching students is important. As Donna explains below, this passion is rooted in that which first lured them into teaching:

> DONNA: What got you here in the first place, your passion for teaching.You may not be happy about it, but you've still got the basic passion for teaching to try and do the right thing by the kids and you go out of the way to make sure, no matter what subject it is, that you're teaching them the best way you can…. It comes down to that you're teaching people, not the subject.

This suggests that a passion for teaching is related to the activity of teaching students, separate from the content matter under instruction. In this case, the passion emerges out of a desire to engage with students.

Aesthetic, Passion and the Subject

Three forms of passion are evident above: a passion for the subject matter, a passion for promoting student engagement with the subject, and a passion for teaching in general. This multi-dimensional framing of what drives teachers is represented by Day (2004):

> To be passionate about teaching is not only to express enthusiasm but also to enact it in a principled, value-led, intelligent way. All effective teachers have a passion for their subject, passion for their pupils and a passionate belief that who they are and how they teach can make a difference in their pupils' lives, both in the moment of teaching and the days, weeks, months and even years afterwards. Passion is associated with enthusiasm, caring, commitment, and hope, which are themselves key characteristics of effectiveness in teaching. (p.12)

As indicated above by Donna, this sense of care can be perceived of as a passion for teaching in general and as separate from the subject matter. This is likely to be important for those teachers with a teaching allotment that includes a subject for which they have limited experience, training and commitment, and more than likely, passion. The question here is where the passion lies for the teacher: in the act of relating with students (as stated by Donna), or in the act of engaging students with subject matter that the teacher believes is valuable, whether it be process or conceptual (as demonstrated by Rose's commitments in teaching mathematics). A question remains as to whether a teacher can be effective at engaging students in the subject matter if they have little passion, or even appreciation, for the subject. Rose believes that teacher interest is vital: "If you're not interested in something, you shouldn't teach it!"

Day also describes the importance of teachers sharing with students a commitment to the subject they are teaching:

> When students can appreciate their teacher as someone who is passionately committed to a field of study and to upholding high standards within it, it is much easier for them to take their work seriously. Getting them to learn then becomes a matter of inspiration by example rather than by enforcement and obedience. (p.15)

The Education and Training Committee's (2006) inquiry into the promotion of mathematics and science education in Victoria supported this view saying that when promoting student engagement there is a "need for teachers to be passionate and deeply knowledgeable about their subject area" (p.172).

Following this view, a passion for teaching is more likely to be coloured by a teacher's conceptual and aesthetic commitments to the subjects they teach; therefore, passion for teaching, at least at the secondary level, is less likely to be seen as generic, but more likely subject specific. Research by Siskin (1994) into the culture of subject departments in secondary schools found that what mattered for the teachers in her study was "not simply *that* they teach, but *what* they teach" (p.155, emphasis in original).

Neumann (2006) asserts that, in the context of scholarship in higher education, "passion illuminates the complexity of both teaching and research, showing that what resides at the heart of both is the *learning of a particular subject*" (p.413, italics in original). Subject here refers not necessarily to a school subject or discipline but a subject of thought on which a conversation can be focused. In the classroom, the teacher makes the focus of conversation the ideas of mathematics or science, however, how they represent these ideas depends on the teachers beliefs about what the subject can offer the students. For Rose, mathematics offers training in logic and a potentially enjoyable endeavour. A passion for teaching remains, then, to be coloured by the teacher's conceptualisation of the subject. According to this view, pedagogy is influenced by an inextricable link between the way teachers see their students and the subject: teachers have an understanding of what students need in order to make the subject matter have meaning. "Teachers understand and value their subjects for what they offer students, and understand their students through the metaphors and assumptions of the subjects" (Siskin, 1994, p.158). Consequently, pedagogical knowledge is tied to how the teacher understands the knowledge of the subject. Conversely, the content knowledge of teachers as representations of the epistemology of the subject is transformed in a way that meets the perceived learning needs of the students. Overarching both of these relationships, however, is the teachers' aesthetic commitments to and appreciations for the subject.

Learning that Brings Unification or Coherence to Aspects of the World or the Subject

This aspect of aesthetic experience acknowledges that “it is not possible to divide in a vital experience the practical, emotional, and intellectual from one another” (Dewey, 1934/1980, quoted in Girod et al., 2003, p.578). Experience is complete and results in deep meaning because the experience retains its value and wholeness, and this coherence can be used to guide future experiences. According to Girod et al., an “aesthetic understanding depends on developing a similar coherence of parts, pieces, ideas, and concepts” (p.578). This is evident in the classroom when the learning of individual parts of a concept brings greater understanding of the entire concept.

The teachers in my study referred to this element of aesthetic understanding when they talked about planning for different subjects. Donna explains here that, she has a stronger grounding in biological science due to personal experiences with the subject matter, the discipline, and the type of thinking required, the manifestation of which is a more intuitive approach to teaching science than mathematics:

> DONNA: I don’t have a big mathematics 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 mathematics you’ve done or what resources you’ve been exposed to, what you might know of... I do a lot more prep for a topic like physics than I would for chemistry or biology. I’m teaching a nine ten combined class in biology, and I’m finding that, like I do my normal prep but I can just go off in class and say, I did this and I’ve got this example, and we’ve been having great class discussions and fun activities. I wouldn’t have the confidence doing that with a physics topic. So I might spend a lot more time researching it, I might check a few things with another teacher. But I wouldn’t have that flamboyance in a topic that, because I haven’t done physics at all, apart from bits and pieces of it.

Donna compares her teaching of biology to that of physics, both sciences and underpinned by a common philosophy of what constitutes knowledge, but distinct in terms of the nature of the phenomena being represented. Donna’s coherent and unified picture of biological science stems from her experiences of learning biology and working with these science concepts in the natural world. Physics, however, is perhaps as foreign for her as any other subject that has not been encountered in any meaningful way. It is for this reason that her teaching of biology requires less planning and research compared to her teaching of physics or mathematics.

Aesthetic, Coherence and the Subject

In Donna’s reflection, there is a degree of understanding of the connections between ideas and content, but also how the content is used in a way that is appropriate for student learning. Knowledge of the content matter and the knowledge required to teach this knowledge is evident.

The knowledge that Donna refers to can be aligned with Shulman’s knowledge domains that he introduced in 1986 and 1987 to emphasise the domain-specificity of knowledge.

Shulman distinguishes between subject matter knowledge, pedagogical content knowledge and pedagogical knowledge.

"Subject matter knowledge", also called content knowledge, is the knowledge that teachers have about the content considered appropriate for teaching. Donna explained that such knowledge is related to the extent of her background with respect to the subject. Having a limited background in physics has meant that she has less content knowledge, and which results in her having to do more preparation for her lesson planning.

"Pedagogical content knowledge" (PCK) adds to this dimension of subject matter the knowledge required for teaching it to students, and includes the "ways of representing and formulating the subject that makes it comprehensible to others" (Shulman, 1986, p.10). PCK refers to that conglomeration of teacher knowledge that transforms the subject matter in a way that is sensitive to the needs and requirements of the learners.

In Donna's case, she recognises that her pedagogical content knowledge, that is, knowing how to make the content understandable for students, is limited by her deficient subject matter knowledge of physics and mathematics. In comparison, she attributes her ability to teach biology to her "background" of experiences, and that this allows her to more meaningfully transform subject matter knowledge using classroom strategies where her richer understanding of the subject narrative can be shared with students. At first blush it appears that knowledge of content, resources and strategies for teaching accounts for her greater confidence with the teaching of biological science. The "flamboyance" she refers to hints to something other than knowledge, such as an intuitive sense of how to use the science ideas and her experiences to draw students into thinking, talking and engaging with the ideas: "You can think of different ways to get it across to the kids." She has feelings of "comfort" and confidence in her ability to bring the subject of biology to life for her students. "To know something," states van Manen (1982, p.295), "is to know what that something is in the way that it is and speaks to us." That which first appears cognitive takes on an intuitive nature, and this becomes part of what teachers do but may not know that they do or why they do it.

PERCEIVED TRANSFORMATION OF THE PERSON AND THE WORLD

Donna's description of her teaching above exudes a sense of pride in what she knows and how she can share this with students in an engaging way. There is passion, no doubt, but she has also "developed a sense of self in which the pride of the craft [is] the key" (Palmer, 1998, p.14). A person is transformed by what they have experienced and what they have come to know out of that experience. "Knowing changes the individual as well as the individual's world" (Girod et al., 2003, p. 578). The transformative nature of aesthetic understanding can lead to identity formation and personal positioning. A person can say "I am the type of person that looks at the world in this way." In the context of my study, this relates to how teachers position themselves as teachers of a subject, and how this positioning stems from their experiences of teaching, learning and participating in mathematics and science. I describe two teachers here, Rose and Pauline, to demonstrate how they position themselves in relation to the subject based on their level of competence and confidence with teaching the subject.

Rose's Transformation

Rose's experiences and interests shape the way she sees herself. Rose stated a number of times that she describes herself as a teacher of students, not a teacher of the subject: "I see myself as a teacher first, not a mathematics teacher… I'd been looking after little kids from when I was this high. I just loved looking after kids." During a different interview she mentioned that being a mother has made her more attentive to the support needs of her students such that she is more attentive to the overall well-being of her students.

> ROSE: I believe I do a lot more instructing than some people and I also do a lot more student helping… I think it is because I'm a Mum. I taught for 4 _ years before I had children and then I came back to teaching and I reckon I was a lot better teacher, because I relate to it… I don't think it's an us and them, I think its an us together.

She situates herself not necessarily outside of being a mathematics teacher, but prefers to identify herself as someone who has strong beliefs about the centrality of the student in the teaching-learning interface. This was demonstrated also when, on viewing her videoed lessons, she said that: "I looked for how the kids were working 'cause that's interesting. What I said and how I responded to the kids. To their needs. That's what I look for."

Over the years, Rose has developed an understanding of her role as teacher that has transformed her into a person that is attentive to the needs of her students. The nature of the subject shapes her pedagogical response, such that a sense of care compels her to teach mathematics in a way that makes it less threatening for students:

> ROSE: I want them to enjoy mathematics. Because mathematics is a threatening subject, it is so threatening because it is so sequential…[At the start of the year] there was hardly anyone that liked mathematics, some of them thought they were good at it, but hardly any of them liked it. You ask them now they have come right round because they enjoy it.

Rose refers here to a mathematics curriculum characterized by incremental learning (Hargreaves, 1994) and sequential progression (Sherin, Mendez & Louis, 2004). Because she understands the threat that such a curriculum structure might pose for students, her sense of care for the students compels her to employ actions that remove the threat and make her view of "mathematics-as-enjoyable" more accessible and in the realm of possibility.

Pauline's Identity Crisis as She Negotiates Subject Boundaries

Pauline spoke of a rich science background with interests and studies in physics, and many engaging and interesting experiences in relation to science. In order to get a sense of how Pauline situates herself in relation to mathematics and science, I need to first reconstruct Pauline in relation to the previous two aspects. Evident in the following quote is a confidence in how she expresses an appreciation for the purpose of science in her own and her students' lives, as well as what it means to be passionate about science:

> PAULINE: 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 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.

In comparison, limited expertise in mathematics teaching makes it difficult for Pauline to be confident in her abilities, and she defers to a label of science teacher rather than mathematics teacher, as evident in the following quotes:

> "I am not really experienced enough or done enough PD [Professional Development] to know better ways of doing it. A major part of my PD plan, especially for middle years, is doing more PD and finding better ways to teach stuff 'cause I don't like the way I teach Mathematics at the moment"
> "I think I am a crap mathematics teacher."
> "It is funny. I feel more confident teaching science than I do mathematics, even though I have been teaching both for the same amount of time"
> "I have always felt Mathematics is kind of my fall-back method. Whereas if I was asked to describe myself I would describe myself as a Science teacher, first and foremost."

Quite clearly, Pauline has a stronger sense of herself in relation to science teaching than mathematics teaching. She attributes this partly to her limited background experience with mathematics: "Well my mathematics method is just a thing on paper that says that I did mathematics to second year at Uni. There was nothing that I did in my teaching degree that prepared me for teaching mathematics. The only preparation that I had was my rounds." She laments at not knowing how to make mathematics learning more interesting for her students because of her limited intuitive sense of what will work in the classroom, she is less capable of finding resources and knowing what to look for, and she has a limited sense of how to be passionate about teaching the subject in a way that will profit student learning at the junior level. She enjoys teaching mathematics at the senior level because she enjoys toiling over problems with the students, but she is unable to do this as much at the junior level. These limitations to her knowledge led her to the conclusion that she is less comfortable with the label of mathematics teacher than she is with that of science teacher.

Aesthetic, Identity and the Subject

In Beijaard's (1995) research into the interplay between the private and public in developing identity, he makes a distinction between role and identity – hope and courage, care and compassion, he asserts, are associated with identity, not role. In the above example, Pauline appears to accept the role of mathematics and science teacher and the associated activities that are assumed as part of this role, but her identity arises out of her history of caring for and committing to science as an area of study.

Further, in Pauline's description above, she attributes her lack of confidence in mathematics teaching with lacking the knowledge of how to teach. Earlier, Donna recognised that her teaching of biology is benefited by knowing what activities will work and when. Day (2004), however, points out that knowing what and how to teach is not limited to cognitive engagement. He states that “good teaching can never be reduced to technique or competence” (p.15). Good teachers, he asserts, tend not to *describe themselves* only in terms of technical competence, but also acknowledge that “teaching and learning is work that involves the emotions and intellect of self and student” (p.64). This difference between a competence view and the aesthetic was demonstrated by Pauline’s appraisal of herself as a mathematics teacher and a science teacher. Her deficit view in relation to mathematics that she attributes to limited technical competence is based on limited knowledge of what and how to teach, and her hope lays in future professional development to provide useful strategies for teaching. By comparison, her appraisal of her competence and confidence in science was laden with meaningful experiences and stories from a history of engaging with the subject. Pauline exhibited a richer sense of herself in relation to her science teaching, one that is positive and based not solely on competence, but she also aligns herself with science teaching at an emotional level. Her knowledge of how and what to teach is ‘continuous with’ her aesthetic response, meaning that one cannot think of one without the other.

INSIGHTS AND IMPLICATIONS

The previous analysis and discussion have explored the idea that a teacher’s aesthetic understanding of and response to the subject determines: where their passions lie with respect to teaching the subject, to what extent they have a coherent and intuitive sense of what is required to teach the subject, and how the teacher is transformed by what they know as they develop an identity in relation to the subject. These discussions are valuable in understanding the relationship between subject culture and pedagogy for two reasons. These reasons are dicussed below.

Appreciation for the Aesthetic in the Teaching Act

The first is that a framework of aesthetic understanding helps to clarify and assign some level of importance to the role of the aesthetic in the teaching of subject matter to students. A teacher who can be regarded as having an appreciative aesthetic understanding of the subject:

- is compelled by and passionate about the subject and students engaging with the subject;
- has a coherent, unified and intuitive sense of what the subject is about and how to bring it to life for students; and
- has been transformed by what they know and believe in a way that aligns them to personally and professionally identify with the subject.

Being attentive to the aesthetic when evaluating teaching redirects the question from simply asking, what does the teacher know and believe about the subject and what is required to teach it? Instead, the question becomes, how does what the teacher know and believe affect her sense of who she is in relation to the subject, and how does this personal positioning spill out into the classroom? The analysis has shown that a teacher with an appreciative aesthetic understanding of a subject see themselves, the subject matter, their teaching and their students in relation to the subject. Even Rose, who labelled herself as a teacher of students rather than a teacher of the subject, expressed her sense of care in the context of, and in response to, the nature of the subject and what was required for students to learn. The student is central to her conceptualisation of the subject. She was unable to describe what the subject is like without including stories about her interactions with students on a personal level, and in relation to how the students learn in the subjects. By talking about how she interacts with students and the students' learning needs, Rose gives clues as to her values and aesthetic commitments to the subject, which is viewed through a lens of what the subject offers her students as well as what it offers herself as learner, practitioner and teacher of the subject.

A common emphasis in current science education reform is to draw on and respond to student interests in selecting contexts for teaching science-related content. Pivotal in achieving this end is giving teachers space within the curriculum to inject their own interests, hobbies and expertise in constructing such contexts. Tytler (2007) provides examples of innovation occurring in schools where "teachers with serious interests [felt] that they were being given permission to import these into the classroom" (p.57-58):

> In one school a teacher with no previous history of innovation was encouraged by the SIS coordinator, who knew of his interest in winemaking, to initiate a *Chemistry of wine making* unit. The school is now producing award-winning wines. (p.52, italics in original)

These types of stories, Tytler (2007) asserts, exemplify a re-imagined science education for Australia. Hence, teachers' interests are highlighted as important in the development of local content and approaches. In these situations, teachers are more likely to possess an aesthetic understanding that is deeply rooted in teachers' experiences, and where the subject matter has personal meaning for the teacher. Pedagogical practices can be enriched by a deep understanding of the associated content, which, provided the learning needs and interests of students are taken into account, provide a strong foundation for knowing what value it might have for students and how such contexts could be generative of new interests for students.

The Aesthetic in the Negotiation of Subject Boundaries

Secondly, examining teachers from the perspective of aesthetic understanding provides insight into what is involved for teachers, aesthetically, as they move between subjects and their enacted subject cultures. Such insights are particularly pertinent at present when a shortage of suitably qualified mathematics and science teachers is resulting in a relatively high percentage of teachers teaching out-of-field, that is, teaching a subject for which they lack tertiary training, and arguably, limited experience, commitment and, aesthetic understanding. A survey involving 8.2% of teachers of junior science in Australia (Harris, Jensz, & Baldwin, 2005) showed that 16% of respondents lacked a minor in any university science discipline, while 8% had not studied any tertiary science. Similarly, a survey of mathematics teachers from 30% of Australian schools (Harris & Jensz, 2006) showed that 20% of teachers of junior mathematics had not studied mathematics beyond first year university, while 8% had no tertiary training in mathematics. Other reports in the media reflect similar or higher proportions of teachers teaching outside their fields of expertise

(Rodd, 2007; Topsfield, 2007). The figures are even more startling for teachers beginning their careers. Unfortunately, these teachers are more likely to be asked to teach out-of-field than their experienced colleagues (Ingersoll, 1998). A recent study of beginning teachers in Australia showed that 40.1 % of teachers nationally and 57% in Victoria had taught subjects outside their qualifications (Rodd, 2007).

While it is acknowledged that tertiary training will not automatically result in effective teaching, the major concern both nationally and internationally is that without solid tertiary experience in the discipline, teachers lack content knowledge, and without studies in the teaching of a subject, teachers are not equipped with the variety of methods and teaching skills required to teach the subject effectively (Darling-Hammond, 2000; Education Training Committee, 2006; Ingersoll, 1998; Thomas, 2000).

The data reported in this chapter suggests that a teacher teaching out-of-field, whether it be a science teacher teaching mathematics (in the case of Pauline) or a biologist teaching physics (in the case of Donna), potentially has limited or unappreciative aesthetic understanding of what the subject can offer his/her students. This has implications especially when the history of engagement with the subject has been negative, restricted to poor traditional learning experiences, or limited. Reliance on traditional teaching approaches may result, as may a lack of "flamboyance" in the way the subject is presented, with a potential outcome of not demonstrating for students what it looks like to appreciate the subject. Also teachers teaching outside of their disciplines, such as a mathematics teacher teaching science, may bring with them a sense of what constitutes good teaching appropriate for one subject that may seem inappropriate in another. A theoretical framework of aesthetic understanding, therefore, helps to identify the barriers, disconnections, and lacking appreciations that may prevent teachers who are not trained in the discipline from personally engaging with the subject, which, inevitably impacts negatively on the quality of teaching. The problem for the "untrained" mathematics or science teacher is not simply a lack of content knowledge, but this framework of aesthetic understanding gives significance to the importance of teachers being committed to the subject, being able to identify with it, and knowing how to bring the subject matter alive for students.

Tertiary training is considered to be the most effective determinant of whether a teacher is suitable for teaching a subject. Having a background in a discipline, it is assumed, equips teachers with the disciplinary knowledge to draw on in their teaching, but it also equips teachers with an appreciation and enthusiasm for the subject that can be transmitted to students (Darby, 2005a, 2005b), something that is a quality of effective teachers and potentially lacking for teachers teaching out-of-field (Ingvarson, Beavis, Bishop, Peck, & Elsworth, 2004). However, 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 focusing on changes to teacher beliefs (Russell Tytler, Smith, & Grover, 1999), have been found to be cogent in determining how teachers approach teaching and learning. There is an assumption here that teachers can be 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 for which they have previously had limited background. *Competence* refers to teachers' development of knowledge and skills that are: subject-specific, such as content knowledge (CK) and pedagogical content knowledge (PCK); and generic, including pedagogical knowledge (PK) (Shulman, 1986a, 1987). *Confidence* relates to teachers' attitudes (Ernest, 1989; Koballa, 1988), agency and self-efficacy (Boaler & Greeno, 2000), professional identity (Connelly & Clandinin, 1999) and aesthetic understanding as is described in this chapter. Allowing inexperienced teachers of the subject to have an aesthetic experience of the subject matter through targeted professional development may allow them to see themselves and their identity in relation to subject matter ideas.

Conclusion

The analysis teases out what it can mean for a teacher to be compelled by and passionate about the subject and students engaging with the subject, to have a coherent and unified sense of what the subject is about and how to bring it to life for students, and to be transformed by what he/she knows and believes in a way that aligns them to personally and professionally identify with the subject. The teachers' construction of the subject, their students and teaching is not simply cognitive but has an aesthetic dimension. An implication of this is that teachers who teach outside of their subject area—their subject area typically being dependent on whether they are "mathematics- or science-trained"—may be lacking an appreciative aesthetic understanding. Their aesthetic response to the content matter and how to teach it may be unlike that of someone who has an appreciative aesthetic understanding of the subject. Such teachers may: attempt to bring in a style appropriate for a subject that has a different set of demands; have a limited set of experiences with relevant phenomena, processes, ways of thinking and attitudes that can feed into their teaching; and fail to exhibit a passion for the subject and what the subject can do for their students. Consequently, any efforts to improve mathematics and science education should be aware that allowing teachers to experience the subject in a way that results in aesthetic appreciation for the beauty and elegance of mathematics and science is just as valuable as them developing conceptual and pedagogical knowledge associated with the subject. A teacher may then experience content in ways that allow them to more clearly see themselves in relation to subject matter ideas.

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