Teachers' Perceptions of the Values that Underpin Science as a Way of Thinking and Acting

Kathy Smith and Deborah Corrigan

Over the past 10 years we have worked with both primary and secondary teachers to explore personal values and beliefs about science and the relationship of these perspectives with science teaching and learning. This was often a complex, difficult and a highly personal area to research. We, as researchers, were extremely mindful of the individualised nature of this work. We worked together with participants to find ways to access and enable all parties to understand the deeply held personal values and beliefs which frame individual professional practice. This chapter attempts to capture the recurring challenges in this work. It is not our intention to share all aspects of the research but to provide insights about how to uncover what has largely remained implicit in teacher thinking in relation to science education. The following story is just one incident, shared by a participant, which captures both the inherent challenges and changes in thinking confronting teachers in this research experience.

> The bell goes and my new Year 10 'Science for Life' class enters the room. The 'Science for Life' course is intended as an option for students who are undecided about what they want to do in the future and as a consequence it just concentrates on the fundamentals of the science curriculum.
>
> I'm still feeling upbeat about my previous lesson so I choose to begin the lesson in the same manner. What do you like about science? How can you see Science playing a role in your future? What do you hope to get out of doing this course next semester?
>
> Daniel put up his hand and replied, "I HATE SCIENCE…When am I ever going to need any of this rubbish in my life?"
>
> I ignored his question and asked Daniel, "What are you thinking about doing when you finish school? He shrugged his shoulders and said in the typical 16 year old boy voice: "I dunno."
>
> Trying to get a gauge of other students in the room, the conversation with my class continued:
>
> "Science is boring."

K. Smith (✉) · D. Corrigan
Monash University, Clayton, VIC, Australia
e-mail: kathy.smith@monash.edu

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> "Science is useless."
> "Do we get to blow stuff up?"
> "Do we get to cut anything open this year?"
> "I'm not doing VCE[1] science next year so I don't see why I should have to do it now so I'm not going to even try!"
> Fifteen minutes ago, I was feeling upbeat and excited about how great this semester was going to be, and now I was thinking how far off the end of the year is and how on earth am I going to get these kids remotely interested in science? (Keating, 2013, p. 16)

Daniel and his classmates hold very strong views about the place and importance of science in their lives. Daniel's teacher also appears to hold views that may not be in keeping with her students' views. In this small interchange between Hannah (Keating) and her students we find that Hannah's initial question "What do you like about science?" implicitly conveys the message to the students that Hannah likes science. What must be very confronting for Hannah is Daniel's extreme (but common for a teenager) response: "I HATE SCIENCE". Daniel is not alone as his peers also share at least a disinterest in science, with comments such as "science is boring". Hannah's next question also puts her at odds with her students. "How can you see Science playing a role in your future?" again implies that Hannah feels it is useful—she is a science teacher—but again this view is not shared by her students. Responses such as "When am I ever going to need any of this rubbish?" and "Science is useless" seem to demonstrate pretty emphatically that Hannah's students do not see any relevance of science to their lives. And finally, the question "What do you hope to get out of this course?" implies that Hannah may be looking to meet some of the needs her students have. She must be disappointed when the responses indicate more entertainment value that science may provide through comments such as "Do we get to blow stuff up?" and "Do we get to cut anything open this year?" These student comments give insights into students' perceptions of what it is about science that might be of interest to them.

Unfortunately, this very real case in not unusual. It captures a clash of values and beliefs at play and provides a powerful reminder that how science teachers see and understand science is not always easily aligned with the experiences and perceptions of their students. The way these students think about school science and possibly science itself and the total disregard they assign to both scientific endeavour and associated knowledge based on their experiences is real and confronting for science educators everywhere. This case also stands as a reminder that years of school-based science education provide little guarantee that learning 'science' will transform such beliefs or even provide a positive educational experience for students.

[1] VCE is the Victorian Certificate of Education, the final secondary school qualification received in Victoria, Australia

Digging Deeper: The Need to Understand Teacher Values and the Challenge of Change

Hannah's case is particularly interesting because when examined closely it appears to be framed around what Brookfield (1995) would define as a key 'paradigmatic assumption', an idea that is so foundational that it is particularly hard to uncover and even harder to challenge. Applying the notion of a paradigmatic assumption in Hannah's case, teaching science is about facilitating students' thinking in ways which align with scientific thinking. This assumption is so fundamental to science teaching that it is unquestioningly reinforced through curriculum documents. Hannah clearly expresses this at the end of the interchange when she identifies the impending challenge of "getting these kids remotely interested in science". Hannah assumes that as a science teacher it is her role to change her students' attitudes and perceptions about science and, ideally, she wants to move her students from seeing science as the content of a school subject to recognising the everyday relevance and importance of science within their own futures through the subject called 'Science for Life'. These values of the relevance and usefulness of science drive her thinking and determine the type of science learning that she strives to achieve for her students. To achieve these outcomes Hannah will need to develop her students' capacity to think differently about the nature of science and the inherent value processes that ensure the construction of rigorously contested science knowledge. She must address not only her students' existing conceptual knowledge but also the resistance evident in student attitudes—undoubtedly a really problematic process.

How Hannah values and thinks about science strongly influences the change in thinking she wants to realise for her students and the conditions for learning that she will seek to create. Hannah wants to achieve change but she is aware of the enormity of the divide between the value sets at play, i.e., her own and those of her students.

Achieving such change in student thinking is the paradigmatic assumption that drives science teaching everywhere. Not all science teachers may be as overtly passionate or well informed about science as Hannah, nor would they so openly seek student input as Hannah does with their students. As products themselves of an outcomes-based education system, each teacher's personal understandings of both science knowledge and the nature of the endeavour may be very different. If we accept the assumption that teachers seek to promote change in student thinking then how these different perspectives shape science learning becomes an interesting consideration. Hannah's understanding of the nature of science informs her awareness of the challenges associated with translating the curriculum, both the explicit and implicit dimensions, to the contextual reality of her classroom. This suggests a level of sophisticated thinking about science education that goes well beyond mastering content knowledge.

How teacher values and understandings of science shape the quality of student learning is not well considered as a significant factor in school-based science education. Hannah represents a teacher with a broad and deep understanding of science who is actively attempting to align her own thinking about science with both the curriculum and her students' learning needs. In contrast, some science teachers may hold a more limited understanding and therefore how they read and enact the curriculum (Roberts, 1982) will align with their personal views, i.e., as a roadmap of content which defines what needs to be achieved. This chapter seeks to explore the relationship between the paradigmatic assumption for change in student thinking and teacher values and beliefs about science, and consequently the implications for science education. The chapter works from a perspective of critical reflection (Brookfield, 1995) as a means of understanding how values are embedded within, give meaning to and determine the routines which shape science education, in particular learning about science as a way of thinking and acting. By attempting to learn more about how teachers understand science and how their beliefs and thinking shapes the kind of learning that students experience we can understand more about why some teachers adopt particular routines, why these are accepted unquestionably and what conditions promote effective change in both teacher and student thinking.

Understanding the relationship between teacher values and science learning requires teachers themselves to undertake a critical stance to noticing existing trends in their practice and a preparedness to expose the more deeply embedded prescriptive and paradigmatic assumptions that drive their actions. Taking such a stance requires particular conditions that not only support teachers to reflect on their personal and professional values but enable them to go further and consider how these values influence the learning their students experience. In these instances, it is important teachers confront the assumptions they hold about the epistemic values of science, societal values, and the personal values of scientists, and how they as teachers use such knowledge to make decisions about curriculum and teaching. We will now outline some of the inherent challenges in this learning process.

The Challenge of Attaining a Shared Understanding About the Nature of Science

What is often not clear to both teachers and particularly students is why an understanding of the nature of science is important. In other words, the reality of how science is a powerful way of thinking and acting is not clear to many engaging in science education. The indication of this lack of clarity is apparent when a person is confronted with the question "What is science?" There is no one answer for this as each response will be dependent on an individual's past experiences and the views generated based on those experiences. Rarely would a response encompass the following:

> Science embodies a way of thinking and acting, a knowledge-seeking enterprise that is continuous and purposeful, generated by a need to understand, make sense of and communicate thinking about phenomena and experiences. In this context, science is a process of human endeavour, a human attempt to create explanations for what is observed and experienced; it is entrenched in human experience, reflects cultural diversity and is built upon

> individual perceptions and understandings. To this end it is a type of thinking which depends upon the rigorous pursuit of evidence for validity of ideas and seeks to effectively communicate findings to a wider audience to establish a shared meaning and understanding. (Corrigan & Smith, 2015, p. 102)

While the explicitly stated goal of school science, as evident in a wide range of curriculum documents, may be to establish a shared set of values about the nature of science like the one articulated above, such an outcome is not common and is difficult to achieve.

All participants in the education process, teachers and students alike, bring to the classroom many different ideas and practices based on their value positions about science. For example, Corrigan and her colleagues (Corrigan et al., 2018) have worked with preservice teachers (PSTs) to monitor their changed personal views of the nature of science as they engage with authentic experiences of contemporary sciences. The PSTs from the study acknowledged the impact that collaborative discussions about the Nature of Science (NoS) had on building their confidence and ability to communicate a coherent and more contemporary view of science. Many of the PSTs spoke of how their thinking and view of science had changed from one in which they originally privileged understandings of science content to one with a broader understanding of the processes by which science is undertaken. On reconceptualising a personal view of NoS, the PSTs reported greater self-confidence in constructing and justifying a personal coherent view of NoS and an improved ability and confidence in discussing and communicating NoS understandings across a range of professional settings.

It is often assumed that everyone holds a shared understanding of what 'science' means. As discussed this is not the case. Hannah's case above demonstrates, by the reactions of both Hannah and her students, a differing view of science. Achieving a shared understanding often presents a challenge for many teachers.

The Challenging Space Between Teacher Values and External Expectations

To effect change in student thinking requires teachers to make decisions about what matters, for their students, their teaching and the contextual reality of their teaching experience. Such decisions are not based on issues of content but are more likely to be framed by professional and personal values, personal experience and a personal sense of adequacy. Even if curriculum documents intentionally position science as a human endeavour and explicitly frame this understanding as critical to science learning, many students experience a school science that is not framed in ways which enable them to appreciate science as that which is entrenched in human experience. Nor do students come to see science as purposeful, or driven by an individual's need to understand (Corrigan & Smith, 2015). Instead students, such as those in the case above, often experience a 'science' at school that they believe represents a static body of 'useless' knowledge, detached from everyday life, irrelevant to their needs and interests, uninviting and ultimately a waste of time and effort. Such representations are inevitably influenced by teacher thinking.

Hargreaves (1994) argued that teachers do not merely deliver the curriculum, they interpret, redefine and re-evaluate it too; it is what teachers think and what teachers do that matters at the level of the classroom. Similarly, many of the teachers in our research translated the curriculum, such as Hargreaves described, based on a tension they experienced between their own sense of purpose as a teacher and the demands of external expectations. Working within education systems that have high demands for accountability, in particular short-term evidence of change, potentially presents challenges for the work of science teachers. Allowing students to experience the endeavour of science and the uncertainty that sits within the nature of the enterprise requires time and opportunity for ongoing exploration and investigation of a range of possible outcomes. The education system, through curriculum, may indicate an expressed value of a particular perspective about the nature of science but the constraints of time and the demands of short-term success which are also imposed by the system creates conditions where it becomes unlikely that such science learning will be achieved.

Many of the teachers in our research had entered the profession in order to be accountable to their students, i.e., to make a difference to the lives of young people. However, the accountability to a system that values statistical evidence of students' learning and short-term improvements dominated their decisions as professional teachers of science. For many teachers, balancing these accountabilities remained an on-going tension throughout their careers, particularly when high-stakes testing was part of their reality.

In summary, the intention of school science may be to enable students to develop a capacity to see, act and think about the world in a sceptical, rigorous, engaging, evidence-based and empowering way. This intention is in reality extremely problematic to achieve as teachers will inevitably respond to many of the complex demands associated with science education in line with their personal values and beliefs. The outcome is a lived experience for students that often intensifies their diversity of views about the nature of science. Our research identified that such experiences frequently nurture oppositional perspectives about the purpose and value of science as evidenced in Hannah's case above. It would be easy to dismiss such diversity on the basis of teacher deficit but the reality is far more complex. School curriculum by its very nature embodies political, economic and social values by prioritising areas of learning. To be effective within any education system a teacher must find ways to coexist within the values of the system itself. Teachers may find that the science they value may not necessarily translate to be the science their students get to experience.

The Challenge of Developing Rich and Deep Understandings of Science While Being a Product of an Outcomes-Based Education System

As products of the system themselves, perhaps teacher thinking about the nature of science has also been shaped by similar processes.

Teacher thinking is deeply embedded in each teacher's personal experience. Individual ideas and understandings about the nature of science have been developed when they as students worked within systems which traditionally valued the reproduction of factual information as the best measure of a knowledge and understanding of science. For example, in Hannah's case above, she describes "[t]he 'Science for Life' course is intended as an option for students who are undecided about what they want to do in the future and as a consequence it just concentrates on the fundamentals of the science curriculum" (Keating, 2013, p. 16). In this phrase Hannah conveys her view that concentrating on the fundamentals of the science curriculum will provide these students with options in terms of their future. Given the students' reactions, their experiences with many teachers across their educational life does not appear to have encouraged these students to see science as creating future options.

Teacher professional knowledge is intertwined with the nature of teaching itself and entrenched within the contextual reality of their teaching situation. Teachers trust what they know to be true and when working within a system that overtly values statistical evidence of student learning, teachers become as much a product of the system structures and agencies to which they are accountable as do their students. Perhaps for many teachers it is possible to effectively and easily align their values with the requirements of the system in which they operate because these values have been nurtured through a similar system and are by nature compatible.

Understanding More About Teacher Thinking and Values

The tensions between teachers' values and classroom realities prompted us to explore in more depth the often tacit and deeply held values teachers hold about science and find ways to identify how these values underpin and shape their science teaching and ultimately their students' learning. 'Conditions for learning' (Smith, 2017) became a major consideration as this was inevitably going to be challenging work for teachers. Therefore, consideration needed to be given to the conditions that would support and actively encourage teachers to lay bare their personal values while also feeling safe and confident. The experience of exploring personal values was developed as an interactive session situated within a professional learning (PL) programme. It was important that the design and approach used in the programme overall actively encouraged teachers to acknowledge and attend to the personal values that drive their teaching. The session required teachers to be critically reflective, actively interrogating their own thinking and articulating their reasoning. The research revolved around two key issues: Identifying the type of learning experience that enabled teachers to identify and articulate the values they hold about the nature of science, and understanding how such an experience enables teachers to see a connection between their own understanding of science and the ways they represent science in their classroom teaching.

Exploring Teacher Thinking About the Nature of Science: Key Conditions for Professional Learning

The reflective experience needed to acknowledge that teacher thinking is always inherently personal while situated within a system that is contextual and overtly driven by external policies and expectations, where teachers often struggle with notions of identity and success. While it was possible that enabling teachers to expose their thinking could be an empowering way of assisting teachers to explore their own professional knowledge in action, this research focus was also potentially intimidating because many teachers could find it difficult to identify and articulate their values about the nature of science and may not be comfortable with confronting the limitations of their own thinking. Indeed, for some teachers there may be a need to acknowledge that there are values underpinning science as many may see science as value free. Therefore, three key elements became vital to the success of this research: trust, time, and using interactive conversation as a prompt for critical reflection.

Conditions for Learning: Trust

Any attempts at accessing teacher thinking required professional learning conditions that were supportive and safe and this inevitably took time and was dependent on establishing effective relationships between facilitators and teachers. Within safe and supportive professional learning conditions, the approaches needed to deliberately create a number of tensions for teachers—moments when they would feel some degree of intellectual or emotional resistance to what they assume to be accepted and shared understandings. These experiences were critical for uncovering deeply personal thinking, and it was believed that in these moments it would be possible to gain an insight into teacher professional thinking. Therefore, the research needed to be positioned within a professional learning programme that valued diversity and followed an extended timeline and which placed strong emphasis on facilitator-teacher relationships and ongoing support.

Conditions for Learning: Time

Investing time to change the accepted routine of conversations, rethink the role of the facilitator and provide challenging yet well supported learning experiences became the focus of the values session. The session was designed to encourage teachers to engage in critical interactive discussion so that they could articulate the professional knowledge that shaped their practice. This required time and attention to and acceptance of such thinking. In the contextual reality of prevailing school activity, reflective collaboration becomes constrained by time and driven by the requirement for collective, agreed outcomes. Extended time is rarely allocated for teachers to examine their personal professional thinking in detail; instead such thinking is often explained as 'intuitive' and an assumption follows that everyone shares the same understandings. In these conditions, it becomes almost inevitable that teachers work to find manageable and efficient ways to think and talk about teaching, in particular (in this case) teaching science. Almost by default teacher talk tends to focus on the tangible and technical aspects of teaching, that is, the practicality of what teachers do. As a consequence, these conversations tend to become systematic, practiced and habitual (Smith, 2017). In the case of science teaching in particular, when teachers can demonstrate they 'know' science through a capacity to articulate and demonstrate science knowledge, the assumption is often that these teachers think about the nature of science in similar ways. On this basis planning and teaching is conducted without ever really examining the prevalence and validity of individual views and beliefs. In our research approach allowing time for teacher talk was considered a vital condition for the research process.

Conditions for Learning: Critical Reflection Leading to Social Construction of Professional Knowledge

When professional thinking becomes routine and operational, by nature it cannot be assumed to any longer be a process of critical reflection. Reflection is not by definition, critical. Brookfield (1995) contends that power underpins all aspects of classroom learning and teaching and critical reflection seeks to understand more about this power-based interplay. Critical reflection also questions the intentions and validity of practices that have become routine in teaching. It was therefore essential to create conditions in our research approach where it was far more likely that teachers would undertake reflection that was critical and purposeful. Therefore, a valued outcome needed to be framed: to collaboratively construct a shared understanding of science. The learning experience by design required participating teachers to clarify their ideas about the fundamental beliefs they hold about science and then move to a group consensus. Conversations then needed to position individual values within a social context of alternative perceptions. These conditions also produced a different type of teacher talk to the very linear and process-orientated talk often present in most science professional development programmes. Often in such situations conversations tend to be one dimensional, focusing on the daily routines of school and on the technical aspects of teaching practice. In our work, these conversations needed to be challenged as this type of talk would potentially struggle to peel back the layers of complex thinking about science that the teachers hold and use every day in their teaching. One-dimensional interactions would be of little assistance in enabling teachers to share personal values and then develop deeper understandings of the nature of science. Conversations needed to enable teachers to contrast and align their thinking with the ideas of others because it was in this process of critical reflection that teachers would more likely realise how their perspectives about science are personal and, in turn, how this thinking may shape the various dimensions of their science teaching.

With these conditions in mind a ‘Values session’ was designed and implemented within existing science professional learning programmes that attended to these learning conditions. Consistent monitoring of these conditions was critical to the intentions of the experience.

The Experience: Articulating Personal Values

The ‘Values session’ became situated within two key teacher professional learning programmes: *The Science Teaching and Learning* (STaL) project, a collaborative in-service teacher professional learning programme involving Monash University and the Catholic Education Office Melbourne (CEOM), and the Professional Learning in Primary Science (PLiPS) programme, developed for the Department of Education and Early Childhood Development (DEECD) involving teachers working in government primary schools located across the state of Victoria in Australia. Both programmes aimed to build teacher capacity as reflective practitioners in science in an attempt to transform approaches to learning and teaching in science within schools. Both programmes were also ongoing; STaL was a five day (2 + 2 + 1) intensive, residential course spaced across the school year and PLiPS was a three day programme (2 + 1) with the final day taking place a short period of time after the first two days. In both programmes, the programme design and implementation facilitators worked to explicitly link their pedagogical purpose to the learning approaches encouraged and teaching procedures adopted. In both programmes all participants received ongoing in-school support; in STaL a ‘critical friend’ engaged teachers in school-based meetings throughout the programme, and in PLiPS ongoing online support was available. In both programmes discussions promoted reflective thinking and supported the trialling of alternative approaches to science teaching and learning. STaL involved both primary and secondary teachers and PLiPS involved only primary teachers. Given the need to attend to the conditions of trust, time and critical reflection leading to the social construction of professional knowledge, the design elements of both programmes provided ideal contexts in which to explore teacher thinking about the nature of science. The ‘Values session’ encouraged teachers to discuss and debate the validity of their ideas while programme facilitators intentionally worked to create conditions where teachers felt willing and confident to express and justify their views.

Part 1: Exploring Individual Thinking

In the 'Values session' each individual teacher was initially presented with a series of 19 statements about the nature of science and how it could be performed. The statements were all deliberately constructed to be highly value laden to intentionally evoke strong opinions from the participants and were taken from Carrier's (2001) Test of Scientific Literacy developed in relation to Lederman's (1992) seven characteristics of the nature of science. These statements are listed in Table 1. We selected 19 of the 24 original statements as we felt the final set were accessible to teachers working across both primary and secondary levels of education. Working individually, teacher participants examined the statements and classified them as either 'true' or 'false', and recorded individual responses.

At this stage, it was often observed across multiple sessions that teachers considered any pre-existing knowledge, experience and ideas to determine a personal view about the accuracy and credibility of the statement under consideration. This first stage of the task revealed a capacity of teachers to identify a personal position in relation to a number of contentious statements about the nature of scientific work, and confirmed our selection of statements as these decisions did not appear to be dependent upon a sense of personal adequacy with science or qualifications or experience with science. Additionally, teachers' language skills became important ways in which they could temper their views around science, and particularly perceived lack of confidence in science, as these language skills could provide an anchor for their decision-making. For example, they focused on the word 'must' in the statement 'To be scientific one **must** conduct experiments'. All participants were able to record individual decisions.

Part 2: Reaching a Group Consensus

The format of the session then required participants to form a group with four to five other teachers to work together to reach a consensus of opinion about each statement. This part of the task was designed to expose teachers to the ideas of others who often provided alternative perspectives or understandings to that of their own. Teachers were required to engage in open debate about the validity of each statement. Reaching a group consensus was seen as an important step in encouraging every participant's voice and discouraging the acceptance of the "loudest" voice. The outcomes were recorded as a group response. At this stage in the session a new option was made available, 'Undecided'. This option enabled the group to record an

Table 1 Value statements about the nature of science

Statement	True	False	Undecided
1. Scientists usually expect an experiment to turn out a certain way.			
2. Science only produces tentative conclusions that can change.			
3. Science has one uniform way of conducting research called "the scientific method."			
4. Scientific theories are explanations and not facts.			
5. When being scientific one must have faith only in what is justified by empirical evidence.			
6. Science is just about the facts, not human interpretations of them.			
7. To be scientific one must conduct experiments.			
8. Scientific theories only change when new information becomes available.			
9. Scientists manipulate their experiments to produce particular results.			
10. Science proves facts true in a way that is definitive and final.			
11. An experiment can prove a theory true.			
12. Science is partly based on beliefs, assumptions, and the non-observable.			
13. Imagination and creativity are used in all stages of scientific investigations.			
14. Scientific theories are just ideas about how something works.			
15. Scientists' education, background, opinions, disciplinary focus, and basic guiding assumptions and philosophies influence their perceptions and interpretation of the available data.			
16. An accepted scientific theory is an hypothesis that has been confirmed by considerable evidence and has endured all attempts to disprove it			
17. Scientists invent explanations, models or theoretical entities.			
18. Scientists construct theories to guide further research.			
19. Scientists accept the existence of theoretical entities that have never been directly observed.			

outcome if a consensus was unable to be reached. In every session teachers were observed openly articulating their personal decisions about each statement and explaining their positions. Participants listened to alternative perspectives and discussed and acknowledged thinking and evidence that was similar to their own and interrogated new or alternative positions. Teachers explicitly demonstrated personal levels of comfort or discomfort with ideas being expressed and this was indicated by volume and tone of voice and body language.

The reasoning shared was sometimes personal and often involved reflections on their own teaching and their own learning. It revealed the capacity of teachers to use new information to re-examine the validity of personal ideas and also the capacity to use group comments to determine where personal thinking was positioned in relation to the group's overall preference. It was at this stage that teachers were given permission to potentially construct new ideas, i.e., move away from initial thinking, and this revealed a willingness or resistance to accommodate different ways of thinking about science. The level of commitment teachers demonstrated to their initial ideas appeared to correspond with the extent to which these ideas represented or reflected their science teaching practice, i.e., if a statement aligned with their teaching practice there was a professional investment worth defending. These statements and the ensuing discussions appeared to bring to the surface deeply held values embodied in the connection between ways of understanding the nature of science and perceptions of personal professional identity.

Each group's results were recorded to provide an overall tally of whole cohort's responses. An example of one cohort's (n = 5 groups, where each group was made up of 6 people) responses from STaL is provided in Table 2 below. While the test developed by Carrier (2001) provided 'correct' answers, the intent in this session was to use the results as prompts for further discussion. In every session, the similarities and differences of responses were explored and discussion was promoted across the cohort to identify the arguments and thinking used when determining the validity of the statements. At this stage in the session, the underlying values driving selected responses were identified and articulated by participant teachers. For example, Statement 14 (Scientific theories are just ideas about how something works) produced responses of undecided, true and false. Groups then provided insights as to why their group responded in those particular ways.

In the STaL programme many of these values were captured in teacher case writing, which was a valued outcome of the programme. All teacher participants produced a written case capturing moments of practice when they began to think about their science teaching differently and the impact this had on their teaching practice, of which Hannah's is an example. Over 200 cases have been produced to date as a result of the STaL programme. This rich data set has been analysed and categorised to develop an understanding of the range of issues that are prominent among school-based science educators, prevalence of these issues across various cohorts of participants, and changes in teacher thinking about these issues that occurred as a result of their experiences in the STaL programme. For further information about these data see Loughran and Smith (2015).

Table 2 2013 STaL cohort's responses to NoS Statements (n=5)

Gp	Statements																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A	T	U	F	U	F	F	F	U	U	F	T	T	T	U	T	T	T	T	T
B	F	T	F	T	F	F	F	T	T	F	T	T	T	U	T	T	T	T	T
C	U	T	F	T	T	F	F	T	T	F	T	T	F	T	T	T	U	U	T
D	T	T	F	T	U	F	F	F	U	F	U	T	T	T	T	T	T	T	T
E	T	T	T	T	F	F	F	T	T	F	U	T	F	F	T	T	T	T	T

ENTER TRUE= T, FALSE= F, UNDECIDED = U

Representations of the Nature of Science in Teacher Writing

It was possible through analysis of these cases to identify teachers' views of the nature of science evident in descriptions of their science teaching practice. When teachers wrote about their science teaching their comments often outlined dilemmas they experienced, and while these statements did not always specifically outline how a teacher defined their understanding of the nature of science, the expectations teachers conveyed about their own teaching practice framed a purpose for teaching science. This purpose in turn conveyed some very interesting information about their intentions for student learning and the models of thinking they valued in science teaching and that they openly represented through their teaching practice.

When examining cases the emergence of repeated themes contributed to the development of a continuum of teacher thinking about the nature of science teaching. This thinking is captured as a continuum of thinking in Table 3. A very depersonalised view of science frames teacher thinking and actions on one side of the continuum moving towards a highly-personalised view of science. This shift in thinking also indicates a shift in the power base of learning and teaching from that of teacher to a shared ownership of all involved in the learning process. Both extremes are represented in the ways teachers talk about teaching science. In these cases, the shift in thinking and practice was reliant upon teachers engaging in a process of critical reflection within a supportive learning environment. Regardless of where teachers are located on these continua, time is of crucial importance.

When reviewing the data from teachers' case writing two strongly opposing views about the intention of science teaching and student learning framed the majority of teacher reflections. For many teachers their initial thinking prior to participating in the STaL programme was best represented in a view that saw science teaching intending to move student thinking from naïve to the 'right' or accepted answer. Following participation in the programme, for many teachers this thinking shifted to enabling students to construct understanding of accepted explanations, i.e., experience the rigours of the social construction of knowledge. This thinking appeared to be more in line with the nature of science as a human endeavour. Teachers' reflections conveyed this change in thinking and such change is captured in the following case excerpt.

> In a crowded curriculum, the covering of content before tests and exams was the ultimate goal of both students and teachers…. this is not to say that the curriculum was bad, or that students did not learn…. What was missing, however, was an appreciation by students that Science was more than just a body of content knowledge to be memorized from a text book. The Science curriculum at Year 10 gave very little time to undertaking 'student inquiry' and the few prac experiments that were carried out were so rushed that they amounted to little more than scripted recipes for the students to follow. The challenge was to embed a culture of critical, scientific thinking into a heavily teacher centred, traditional curriculum. (Bell, 2013, p. 29)

Table 3 A Continuum of Teacher Thinking about the Nature of Science

	What is** (the nature of) **science?	
	A continuum of teacher thinking as evidenced in teacher writing	
Science is depersonalised	→	**Science is highly personalised**
A rigid body of knowledge		*Science as a human endeavour*
	Intention of teaching:	
Moving student thinking from naïve to the 'right' or accepted answer	→	Enabling students to construct understanding of accepted explanations, i.e., experience the rigours of the social construction of knowledge
	Characteristics of teacher talk:	
Emphasis on the delivery of information	→	Use of student questions to drive inquiry & purpose for learning
Teacher controls all decisions about learning		Continual reflection on ownership of learning: whose learning is it?
Teaching driven by planning & curriculum agendas		Attends to curriculum while demonstrating flexibility in teaching approaches & time for learning
Frames discussions around the need for students to get the right answer, i.e., content acquisition		Sees value in exposing students to a variety of alternative perspectives
Assumes science teaching requires a level of expertise in content knowledge		Focuses on pedagogical issues of teaching and learning
Little discussion about teacher's personal level of knowledge.		Teachers identify themselves as learners within the learning process.
Implements accepted & unquestioned routines of teaching		Trials alternative classroom teaching
	Tensions for teaching practice	
Pressures of curriculum & sector expectations	→	Reframing teacher's role, letting go, shifting students' learning behaviours
Time		Time

Conclusion

It is undeniable that students often leave their years of school science with little appreciation of science as a way of thinking and acting that is entrenched in human experience, a purposeful and continuous knowledge-seeking enterprise driven by a need to understand. It is also undeniable that teachers possess a diverse range of understandings about the nature of science. It is the values which shape these perceptions that often determine what 'play outs' to become the 'science' students experience at school.

The decisions teachers make about how they frame science education are complex and are influenced by the many demands and expectations of the systems within which they work and also their own knowledge and experience. Changing school-based representations of science is challenging. The greatest challenge is finding ways to empower teachers to notice the values they hold while supporting teachers to consider how these values both sit within the requirements of their work as science teachers and shape their approaches to science teaching in ways that influence student learning. If done effectively this thinking can be explicated and shared collectively in ways that potentially enable teachers to develop broader understandings, and a deeper and more accurate conceptualisation of the humanness of science. The 'Values session' achieved the conditions necessary to enable such critical reflection and the social construction of professional knowledge. Teachers were able to use knowledge gained from this collective experience to shape their practice and as a result many were better equipped to find ways to enhance a richer student understanding of the nature of science as a human endeavour.

A Final Comment

Many readers of this chapter would be wondering—so what happened to Hannah? While Hannah's story is intriguing, its real value lies in the contribution it has made to our research in building an overall understanding of the complexities associated with teaching science. One insight may be revealed in one final comment Hannah included in her case:

> I was no longer hearing any of the usual, "I hate science!" In fact I was hearing more things like, "That's actually pretty cool." What a turn around, well it was at least a good start. (Keating, 2013, p. 17)

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