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Storylines and the Acceptance of Uncertainty in Science Education

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This article investigates the influences on a teacher's uncertainty through the use of storyline methodology. As a research method, storylines can be utilised to educe a teacher's responses to inquiries into their practice. The particular storylines in this article are drawn from the uncertainty work of Floden and Clark (1988) and reflect aspects of teaching that are of concern to all teachers: content knowledge, assessment, teaching and learning and knowledge. By drawing these storylines together, we present two key findings to our research question: 'how does a teacher accept uncertainties in his teaching, and how does that acceptance interact with his implementation of a new course?' Our analysis suggests that a teacher's continued professional learning is underpinned by an acceptance of uncertainty in their teaching. Further, the analysis highlights the value of a culture of long-term professional learning that allows teachers to respond positively to uncertainties that are important to them. This suggests that a science department that is committed to questioning practice may provide many of the supports that teachers need to pursue their own questioning of practice.

Keywords: Uncertainty, professional learning, storyline methodology.

INTRODUCTION

Uncertainty is part of teaching practice, and derives from a number of sources: the lack of an agreed knowledge base; the lack of consensus around goals and methods; the multiple and often conflicted values that are held around education; and all the complexities inherent in relating to, and working with, other people (Helsing, 2007). A desire to resolve uncertainty 'is a major factor driving human activity' (Wheatley, 2002, p. 9), while at the other extreme, uncertainty can entrench routine and predictability, leading to a 'limited conception of education' (Floden & Clark, 1988, p. 513). Helsing (2007) argues that both extremes are limiting in terms of understanding teachers' psychological and pedagogical responses to uncertainty. If uncertainty is viewed as a negative, then a teacher's psychological responses can include fear, doubts around efficacy, and active attempts to avoid the source(s) of the uncertainty. Consequent impacts on the teacher's pedagogy can include a compromise on standards, reversion to routine, adherence to convention and blaming others. Conversely, accepting uncertainty as a positive can be seen as simultaneously threatening and liberating to a teacher. The pedagogical impact of such a stance is a desire to develop higher levels of expertise through engagement and experimentation with questions of practice (Helsing, 2007).

We conceptualize uncertainty in a positive sense, believing that when teachers accept 'some uncertainty about the validity of their own teaching practices and beliefs that they can begin to imagine and construct new and more effective ones' (Helsing, 2007, p. 1322). Within this conceptualization, we acknowledge that teachers can hold, at times, different levels of acceptance towards uncertainty for specific aspects of their work. For example, while a teacher may be accepting of the general uncertainty inherent in teaching inquiry, they may simultaneously struggle with the specific uncertainty of changing their assessment practices. Our conceptualization is grounded in both our conceptual understandings and our own experiences as secondary science teachers. There are periods in many teachers' lives (including our own) in which the apparent safety of certainty has exerted a strong allure. We say the 'apparent safety' of certainty because complete certainty is an unrealistic notion in teaching; indeed, complete assurance in teaching would obviate any need to change.

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A teacher's ability to accept uncertainty requires a level of confidence in their capacity, and willingness, to deal constructively with those uncertainties (Britzman, 2007). Such acceptance of uncertainty may lead teachers to develop greater confidence in their own abilities, which in turn may open opportunities to experiment with their own teaching, to teach new courses, and collaborate with both colleagues and the wider community. In this article we consider the case of one teacher who, over seven years, became more accepting of uncertainty. Specifically, we are considering how he accepted uncertainties in his teaching, and how those responses interacted with his implementation of a new course in Environmental Science.

Environmental Science, as a specific course of study in the Canadian province of Ontario, has been something of a poor relation within the science education curriculum over the past two decades. Initially incorporated into the 1988 science curriculum due to a growing concern for environmental issues, it was removed by political fiat in 2000 at the direction of a government that was pushing a neo-liberal agenda. However, individual schools and boards could continue to offer Environmental Science as a 'locally developed' course subject to Ministry of Education approval. Following a change of government, a high-profile public inquiry was conducted to consider the future of environmental education. In 2007 the inquiry, headed by the Canadian astronaut Roberta Bondar released the *Shaping our Schools, Shaping our Future* report (more commonly called the Bondar Report). Consequently, Environmental Science was reinstated as a formally mandated course, to be fully implemented in 2009 (Ministry of Education, 2008). Within the science curriculum, it is taught as a grade 11 course that can be applied towards both university and college admissions requirements. Given this on-again off-again history, questions arise as to the uncertainties that science teachers may face in implementing this course. A principal area of concern is the relationship of environmental science to the broader notion of environmental education. Sauvé (2005, p. 17) notes that the relationship is subject to ongoing debate, with science teachers seeing the environment as a hook that 'stimulates an interest in sciences or one that offers a social or ethical dimension to scientific inquiry'. Following this line, while the provincial curriculum documents may be clear as to course requirements, uncertainties abound, as Pedretti and Nazir (2011, p. 602) state:

> *There is much confusion and perplexity surrounding the STSE (Science Technology, Society and Environment) slogan … Widely differing discourses on STSE education and diverse ways of practicing have led to an array of distinct pedagogical approaches, programs, and methods.*

The following article is in four sections. The first section provides the theoretical foundations of the study in terms of uncertainty and teacher change. The second outlines our methodology, methods and the context of the research. The third section provides the storylines and analysis. The final section discusses the work in terms of science teacher professional learning and the future direction of the research.

Uncertainty and Teacher Change

Uncertainty has a crucial role in teacher change, for in accepting uncertainty teachers develop their expertise: 'The scientific attitude may almost be defined as that which is capable of enjoying the doubtful' (Dewey, 1929, p. 228). According to Wheatley (2002), the ability to 'make peace' with uncertainty is both a feature of teachers' ability to know and inherent to the human ability to make decisions. This becomes important when working to introduce a new course, especially an expansive course such as Environmental Science. Jenkins and Pell (2006, p. 777) state that environmental education 'constitutes a challenge to a conventional subject-based curriculum and pedagogy'. Given the uncertainties that surround the course, one would be entitled to ask how well-equipped science teachers are to teach it, especially given its strong links to the social, economic and moral spheres of human activity.

According to Floden and Clark (1998), there are five sources of teacher uncertainty. First is the question of teachers' influence on student learning, which involves teachers questioning how student understanding changes over time. Second, there are uncertainties about the impact of classroom practice on student learning, especially if the teacher is working to reshape their practice. Third, there are questions of content, such as the emphasis teachers place on particular concepts, their own understanding of difficult concepts and the shifting nature of knowledge. Fourth, there are uncertainties around the social and intellectual authority of the teacher, particularly in terms of the moral obligations that teachers have towards their students. The final uncertainty is to question how to improve practice, especially if implementing new teaching strategies and/or programs.

Understanding the sources of uncertainty are important, for it guides how teachers respond when challenged by significant problems and dilemmas. According to Wallace and Louden (2003), teachers work to resolve uncertainties in ways that are coherent with the understandings that they already have. The processes they work through during a period of change, according to Timperley, Wilson, Barrar and Fung (2007, p. 7) are 'cueing and retrieving prior

knowledge, becoming aware of new information and skills, and creating dissonance with a teacher's current position'. These processes are not mutually exclusive, with potentially all being present in any professional learning opportunity. In dealing with issues of teacher uncertainty, it has been suggested that individual efforts to improve perceptions of personal efficacy in the face of uncertainties are unproductive: the life of the 'lone inquirer is difficult' (Dana & Yendol-Silva, 2003, p. 7). To overcome this, collaboration is often cited as a strategy to positively influence teachers' acceptance of uncertainty (Helsing, 2007). Collaboration that challenges teachers' thinking, encourages reflective experimentation with new behaviors, practices and ideas, and understands that success is often preceded by failure has been shown to build a common sense of purpose and agreement as to what constitutes good practice (National Research Council, 1996). In summary, for teachers to become more accepting of uncertainty requires access to appropriate professional learning opportunities and materials, the opportunity to develop and refine teaching strategies, and the long-term support of colleagues and administrators (Garet, Porter, Desimone, Birman & Yoon, 2001).

Teacher change, therefore, rarely comes as a sudden revelation; teachers change incrementally as they work to extend their 'horizons of understanding'. While uncertainty may have five sources, it can manifest itself in various aspects of teachers practice. Floden and Clark (1988) highlight four of these aspects that are of particular interest to us. The first is assessment of student learning, whereby 'teachers are seldom sure what their students know and what they are learning' (p. 508). The second is content, where teachers face uncertainties ranging from content coverage and appropriate emphases, to the most appropriate orientation for teaching the material, which can stretch from facts and rules to relationships among concepts and broad understanding. The third is teaching and learning, where teachers 'remain uncertain about the links between their teaching and pupils' learning and about what to do to enhance learning' (p. 510). The fourth is the observation that teachers may possess an incomplete disciplinary knowledge, which is more than knowledge of canonical knowledge. For example, informed decision making of the type envisaged in the Environmental Science course requires more than content knowledge. As Pedretti and Nazir (2011, p. 604) explain, it can also include: 'the ability to analyze, synthesize, and evaluate information; nature of science (NOS) perspectives; the coupling of science, ethics, and moral reasoning; and agency'. These four aspects of uncertainty are the focus of our research.

This article focuses on the work of one teacher, Jason, who is also the second author. Our overall research question can be stated as 'how does a teacher accept uncertainties in his teaching, and how does that acceptance interact with his implementation of a new course?' From this overall question, subsidiary research questions that inquire into the specific aspects of teacher uncertainty have been developed:

- What influences Jason' acceptance of uncertainty towards assessment of student learning?
- What influences Jason' acceptance of uncertainty towards the course content?
- What influences Jason' acceptance of uncertainty towards his own teaching and learning?
- What influences Jason' acceptance of uncertainty towards knowledge uncertainties?

METHODOLOGY

Methods and Context

According to Henze, van Driel and Verloop (2009), few investigations have been conducted into in-service teacher professional learning around particular workplace innovations. Part of the issue is that educational change is a process, not a specific event (Hall & Loucks, 1978). Consequently, we believe that a narrative methodology is appropriate, for narratives are a way of telling stories about teachers that are both 'personal - reflecting a person's life history [and] social - reflecting the milieu, the contexts in which teachers live' (Connelly & Clandinin, 1999, p. 2). Stories, as the 'linguistic form in which human experience as lived can be expressed' have the capacity to draw together, and organise, events and actions by means of a plot, or storyline (Ricoeur, 1991, cited in Polkinghorne, 1995, p. 7). Storylines offer promise as a narrative method by allowing the storyteller to evaluate, over time, the significant events within their narrative (Gergen, 1988). To realize this promise, however, four salient points need to be made:

Structure of the story line. The structure involves a teachers' perception of particular events being plotted on the vertical axis, against a horizontal time axis (Gergen, 1988; Beijaard, van Driel, & Verloop, 1999). The second is that a coherent story must have a 'valued endpoint or goal towards which the action of the story is directed' (Gergen, 1988, p. 97). In this article, the valued endpoint was taken as Jason' acceptance of certainty in dealing with assessment of student learning, teaching and learning, content, and knowledge. Acceptance of aspects of uncertainty is a feature of teachers' ability to know (Wheatley, 2002), and can only be perceived by the individual concerned

(Tripp, 1994). To accept uncertainty is to be in a position to develop the positive psychological and pedagogical responses to uncertainty discussed by Helsing (2007). Following Beijaard et al. (1999), it was decided to use a five-point scale (5 being Jason' perceived acceptance of uncertainty and 1 being a negative view of uncertainty). Asking Jason to decide on his acceptance of uncertainty may appear highly subjective, but can be justified, we believe, on three grounds. First is that change is a 'highly *personal* experience' and that the participants are in the best position to judge their position in the change process (Hall & Loucks, 1978, emphasis in original). Second, alternative methods of collecting data from participants are acceptable strategies in attempting to understand change (Hall & Loucks, 1978). As Tripp (1994, p. 72) states, by 'recording thoughts and events, we are moving beyond the "it happened that" stage to "that happened because" stage'. Finally, working with Jason as a teacher-researcher ensures that storytelling and evaluation are not independent activities, an important consideration in this type of research, as it remains problematic for researchers to interpret, and evaluate, the significant events of a teacher's story (Beijaard et al., 1999).

Endpoints. The establishment of appropriate endpoints is important as it allows for the evaluation of events with respect to the endpoint. According to Wagner (n.d.), storylines shape teachers' responses by acting as a reference point for contemporary decision-making. Particular responses to past uncertainties may be regarded as significant by a teacher if they are understood as being 'indicative of underlying trends, motives and structures' to current practice (Tripp, 1994, p. 69). By working back in time, teachers can come to an understanding of the genesis of their practice 'in order to use that knowledge to change ourselves and our current practice' (Tripp, 1994, p. 71). Some may consider such a position implies an inevitable path for teacher change and improvement and judges the past in the light of the present. We would argue against such a consideration for two reasons. The first is that, while a teacher may claim an increasing acceptance of uncertainty in their work, could that claim be reasonably made simultaneously across all sources of teacher uncertainty? The work of Capobianco (2011) and Wallace and Louden (2003) suggests that teachers always have some level of uncertainty across their practice. Secondly, a storyline reflects the point in time in which it was created. A storyline is always a work in progress in which 'new links can constantly be made, not only to current practice, but also how we see ourselves to current and past selves and practices' (Tripp, 1994, p. 73). In terms of the storyline methodology, what is seen as accepting of uncertainty today may not be viewed in the same manner in the future.

Events that lead towards the endpoint can be positively valued, while those that lead away from the endpoint can be negatively valued. In this article, an increasing acceptance of uncertainty is valued positively, as it is linked to the potential for professional learning. This process of valuing allows the narrative to be viewed as if in a two-dimensional (positive or negative) evaluative space (Gergen, 1988). Further, the process of valuing over time allows the temporal narrative to be converted to a linear form, or storyline (Gergen, 1988) that gives a clear visual representation of a teachers' diachronic development of practice. A progressive narrative is represented by a storyline in which events become more positive over time, while a regressive narrative is represented by a storyline in which events become more negative over time. Storylines that are unchanging with respect to the endpoint can be described as stability narratives. A positive stability narrative would be representative of events in which everything worked as planned, while negative stability narratives would be representative of events in which nothing went according to plan.

Responses. The third point is that 'different stimuli may bring to the fore different narrative forms' (Gergen, 1988, p. 107). Issues such as assessment of student learning, teaching and learning, content, and knowledge will elicit different levels of teacher acceptance of uncertainty over time. There are three related reasons for these differing responses, the first being that 'personal satisfactions, frustrations, concerns, motivation and perceptions generally all play a part in determining the success or failure of a change initiative' (Hall & Loucks, 1978, p. 38). The second is that change over time is not an '… undifferentiated continuum. Individuals involved in change go through stages in their perceptions and feelings about the innovation, as well as in their skill and sophistication in using the innovation' (Hall & Loucks, 1978, p. 38). Third, the environment in which the teacher works is an important consideration, for in dealing with uncertainty, teacher collaboration 'can create a climate where uncertainty is viewed as appropriate to experience and address … and because it also serves as a mechanism for the creation of knowledge about instruction, thereby diminishing teacher uncertainty' (Helsing, 2007, p. 1326).

Advantages and disadvantages. This section addresses the perceived disadvantages and advantages of the methodology. For Gergen (1988), the major disadvantage is that the storyteller may generalize particular years or events, by averaging the highs and lows over a period of time to produce a result that is too general and hence fails to do justice to the data. Storytellers may also rush to produce unreflective storylines. These disadvantages, however, may be outweighed by the advantages described by Beijaard et al. (1999, p. 49): 'participants evaluate experiences and events themselves, which appear to be a difficult task for a researcher when using other narrative research

methods … subjective evaluations of experiences and events can be quantified … [and] storylines are relatively quick and easy to make'.

INITIATION AND DATA COLLECTION

In the second semester of the 2010 school year, the first author approached Jason regarding his involvement in a research project. The initial approach was made on the basis of their successful collaboration in publishing a book chapter on the establishment of the Environmental Science course (see Pilot, Melville, Jones, & Bartley, 2010), Jason' developing interest in educational research, and a high level of mutual respect. Given Jason' expertise in environmental education, the discussions turned to his experiences in this area: consequently, the storyline methodology and uncertainty began to crystallize as suitable constructs for considering those experiences. As part of understanding these constructs and how they could be operationalized, Jason read Beijaard et al., (1999), Helsing (2007), and Floden and Clark (1988). From these initial conversations, it was decided to focus specifically on Jason' teaching of the Environmental Science course since 2004. The main reason for selecting this course was the continuous length of time that Jason had taught it. Further, we decided to emphasize Jason' uncertainty regarding assessment of student learning, teaching and learning, content, and knowledge (Floden & Clark, 1988). Based on the readings and conversations, Jason understood these aspects of uncertainty as being crucial in his work, an important point to consider in working with storylines (Beijaard et al., 1999). The selection of these aspects was based on our discussions as to what was important to understand about Jason' teaching at the time of the research. Beijaard et al. (1999, p. 58) emphasize that the storyline method is most beneficial when it elicits 'what really matters for teachers in the teaching profession.'

Over the first semester of the 2011 school year, Jason drew up the four specific storylines with a vertical scale from 1 to 5 (with 5 being seen as an acceptance of uncertainty as determined by Jason), and a horizontal scale from 2011 to 2004 (see Figures 1-4). Working chronologically backwards is important for two reasons: setting the stage from the present to the past stimulates teachers' memories and also helps to clarify the critical incidents of the storyline (Beijaard et al., 1999). These critical incidents (as rendered by the individual) are important in that they 'help maintain a balance between the academic understanding of history and the use of biography as an aid to … improved teaching performance' (Tripp, 1994, p. 71). Drawing from the work of Cameron (2011), Jason also wrote commentaries to explain the critical incidents and general trend of each storyline, the reasons for changes over time and his evaluation of the factors that influenced each storyline. As each commentary was completed, it was discussed with the first author in order clarify Jason' statements and probe his reasoning. A developmental grid was also used to elicit memories of specific events or incidents on each storyline; for example, significant progressions, regressions, or periods of stability. For each specific event, Jason was also asked to describe the event or incident. Quotes from these materials, along with material from the 2010 book have been reproduced in the storylines presented below. An example of the materials involved in data collection stage are reproduced in Appendix A.

DATA ANALYSIS

The data analysis initially involved the first author in a consideration of the book chapter, storylines, commentaries and grids. This aim was to identify the predominant narrative forms (progressive, regressive or stable) in each storyline and the professional and/or personal stimuli that influenced them (Gergen, 1988). Each storyline was considered in terms of the subsidiary research questions. The initial work prompted a number of clarification questions of Jason. In particular, questions about the role of the department in helping him become more accepting of uncertainty. The first author then developed four storylines that sought to understand each aspect of uncertainty and Jason' changing levels of acceptance, in terms of personal and professional incidents. The next stage was to consider the themes that emerged across the narratives, with particular emphasis being placed on any ambiguities and tensions that appeared to exist between them. At this point, Jason was asked to critique the analysis and comment on the tentative conclusions.

CONTEXT

The Environmental Science courses, both the locally developed (2004-2008) and centrally mandated (2008-present) versions, have been the exclusive teaching responsibility of Jason. The 2004 locally developed course was based on materials obtained from boards in southern Ontario, which were tailored to meet the needs of northern Ontario, where Jason' school is located. Beginning in 2007, the Ministry of Education began trialling a grade 11 Environmental Science course which encouraged schools to use the strengths of their community to develop

appropriate lessons and activities to cover the curriculum (Ministry of Education, 2008). In this emphasis, the trialled course was identical to the locally developed course. Jason was involved in this trial, and was invited to attend planning workshops on the basis of his work with the locally developed units and the personal links that existed between his department chair, university science education faculty, including the first author, and curriculum personnel at the Ministry of Education. The course was formally implemented in 2009.

The department in which Jason works has pursued a long-term program to develop inquiry based teaching and assessment as an over-arching teaching philosophy. The work has been reported on else where (see Jones, Kaplanis, Melville, & Bartley, 2009), but can be summarized, in the words of the chair, as

> *Our department sees science education as a program. It is not one teacher, it is all of them. It is not one course or grade, it is all of them … It can't be just knowledge. We must model the ways and understandings of scientific inquiry; we must teach those ways and understandings; we must practice those ways and understandings; we must provide an opportunity to experience those ways and understandings in novel and authentic contexts; and finally we must provide quality assessments in order to improve performance of those ways and understandings* (Jones et al., 2009, p. 154).

Jason' undergraduate degree is in Chemistry, and he has taught science in this department since 2000. He has been an active participant in the wider departmental professional learning (see Pilot et al., 2010; Melville, Jones, & Campbell, 2014). Consequently, a major part of Jason' work has been to achieve coherence between the departmental inquiry focus and the Environmental Science course. This coherence is partly achieved by working towards a culminating activity that assesses students' knowledge, skills and abilities, and crucially, their capacity in engage in discourse around a particular environmental issue. The culminating activities in Environmental Science have varied over the years: designing a greenhouse for the school community; planning a five year forest management harvest plan for a provincial park; and, the design of a water treatment system for northern Aboriginal communities. In each of the culminating activities, the students have worked with government agencies, individuals and companies.

Four Storylines and Analysis

This section provides the individual storylines that Jason developed for each of the four aspects of uncertainty. Analysis of these storylines provides us with an understanding of the interplay of factors that allowed him to identify, and then become, more accepting of uncertainty. Jason' words are italicised in the following text.

Uncertainty towards Assessment

Jason' storyline (see Figure 1) can be represented as an uncertain stability narrative from 2004-2006, a certain stability narrative from 2008-2010 and progressive narratives from 2006-2008 and from 2010 to the present (Gergen, 1988).

Jason' evaluation of the storyline highlighted two inter-related professional factors. First, while he had opportunities throughout the entire time period to engage in professional learning about assessment, the negative stability narrative (2004-2006) and the positive stability narrative (2008-2010) were both periods in which he wrote of trying to *'understand the "science" behind why certain things work for specific learners and others do not'*. Jason explained that from 2004 he was working with his departmental colleagues on the development, and classroom use of, rubrics and other assessment strategies that aligned with inquiry as an overarching teaching philosophy. These developments *'were largely trial and error, and still heavily influenced by a traditional view of science education. Over time, we became better at linking assessment and inquiry'*. From 2007, this departmental work was supplemented by board level initiatives that were driven by provincially mandated changes to assessment practice. Jason' assessment practices were initially aligned with a traditional view of science education. This view emphasised assessment of the content through end of unit tests and formal examinations. His uncertainty arose when the departmental professional learning into inquiry challenged those practices. To reduce that uncertainty required Jason to be inquisitive about *'why certain things work'* and persevere with the new strategies such as the rubrics and culminating activities.

The increasing confidence that Jason' felt in his assessment strategies is reflected in this excerpt from a book chapter that he wrote in 2009 (Pilot et al., 2010, p. 220):

> *Once the issue for the Culminating Activity has been determined, the learning expectations required by the curriculum are highlighted and used as the building blocks for the course. The units of work that develop from the expectations are not discretely sequenced one at a time, but rather they are woven into sub-units based on different environmental issues (not necessarily the one*

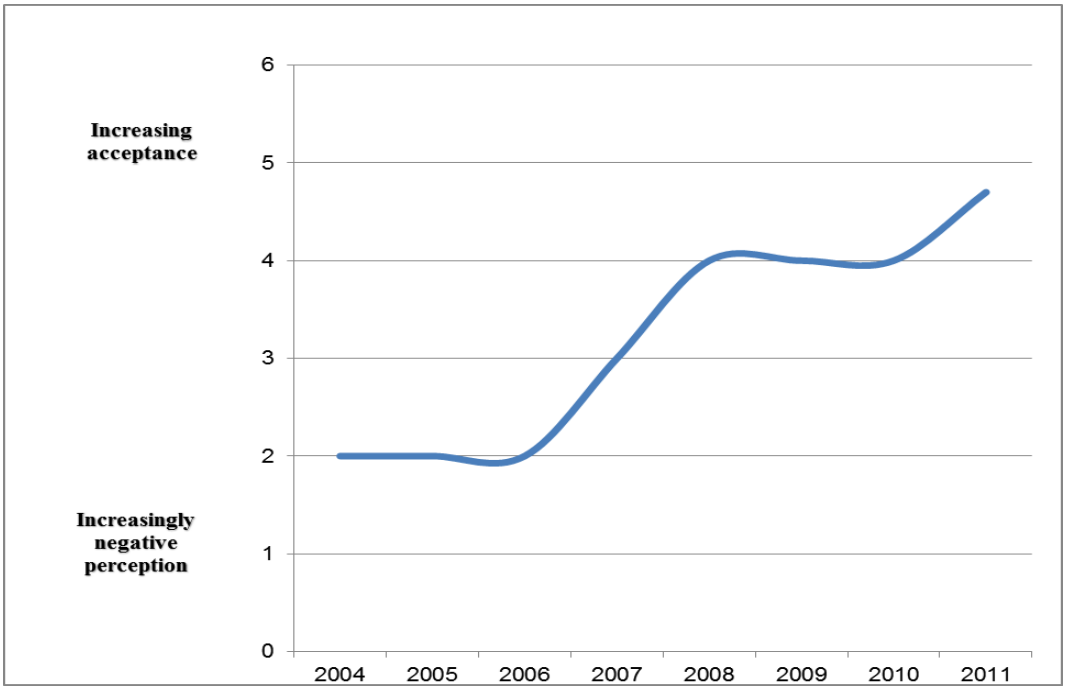

Fig 1: Assessment Uncertainties

used for the culminating activity) with overlapping expectations from multiple strands of the course. These learning expectations outline the core knowledge and skills of the course and are provided to the students at the start of the semester. This strategy helps to make assessment as transparent as possible, and also provides a framework for students to understand the direction and purpose of the course's component and how they are woven together throughout the semester.

The second factor that influenced Jason' levels of certainty was the opportunity to develop his assessment strategies with the same courses over a number of years. During both stability narratives, Jason started teaching new subjects for the first time. The negative stability narrative was a period when he was teaching the locally developed Environmental Science courses for the first time, while concurrently starting to reform his assessment and inquiry teaching strategies. The 2008-2010 positive stability narrative indicates an acceptance of uncertainty in his assessment abilities even as he was teaching the new centrally mandated Environmental Science courses and the grade 11 Chemistry course for the first time. As he wrote: *'I have steadily been increasing my abilities … as I become more comfortable, I move on'*. Recognition of increasing ability has allowed Jason to becoming more accepting of uncertainty. The two progressive narratives were periods in which Jason felt that the professional learning was directly applicable to the subjects he was teaching. This applicability is exemplified in the following comments: *'I am now catching my stride in terms of course delivery and the [assessment] training'* (2006-2008), and *'the assessment and evaluation training … is an excellent opportunity to network, observe, and develop my understanding and technique'* (2010-present). Importantly, the acceptance of uncertainty that developed in 2006-2008 was attributed to the departmental work and *'having years to experiment with techniques for all types of learners'*.

In summary, Jason' uncertainty in assessment arose as the departmental professional learning challenged his traditional view of science education. An increasing acceptance of uncertainty was influenced by two factors. The first was having extended opportunities to work with colleagues on assessment strategies that aligned with inquiry. The second was the opportunity to develop his assessment practices with the same courses over a number of years.

Uncertainty towards Course Content

Jason' storyline (see Figure 2) can be represented as a negative stability narrative from 2004-2006, a progressive narrative followed by a positive stability narrative from 2006-2008, a progressive narrative from 2008-2010 and a positive stability narrative from 2010 to the present (Gergen, 1988).

Jason was emphatic as to the major influences on his understanding of the course content. Confident in his own knowledge, Jason initially taught science from a traditional perspective that emphasised content. This perspective was being challenged as the department began to develop inquiry based teaching strategies. For Jason, the

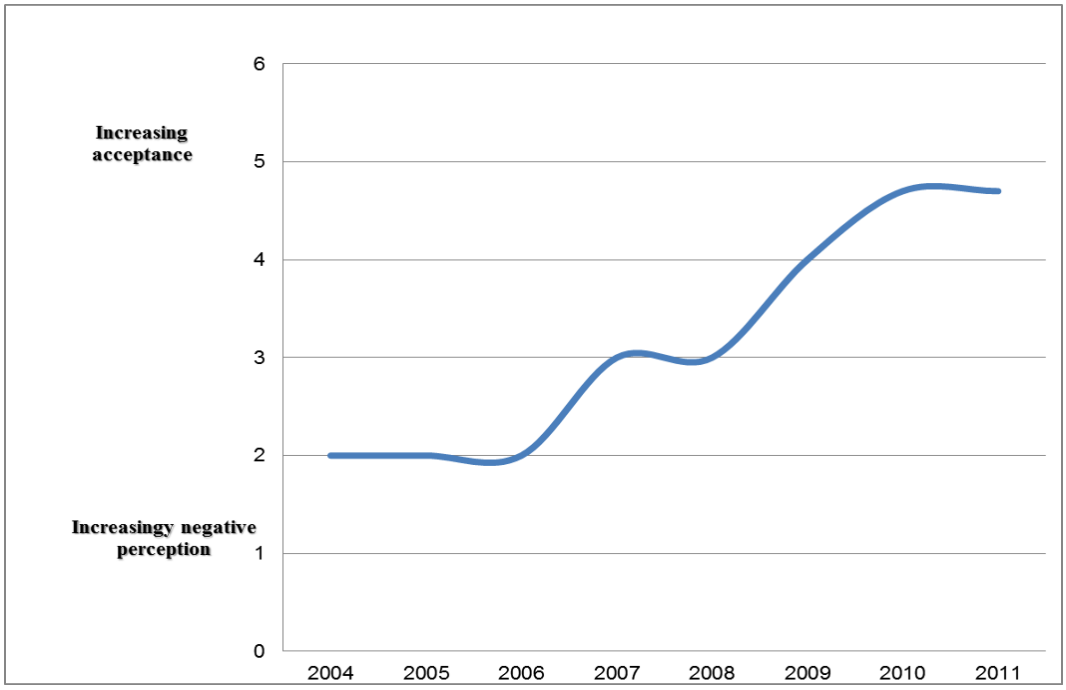

Fig 2: Content Uncertainties

uncertainty about inquiry manifested itself in concerns about content coverage and how to appropriately emphasise both content and inquiry in his teaching. Teaching the locally developed Environmental Science course for the first time in 2004, he felt *'inundated by so much material to cover'*. A complication was that the course was offered at the Workplace level (for students looking to join the workforce after high school), and the Mixed level (students who will enter either college or university). Consequently, Jason felt uncertain about delivering content, and how to strike a balance between applied and academic learning.

This uncertainty prompted Jason to talk to other teachers and people involved with industry and community issues in the region. By 2006 he had gained some experience in inquiry based teaching strategies and was working with industry and environmental groups. In 2009, Jason wrote that both courses had been, or were being: *'delivered in a manner that balances subject knowledge and its application. For example students collect tree stand data in the forestry inquiry, or alter the abiotic conditions of soil in an agricultural inquiry'* (Pilot et al., 2010, p. 220). Jason' work had provided a context for the courses and a: *'view of a much larger picture of the content I needed to cover and the threads that hold the course together'*. In 2007, Jason began piloting the centrally mandated grade 11 Environmental Science course and was involved in Ministry of Education implementation workshops. The progressive narrative from 2008 to 2010 was built on the work of the previous two years, and the decreased uncertainty that Jason had in teaching grade 11 Chemistry from an increasingly inquiry centred perspective. Jason also returned to school, completing courses in Environmental Chemistry and Biology. Being more accepting of uncertainty and adding new content knowledge allowed him to experiment with his teaching and make links between Chemistry and Environmental Science: *'this helped focus my content development into threads that really began to connect all the content [in both courses]'*.

In summary, Jason' capacity to address uncertainty about content coverage and the appropriate emphasis to place on content and inquiry was influenced by two factors. The first were the discussions Jason had that led him to commit to the use of inquiry strategies in his teaching. The second was the incorporation of expertise from the wider community into his classes and the adoption of a more holistic view of knowledge. In turn, this now affords him the opportunity to *'focus on developing a broader understanding into other areas I didn't have time for before'*.

Uncertainty towards His Own Teaching and Learning

Jason' storyline (see Figure 3) can generally be represented as progressive narratives from 2004-2006 and 2009-2010, punctuated by a positive stability narrative from 2006-2007 and from 2010 to the present (Gergen, 1988).

Two features immediately stand out in this figure. The first is Jason' differentiation of his own teaching and learning. The second is the temporal pattern in which increasing acceptance of uncertainty in learning precedes increasing acceptance of uncertainty in teaching. Having taught secondary science since 2000, Jason was initially

Fig 3: Teaching and Learning Uncertainties

neutral about his own learning, but did recognise that the demands of incorporating inquiry into his teaching meant that he was being *'inundated with too much "learning" to be efficient in my teaching'*. As that inundation receded, Jason' acceptance of teaching uncertainties increased, and remained higher than his acceptance of learning uncertainties until 2007. The positive stability narrative of 2006-2007 is interesting for two reasons. The first is that, during this period, Jason was beginning to develop strong links with local agricultural and forestry businesses and a community based food security organisation, and incorporating them into his teaching. The second, related, reason is that Jason was working with his colleagues on operationalizing inquiry as a philosophical underpinning of their work: *'I was making contact with community partners and starting to learn the real connections between Environmental Science, my other courses and inquiry'*. Such work would underpin his growing acceptance of uncertainty in both his own learning and teaching. As noted above, Jason was accepting of uncertainty when he consciously: *'chose to use … inquiry as the key foci for the teaching strategies and planning of the courses'* (Pilot et al., 2010, p. 218).

Beginning in 2007, with the piloting of the centrally mandated grade 11 Environmental Science course, Jason was invited to be on a Ministry implementation team to lead, and evaluate, the pilot course. Within the implementation team, Jason was *'seen as a leader … and I was getting a much clearer picture of how to teach my courses and what to focus on: issues-based learning and inquiry'*. This 'clearer picture' corresponds with the growing acceptance of uncertainty in assessment and content seen in Figures 1 and 2. The storyline shows that as Jason' acceptance of learning uncertainties increased, the acceptance of teaching uncertainties also increased. Currently, both are at a very high level: *'I continue to increase my understanding of Environmental Science and how it can be taught, and then put that knowledge into practice'*. What is intriguing is that this high level of acceptance has co-existed, since 2007, with a prolonged regressive storyline around knowledge. Over this time period, Jason appears to be more accepting of uncertainty in his own teaching and learning, even as he struggles with the uncertainties of knowledge. Helsing (2007, p. 1330), offers an insight that explains this tension: Jason is seeking to 'manage the tension between [the] need for some certainty with a commitment to and curiosity about their unresolved questions'. With that tension, which only began to be resolved in 2010, in mind, we now turn to knowledge uncertainties.

Uncertainty towards Knowledge

Jason' storyline (see Figure 4) can be represented as a saga: a series of regressive and progressive storylines (Gergen, 1988). A consideration of this storyline was the emergence of a personal factor for the first time. Jason' two children were born in 2005 and 2008. Both happy personal events correspond with periods of professional uncertainty, and the interplay of personal and professional should not be discounted: 'changes in life circumstances may produce shifts in the levels of involvement in career' (Friedman & Greenhaus, 2000, p. 27). From the written

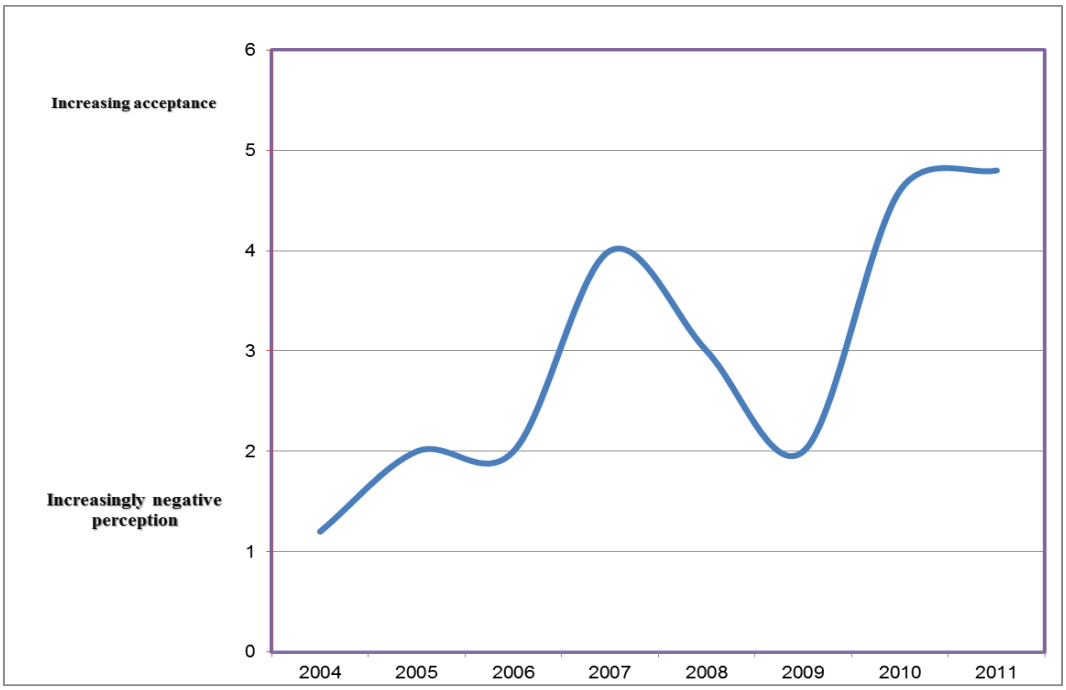

Fig 4: Knowledge Uncertainties

descriptors, however, there were a number of professional factors that appear to have acted against a greater acceptance of uncertainty.

Jason' uncertainties from 2004 to mid-2006 were bound up in the need to decide on the content that could be incorporated into the locally developed course, the context in which that content could be presented and the need to *'balance content and assessment'*. These challenges began to be resolved after two and a half years, with the increasing collaboration with businesses and community groups. These collaborations provided Jason with a context around which to build the course and determine the key content to include: *'I began to balance knowledge and its application'*. The piloting of the centrally mandated Environmental Science course in 2007, however, renewed the uncertainties: *'I had concerns about the new curriculum and changing my program'*.

Through 2008 Jason' storyline becomes more regressive towards Environmental Science, as he started teaching grade 11 Chemistry, returned to school and further study, and his son was born. Teaching Chemistry proved to be liberating, and led Jason to recommit to the teaching of Environmental Science: *'I began to look for a new focus to my program'* and he '*really began to connect all the content [in both courses]'*. The refocusing in 2009 coincided with Jason collaborating with his science chair and two faculty science educators in writing a book chapter for the National Science Teachers' Association (Pilot et al., 2010), which set out how the Environmental Science courses met the third goal of the National Science Education Standards, engagement in 'public discourse and debate about matters of scientific and technological concern' (National Research Council, 1996, p. 13). This exercise was pivotal for Jason in valuing, and becoming increasingly accepting of uncertainty, in his work: *'it allowed me to develop my understanding as a teacher …writing was cathartic as it forced me to take an objective look at my courses … my confidence in my program was reaffirmed'*. In summary, Jason was in a position to integrate his knowledge across subject boundaries, giving his teaching a greater level of coherence. A consequence of this was that he felt more confident in considering his teaching, and how it could be improved further.

Having considered the four storylines independently, we are now in a position to answer our overall research question: 'how does a teacher deal with uncertainty when establishing a new secondary science course?' In providing an answer, we are mindful that Jason' dealings with uncertainty, while they may resonate with science teachers, are by no means representative of all science teachers' experiences. With this caveat in mind, the analysis points to Jason' increasing acceptance of uncertainty as being evolutionary. This definition is characterised by extended participation in a variety of professional learning strategies, on-going experimentation within the classroom and collaboration with both teachers and external experts (Henze et al., 2009). Examples of this increasing acceptance include his work to integrate the work of outside experts into the course, his work in assessment at the school and provincial level and his development of a clearer picture of how his courses could be taught from an inquiry

perspective. An evolutionary understanding suggests that the answer to our research question is in two parts; accepting uncertainty and a long-term culture of learning.

Accepting Uncertainty

The analysis suggests that a teacher's continued professional learning is underpinned by an acceptance of uncertainty in their teaching. In the words of Britzman (2007, p. 3): 'Uncertainty resides within the acts of the self-committed to becoming'. This aligns with the notion that teacher change is incremental. Professional learning may afford opportunities for teachers to work through the processes of change outlined by Timperley et al. (2007), but will only produce change when a teacher accepts the need to resolve specific uncertainties of practice highlighted by professional learning opportunities.

In 2004, Jason held a negative perception of uncertainty except in terms of his own learning. At the time his conceptions of science teaching were being challenged by the departmental work on inquiry. Jason felt he was being *'inundated'* by the learning required in establishing the new course in the period 2004-2006. By 2007, as his understanding of inquiry developed, he was becoming increasingly accepting of uncertainty across all aspects of his work. However, the trialling, and subsequent introduction, of the new Environmental Science course changed his perception towards knowledge uncertainties. These became increasingly negative towards mid-2007 and remained there for the following two years. Implementing a new course is an uncertain time for teachers, involving them in learning new content and/or pedagogic strategies (Henze et al., 2009). As Jason stated for 2005-6, he was *'grasping the weight of creating a program and balancing content with assessment'*. The trialling of the new course in 2007, was a source of uncertainty. Despite similarities to the locally developed course, the trial was sufficiently different for Jason to express *'concerns about the new curriculum and changing my program'*. Given the curriculum changes that Jason faced, it is entirely understandable that he was uncertain around knowledge for the majority of the period 2004-2009.

More significant than this expected uncertainty is the realisation that Jason continued to develop his content and assessment knowledge and came to accept his uncertainties in these areas. In doing so, Jason appears to answer the question posed by McDonald (1986, p. 362): 'Discovering uncertainty when certainty is the measure of knowledge can only produce demoralization, and perhaps paralysis of action as well ... But what if teachers, recognizing the uncertainty in their work, raised their voices instead of growing silent?' Far from being demoralized, paralysed, and silent, Jason developed strong working links with industry and community groups, returned to school for academic courses related to his teaching, taught courses that allowed him to experiment with teaching strategies and develop links between courses, and participate in formal training programs in assessment and course implementation at the department, board and ministry level. As a result, there was an increasing acceptance of uncertainty in both content and assessment of student learning, followed by an acceptance of uncertainty in his own learning. This acceptance of uncertainty in his teaching is demonstrated in the progressive storyline from 2007-2010. As Barth (1990, p. 50) states so succinctly: 'When teachers stop growing, so do their students'. In considering the first part of the answer to the research question, we have focused on Jason. In developing the second part of the answer to the research question, we now need to consider the department in which Jason works, for it not just an administrative unit within his school; it is also the culture that supports his, and his colleagues', professional learning.

A Long-Term Culture of Learning

The analysis highlights the value of a culture of long-term professional learning that allows teachers to respond positively to uncertainties that are important to them. For Lord (1994), this movement involves teachers taking:

> *… opportunities to voice and share doubts and frustrations as well as successes and exemplars. They need to ask questions about their own teaching and the teaching of their colleagues' teaching. They need to recognise that these questions and how they and their colleagues go about raising them, addressing them, and on occasion even answering them constitute the major focus of professional [development] (p. 183).*

Accepting uncertainty in teaching relies on both personal and corporate qualities. Teachers need to possess the intellectual capacities and emotional temperament necessary for dealing with uncertainty: the capacity to frame problems, collect and analyse (at times contradictory) data, developing courses of action and establishing the criteria for assessing the quality of the resolution (Helsing, 2007). While teachers can develop these qualities individually, they are more likely to be developed in collaboration with other teachers (Henze et al., 2009).

Since 2000, Jason has worked in a collaborative department that has focused on inquiry as an overarching teaching philosophy (Jones et al., 2009). The culture of departmental learning is important, for teachers in a learning

culture are more likely to engage in specific professional learning for extended periods, and perceive themselves to be more certain in their abilities, than individualistic teachers (Henze et al., 2009). Jason, in his written descriptors of the storylines, specifically commented on the ongoing nature of his professional learning in assessment and the teaching of inquiry at the departmental level. This learning has not been limited to the theoretical realm: it has been theoretical, practical and attended to the emotional aspects of teaching (Zembylas, 2003). As Jason wrote, the culture of learning within the department has helped him '*develop as a person and as a teacher. I am a lot more comfortable now with my strengths and weaknesses and have a clear idea of how I can improve and where I want to go'*. Such a statement aligns with Rosenholtz (1989, pp. 111/114), who suggested that in collaborative teacher cultures uncertainty is accepted and 'there is … a codified base of professional knowledge which is ever-expanding because of new problems, fresh goals, and either serendipitous or calculated discoveries of alternative teaching practices.'

The need for a long-term culture of professional learning is highlighted by Jason' storyline for knowledge uncertainties, which only became a sustained progressive narrative from 2009. From first teaching the locally developed course in 2004, Jason did not express an acceptance of uncertainty in his teaching until 2009, when he was lead author on a book chapter for the National Science Teachers Association (Pilot et al., 2010). This proved cathartic for Jason as it asked him to objectively compare his work against the National Science Education Standards. Finding that his work did align with the third goal of the Standards engendered confidence in his progress as a teacher. Jason became sure of how much he knew in terms of content, about what he was learning from his pedagogical experiences, and the freedom to admit his uncertainties (Wallace & Louden, 2003). To reach that point took the best part of five years, reinforcing the idea that professional learning is a long-term proposition.

Final Comments and Further Research

In using the storyline methodology, and focusing on four aspects of teacher uncertainty, we have considered how one teacher has responded to uncertainty while introducing new secondary science courses since 2004. While the experience of Jason cannot be held to be representative of all science teachers, the consideration of storylines allows us to ponder and describe the relationships between teachers and uncertainty. A progressive understanding of content and assessment appeared to be foundational to Jason' increasing acceptance of uncertainty in his own learning. Understanding that change is gradual, continued professional learning appears to be underpinned by an acceptance of uncertainty in teaching and learning. The storyline for knowledge uncertainties supports the need for teachers to continue in cultures of professional learning that support them to the point when they are confident enough to admit, and accept, their uncertainties. These findings resonate with what is already known about effective professional learning.

Yager (2005) argues that aligning science teaching with inquiry focused reforms requires teachers to focus on questioning teaching and learning. This process 'emphasizes the use of questions that leads to learning and the identification of possible answers that could be tested as a means of collecting evidence that the explanations and ideas are valid' (p. 17). To question practice is to invite uncertainty, especially with teachers who are comfortable with the status quo. Jason' experience suggests that a science department that is committed to questioning practice may provide many of the supports that teachers need to pursue their questioning. Garet et al., (2001) set out the importance of structural and core features for professional learning opportunities, and all of them are evident from Jason' experience. Structural features include form, duration and active participation. In terms of form, the department provided a forum where Jason and his colleagues could discuss the teaching of inquiry and also draw on outside expertise as required (Pilot et al., 2010). In terms of duration and active participation, conversations about inquiry and questioning of practice have been part of the work of all the teachers in this department since 2000 (Melville et al., 2014). Core features include a content focus, active learning and coherence. The content focus of the departmental professional learning was the work on inquiry and assessment. The high level of engagement in the professional learning has been documented elsewhere (see Jones et al., 2009; Melville et al., 2014), while the consistent focus on inquiry has given the work a high level of coherence.

This article has focussed on one teacher in one department. Our future work will involve working with more teachers in the department in order to investigate the relationship between their uncertainties and the professional learning culture with the department. One aspect of this work will be to trial the use of the storyline methodology as a strategy to identify those key moments when departmental professional learning is congruent with the professional learning of individual teachers. Primary questions that we would like to pursue include the efficacy of various forms of professional learning on the aspects of uncertainty, the links between professional learning, teacher emotions and uncertainty and the importance of teacher leadership in managing the inevitable tensions between the need for some certainty of practice and an ongoing commitment to curiosity about the teaching and learning of science.

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Appendix A: Example of Data Collection Material

STORYLINES

Think back over the period that you have taught Environmental Science and recall any 'turning points' in your professional or personal life that had a positive or negative impact on your teaching and learning.

On the graph below, sketch a line to show how effective you're teaching and learning has been at various points in your career. Start at the present (right) and work towards the past (left).

Recall the times that you felt particularly good about your teaching and learning and mark these first. Recall any low points in how effective you felt you were as a teacher and learner and mark these next.

Now join these points to plot how you feel about your teaching and learning of Environmental Science.

Assessment of student learning

5+
4
3
2
1-

Years of teaching _____

Explain the features of the graph.

1. The end of my graph is different from the start because_____
_____
_____

2. I would describe the shape of my graph as _____ because_____
_____
_____

3. My graph is mainly influenced by professional / personal factors because_____
_____
_____

1. Please be as explicit as possible in describing the events or incidents that have influenced the shape of your graph and how these have influenced your teaching and learning of Environmental Science.

Feature of the graph	Explanation
Feature 1.	
Feature 2.	
Feature 3.	
Feature 4.	
Feature 5.	