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Subject, Relationships and Identity: The Role of a Science Department in the Professional Learning of a Non-University Science Educated Teacher

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Abstract This article employs the concept of community to interpret teacher professional learning in the context of the school science department. Using the transcripts of staff meetings, lesson observations and the conversations of school administrators, the departmental community is examined in terms of three metaphors: subject, relationships and identity. In an era of a rapidly changing science teacher demographic, the article highlights potential differences in professional learning opportunities between teachers who are university educated in science and those without a science background. The research raises three issues for the science education community to address.

Key words science teacher community · professional learning · subject department · relationships · identity

Introduction

In Australia, as in many other OECD countries, the profession of science teaching is experiencing a state of rapid change (Organisation for Economic Co-operation and Development, 2003). In 1999, for example, four out of five Australian secondary science and mathematics teachers graduated with a science based degree and a one-year education qualification (Committee for the Review of Teaching and Teacher Education, 2003). In 2005, Harris, Jensz and Baldwin reported that 72% of those teaching secondary science held a science degree, while 21% held education degrees. The traditional dominance of initially science educated teachers reflects the "academic orientation" of science teacher education, an orientation that favours a perception of the "teacher's role as intellectual leader, scholar, subject matter specialist... [and stresses] the importance of teachers' academic preparation" (Feiman-Nemser, 1990, p. 22).

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This academic orientation is clearly supported by the Australian Science Teachers' Association (ASTA), the peak body representing the nation's science teachers. In its submission to the Australian federal government's discussion paper, *Strategies to Attract and Retain Teachers of Science, Technology and Mathematics*, ASTA (2002) argued that "teacher knowledge and expertise is paramount. That knowledge is subject specific, at least to some degree. There is an increasing assumption that a good teacher can teach anything and everything... [an assumption] that needs to be challenged" (pp. 2–3). ASTA (2002) further submitted that secondary science teachers should have at least a "second year tertiary qualification in the subject being taught" (p. 2). This academic orientation to teacher preparation is also supported by Australian secondary school heads of science who overwhelmingly prefer teachers with a science background over those with an education background, the predominant reasoning being that a science specialisation provided a greater depth of content knowledge than a general education degree (Harris, Jensz, & Baldwin, 2005).

The traditional academic orientation to teacher preparation contrasts with a different kind of emerging reality about science teacher supply and demand. Australia, along with much of the English-speaking world, faces an increasing shortage of secondary science teachers; in particular, teachers with a university science qualification (Goodrum, Hackling, & Rennie, 2001). While the full extent of this shortage is unclear, the number of non-science educated teachers who teach science may be "masked by the numbers of teachers without adequate specialist backgrounds teaching in these areas – that is, the numbers of teachers teaching 'out of field' hides true shortages" (Committee for the Review of Teaching and Teacher Education, 2003, p. 8). Moreover, the number of non-science educated teachers who are teaching science is increasing, a trend unlikely to alter in the near future (Goodrum et al., 2001; Harris et al., 2005).

In response to this new reality, education authorities are looking to mature age entrants as a valuable source of supply in the short term. The pathways required for these teacher candidates need to be, of necessity, flexible as they are "designed around career change professionals with industry or vocational experience" (Committee for the Review of Teaching and Teacher Education, 2003, p. 127). A significant difference between the qualifications of the majority of science teachers and the qualifications acquired through these flexible pathways is the formal recognition of "prior experiential and non-formal learning rather than Year 12 results alone as a basis for entry to courses has enabled people with a varied employment and other experience to enrol in university teacher education programs" (Committee for the Review of Teaching and Teacher Education, 2003, p. 128).

At the school level, science staff and leaders steeped in the academic orientation are finding themselves dealing with a new mix of faculty, including increasing numbers of mature age, beginning teachers without the usual science background. In this context, school based teacher professional development, focussing on promoting teacher learning, has become an urgent and ongoing priority. According to Goodrum and his colleagues (2001), "professional development must involve all of the science staff within the school... professional learning must be school based and directly related to the classroom" (pp. 174–175). This statement reflects the growing realisation that teacher professional learning is "situated, specific and practical in character" (McCullough, Helsby, & Knight, 2000, p. 90) as well as social and distributed (Wallace, 2003). The report by Committee for the Review of Teaching and Teacher Education (2003), *Australia's Teachers: Australia's Future*, emphasises that the professional learning of teachers,

especially beginning teachers, is an activity that must be carefully structured and properly resourced at the school level, requiring pro-active and ongoing leadership.

It is against this backdrop – an increasing shortage of science educated teachers, a changing mix of backgrounds of school science staff, and new challenges for school-based teacher learning – that this study is conducted. In doing so, we focus directly on the school, and particularly the science department, as the site for teacher professional learning. Our research question is: What is the role of a school science teacher community in the professional learning of a non-university science educated teacher? In addressing this question we employ three metaphors of subject, relationships and identity to analyse a narrative account of the communal practices of one high school science department. In doing so we highlight several issues related to teacher learning in school based communities comprised of a mix of university science and non-university science educated teachers.

Methodology and Methods

In this study, we employ a narrative methodology to examine professional learning within a science teaching community. Narrative "is a way of characterising the phenomena of human experience" (Connelly & Clandinin, 1999, p. 2). For Polkinghorne (1995, p. 5) narrative descriptions "exhibit human activity as purposeful engagement with the world. Narrative is the type of discourse composition that draws together diverse events, happenings and actions of human lives into thematically unified goal-directed purposes." According to Czarniawska (2004), the rise of narrative in the humanities is due to a belief that narrative is at the centre of social life. Narrative offers a powerful means of representing, and hence, understanding teachers' worlds as well as our own. In other words, narrative "gives us explanatory knowledge of why a person acted as he or she did; it makes another's actions, as well as our own understandable" (Polkinghorne, 1995, p. 11).

This article, developed out of a three year long study into the professional learning of a school based community of science teachers, focuses on the experiences of one non-university science educated teacher, named Daniel (pseudonyms are used for all participants), who entered the community in the second year of the study. The participants in our research are the 10 members of a science department in an Australian co-educational secondary (Years 7–12) school. Prior to the commencement of the study, the participants were consulted about their potential involvement and written approval was obtained from the teachers and the school principal. When Daniel joined the staff, he was also consulted about the purposes of the study, and agreed to participate on the same basis as the other science teachers. In addition, Daniel provided written permission for the use of notes made as part of the mentoring process in the first year of his career.

Data for the study were principally of two kinds, transcripts of staff meetings and field notes of other activities. Transcripts were compiled from tape recordings of the hour-long monthly science department staff meetings. These meetings, led by the department head, were convened to discuss matters relating to the organisation and conduct of the science department, including curriculum and assessment, organising equipment, student behaviour, professional development and the induction of new teachers. The field notes were written during and after observations of several lessons taught by Daniel and informal discussions with the school's head of science about matters arising from the staff meetings and the lessons observed. The data referred to in this article were collected over a 10-week period at the beginning of the 2003 Australian school year.

The analysis of these data was based on the narrative analysis and analysis of narratives strategies described by Polkinghorne (1995). Under the first strategy, narrative analysis, the events and actions described within the data were synthesised, through a plot, into a story or vignette. The plot for the vignette was the professional learning that occurred within the science department community, focussing on the difficulties faced by Daniel and the department's response to those difficulties. In the second strategy, analysis of narrative, the vignette was analysed using paradigmatic processes in order to describe themes across the data.

This kind of analysis is consistent with Czarniawska's (2004) ideas about the use of stories in educational research. Czarniawska (2004) proposes a three step process, including constructing characters, attributing functions to events and actions, and finding an interpretative theme. The process is non-linear, with an interpretative theme becoming clear, and then dominant, through the construction of characters and the attributing of functions. The emergence of a dominant theme is cause for the researcher to re-examine the text and 'tighten up' the story (Czarniawska, 2004, p. 126). This close-knit relationship between the story and the data is described by Bruner (1986):

> It is not that we initially have a body of data, the facts, and we then must construct a story or theory to account for them... instead... the narrative structures we construct are not secondary narratives about data but primary narratives that establish what is to count as data (p. 142–143).

The analysis described herein draws on the three metaphors of subject, relationships and identity obtained from the literature on communities to raise several dominant issues related to teacher learning in school communities.

Three Metaphors: Subject, Relationships, Identity

The three metaphors – subject, relationships and identity – provide an understanding of community that forms the foundation for this research. The metaphors were developed principally from the work of Siskin (1994) on school academic departments, Van Maanen and Barley (1984) on occupational communities, and Wenger (1998) on communities of practice. Our efforts to understand the notion of community are motivated by a desire to understand how teacher learning proceeds in such communities and how to "create workplace environments that respect, support and nourish the efforts of those involved" (Mayer-Smith, 2003, p. 96).

Subject

The boundaries of a community are set by the members of that community. Van Maanen and Barley (1984, p. 295), cite Gusfield's (1975) idea that a "consciousness of mind" is the foundation of a community. For secondary school teachers this means that those educated in a discipline can describe themselves in terms of "what they teach" (Siskin, 1994, p. 155) because they share, along with similarly educated teachers, a set of values, norms and perspectives based around their subject discipline. Siskin (1994) found that a teacher's academic discipline is fundamental to the individual teacher's, often subconscious, "choice of words, the structure of their arguments, or the goals that they hold" (Siskin, 1994, p. 153). The subject has a very real role in influencing how teachers "construct their norms of community, their standards of practice – their professional identity and behaviour"

(Siskin, 1994, p. 154). Thus, a community is made up of people who accept these norms and standards as their own, and are accepted by the other members of the community as operating according to these norms and standards. To teach science proficiently, and to be accepted into the science teaching community, therefore, it would seem to be important to be educated in both pedagogy and the discipline. For the purpose of this article, teachers are said to be non-science educated if they do not have a university degree with a major in biology, physics, chemistry or geology.

Hence, science educated members of science departments set the boundaries of their science teaching community in the same way that mathematics teachers establish the boundaries for their mathematics teaching community. There are, of necessity, many overlaps between the communities found within schools, as many teachers teach more than one subject. Within these boundaries, the members of communities share "occupational practices, values, vocabularies and identities" and possess the "proper skills, knowledge and orientations necessary to make decisions as to how the work is to be performed and evaluated" (Van Maanen & Barley, 1984, p. 308). Many commentators emphasise the importance of teacher development in this context of teaching and learning specific content knowledge (Ingvarson, 2002; Shulman, 1986).

Relationships

The importance of relationships within departments is not to be underestimated. Departments, according to Siskin (1994, p. 5) are "primary site[s] for social interaction," while social relationships are considered one of the attributes of an occupational community (Van Maanen & Barley, 1984). According to Harris, Bennett, and Preedy (1997), one of the crucial features of an effective department is a sense of collegiality. Gulledge (1998, p. 12) argues that the development of relationships is a "very valuable potential benefit" in the development of a middle school social science curriculum. Scribner (1998, p. 33) writes, "teachers working in the same context as their peers are much more likely to address critical teacher issues, and peers are much more willing to listen." If teachers are not given the opportunity to tell their stories, then their colleagues cannot draw upon the professional knowledge that they possess. The result is that knowledge is "locked in the heads of individual teachers" (Hargreaves, 2000, p. 225).

It has been argued that the whole school, with its inherent complexities, especially in secondary schools, possesses few of the "requisite conditions" for becoming a "socially cohesive community" (Huberman, 1990, p. 32). The size of secondary schools tends to work against collegial decision-making, whereas subunits such as subject departments are more conducive to strong collegial relations (Bush, 1997). The conditions necessary for the development of a professional learning community in a high school are, according to Siskin (1994), more likely to be found within academic departments, because the individuals involved develop "frequent and close relationships," and "through these connections shape and reshape their own teaching – and bring it into line with local practice" (p. 95). It is through the agency of relationships that teachers negotiate the meanings that they bring to their work and, consequently, their own sense of identity.

Identity

Members of a community derive their identities from their roles within the community, and their participation in the negotiation of the meaning of the community (Van Maanen & Barley, 1984; Wenger, 1998). Identity is contextually tied, but for members of communities

they are crucial, being "central to one's self-image" (Van Maanen & Barley, 1984, p. 299). The teachers in Siskin's (1994) study found that their professional identity lay not in teaching, "but in the teaching of their subject," as the "subject plays an active role in influencing teachers' actions and attitudes" (p. 153). If teachers describe themselves in terms of what they teach, then it would be entirely reasonable to assume that what they teach is something that matters deeply to them. Therefore, professional learning is generative learning that allows a person to expand her or his ability to create. Professional learning only occurs "when people are striving to accomplish something that matters deeply to them" (Senge, 1990, p. 206).

Wenger (1998, pp. 192–197) discusses identification in terms of modes of belonging. This framework, which is a process of both participation and reification, can arise through engagement, imagination and alignment. Identification can occur through the engagement of the individual in the practice of the community. Through such an engagement, individuals can identify with both their work and with their colleagues. This identification that arises through practice can be demonstrated in three ways (Van Maanen & Barley, 1984, p. 300–303). Firstly, the individual can demonstrate the use of an occupation's "codes" such as vocabulary. Secondly, the individual can possess a skill that is considered "esoteric, scarce, socially valued or unique" (p. 301). Thirdly, the individual can claim a responsibility for the work of others. Identification can also occur through imagination, which allows for the individual to "try things, take liberties, reflect, assume the existence of relations of mutuality and position ourselves in a completely different context" (Wenger, 1998, p. 194). Identification can also occur when the identity of an enterprise becomes part of the identity of its members. In the professions, this means that individuals will make use of a "collective perspective in every day matters" (Van Maanen & Barley, 1984, p. 303). These modes of belonging, which apply only to the individual, are not the only forms of identification.

A sense of identity is not restricted to individual teachers. Subjects also shape the identities of their departments (Wildy & Wallace, 2004). Subjects give "departments their very reason for being" (Siskin, 1994, p. 153). Effective subject departments, moreover, are characterised by "a clear and shared sense of vision ... [which] embrace[s] the nature of the subject and how it should be organised for teaching purposes" (Harris, Bennett, & Preedy, 1997, p. 151). Thus departments can be seen as communities as well as subunits of the school organisation. Importantly, Wenger (1998, p. 74) in his work on communities of practice, makes the point that membership of a community is not a synonym for "belonging to an organisation, or having personal relations with some people."

Taken together, the metaphors of subject, relationships, and identity, provide a framework for interrogating the data using the strategy of analysis of narrative (Polkinghorne, 1995). In this research we focus on Daniel, a beginning mature age teacher without a university background in the sciences. The following vignette describes the first term of Daniel's career and his attempts to teach science, highlighting the difficulties that he encountered when trying to participate in the negotiation of the work and the meaning making of the community of the science department.

Narrative Analysis

A Struggle to Identify

The teachers returned from the long summer break in late January, a week before the students arrived. Apart from the obligatory whole-school staff meetings, there was also a

picnic outing to the local lake to enable the teachers to catch up socially with their colleagues. In addition, each department was allocated time during the week to arrange meetings for its own members. The first science department meeting for the year also provided an opportunity for the science faculty to formally meet Daniel, the newest member of the department.

Daniel joined the school teaching staff as both a mathematics and science teacher. He qualified in engineering at a technical college after leaving school. Prior to teaching, he had worked for 25 years in the power distribution division of a large manufacturing plant. This plant had been progressively downsized and restructured over the previous decade. Daniel resigned from the company and enrolled at university to complete a bachelor's degree in adult and vocational education to qualify as a teacher. This was his first secondary teaching position. His technical background and degree in adult and vocational education allowed him to obtain a provisional registration to teach from the state's teacher registration authority. To gain full registration as a teacher, Daniel was required to complete a series of secondary education units at university.

Daniel joined a department with a solid reputation within both the school community and the wider science education community. Zoe and Stuart, both of whom served as subject moderators for the state's secondary assessment board, were also involved in writing the new state science courses of study. Zoe helped develop the life science and matriculation level biology courses, and Stuart assisted with the writing of the general science course. Another member of the department, Maddie, was closely involved with the setting of the statewide examination for the matriculation level physical science course.

With the exception of Daniel and the youngest teacher, Louise, the other eight teachers in the department were university educated in both a science discipline and education. Louise's background was in physical education; her degree included some physiology and anatomy. All of the university science-educated teachers, with the exceptions of Rob, Jenny and Stuart, had been members of the science department for at least 15 years. Rob was a member for four years, Jenny for six years and Stuart joined the group at the beginning of 2002, although all three had taught science for at least a decade. This was a department group well educated in science and with a wide collective experience in science education. Given the low staff turnover that tended to characterise the entire school, it was also a department that had a considerable number of years to negotiate its sense of meaning and identity.

Included on the agenda for the first departmental staff meeting of the year was the dissemination of course information and update of staff members on new resources. Information booklets outlining the content of courses, assessment criteria and attendance registers had been distributed to teachers earlier in the week. Stuart, in his second year at the school, but with 15 years of teaching experience, was appointed by the school to mentor Daniel and prior to the meeting the two teachers had met to discuss Daniel's Year 8 science course. From the start Daniel did not exude a great level of confidence and this became more evident during the first staff meeting.

"Any comments," asked Rob, the head of department, as the discussion turned to the Year 8 course outline. The question was directed to the other teachers of Year 8 for that year, Stuart, Daniel and Jenny. Rob was also taking a Year 8 class.

"No surprises," replied Stuart.

Daniel's first question surprised Stuart, as the two of them had looked over the course outline together that morning. "Is there a book that goes with Year 8?" Daniel asked.

"No, we don't have text books," replied Rob, who proceeded to explain that the usual practice was to select and use relevant material from any text. At this point Stuart realised

the enormity of the task that awaited him in mentoring Daniel. The 'usual practice' that Rob had just referred to might work well for those with a deep understanding of the subject that they were to teach, but would probably not be a great deal of assistance to someone lacking that understanding. Even as this realisation was dawning on Stuart, the conversation had moved on, further highlighting the weakness of Daniel's teaching knowledge.

"I bought a Year 7 book, a whole lot of them," Daniel said, "I had the idea of photocopying that and testing them on... on...on..."

"Apparatus," offered a somewhat bemused Jenny.

"The names of the bits and pieces and going over safety again," continued Daniel. "Given that I haven't done any science teaching before, I thought I should know what they can do. That's what I'm here to find out, I haven't looked at anything, I haven't seen the assessment criteria or anything yet."

Rob, knowing that Stuart had spent time with Daniel that morning, pointed out where the materials could be found. "The assessment criteria would be in with the notes with this," he said, referring to the booklet. Daniel did not respond.

The Year 8 teachers moved on to discuss the order in which they would teach the topics. The idea was to avoid too many classes seeking to use the same equipment concurrently. Daniel would start the year with the unit of work on chemistry, which included acid-base, acid-metal and acid-carbonate reactions, word equations, and corrosion and its prevention. Stuart, in his capacity as mentor, offered to work in tandem with Daniel.

"It might be worth, Daniel, if we work together."

"Yeah, I'd be happy with that. My weak area is chemistry," replied Daniel.

"I'll give you a hand with that, I've got some resources," offered Jenny, who was an experienced chemistry teacher.

"Meet the chemistry guru," said Stuart, showing his respect for Jenny's abilities.

Daniel's response did not inspire confidence. "Chemical formulae and that used to scare me," he said.

The arrival of the students in the following week gave Daniel the opportunity to observe Stuart and Rob at work in their classrooms, before he took his first science class. He made notes on how the teachers organised and managed their classes. The majority of his notes, however, referred to the content that was being taught. In Stuart's class, Daniel made notes about revising the properties of acids and bases and their uses. It turned out that these notes were to form the basis for Daniel's lesson plans.

Rob, as head of department, and Stuart, as the school appointed mentor, offered to sit in on Daniel's science classes, to provide feedback on his progress and ideas for future lessons. The head of mathematics also observed Daniel's mathematics classes. These early observations were designed to offer assistance, but, for Rob and Stuart, they also highlighted some concerns about Daniel's depth of subject knowledge.

Daniel's subject knowledge was further exposed during the March science staff meeting. The school administration had previously requested that departments consider the potential dates and costs for excursions during the year. During the meeting, staff members responded to the request by suggesting various astronomy, geology and biology excursions, based on outings in previous years. Looking for an opportunity to make a contribution, Daniel proposed a visit to the school by an organisation promoting creation science. He asked:

"Have you heard about the creation science van that travels around schools, to give a scientific presentation of creation?"

"Scientific presentation would be one definition of it," was Stuart's curt response.

"One description of it," was Jack's sarcastic contribution to the discussion.

Stuart continued, "The creation science bus is fairly dogmatic. If you disagree with..."

At this point Daniel was back-pedalling rapidly from his initial question, "I've never seen one, I just heard about it." The damage had already been done.

Stuart finished his sentence. "It's not terribly scientific, if you don't go along with them, then, you're wrong. There is no space for disagreement with those people." The meeting moved quickly onto the next agenda item.

There was also, apparently, no room for disagreement within this department as to what constituted science, or science education. As a result, Daniel's attempted contribution to the department was abruptly truncated.

Over the following seven weeks, Stuart and Rob continued to support Daniel's teaching. Both occasionally taught Daniel's class in order to model classroom management, helped with the development of lesson plans, and discussed available resources and experiments. As the weeks went by, however, there were growing concerns about Daniel's subject matter knowledge, the quality of his teaching and the effect on student learning. Rob also fielded complaints raised by some of Daniel's students about the poor classroom climate. Most of the problems, according to Rob, could be attributed Daniel's poor subject knowledge. In Rob's words, he "doesn't understand the core concepts well enough to teach them. He goes off with explanations that are not correct, and the kid's eyes glaze over. They know he doesn't know."

After observing Daniel's teaching for a few weeks, Rob felt that he needed to act on his perception of Daniel's failure to develop as a science teacher. Within a week of Rob taking his concerns to the school's administration, another science teacher, Jill, was assigned to Daniel's class. Jill was primarily part time, and the increased teaching load brought her up to nearly a full time teaching load. Daniel was told by the school's administration to use the extra time allocation to concentrate on his mathematics classes. For Rob's part, he felt that he needed to act decisively to protect the status of the subject from what he perceived as an unacceptable standard of teaching.

This vignette highlights the difficulties faced by the members of one science department in trying to accommodate a new teacher with limited science content knowledge and pedagogical content knowledge. Three incidents are critical in our analysis of the vignette. The first critical incident concerns the nature of the support structures that the school and department put in place when Daniel joined the school to commence his teaching career. Stuart was appointed by the school as a mentor, with a responsibility for assisting Daniel settle into the routines and expectations of the school. In addition to this school level assistance, individual science teachers offered Daniel both resources and assistance in his self-identified area of weakness, chemistry. Teachers also offered Daniel the opportunity to observe their classes and take notes on their methods of organising and managing their classes.

The second critical incident involves the discussion surrounding Daniel's 'proposal' for a visit by the creation science van. Rather than promoting a conversation into the nature of science and science education in schools, Daniel's suggestion provoked a sharp sarcastic response by his colleagues, and the proposal was comprehensively rejected. As this incident unfolded, Daniel was given little assistance to help him to understand what his science department colleagues actually meant by science and science education. Daniel remained, unintentionally but very firmly, on the periphery of the department.

The third critical incident involves the final 'resolution' of the 'problem', when Daniel's science class was reassigned to another teacher. It seems that, notwithstanding the genuine efforts to support Daniel in his teaching, Rob saw no other recourse but to report the

situation to the school administration. This move ultimately resulted in Daniel losing his science class.

These three critical incidents – the initial, well intentioned attempts to assist Daniel's induction into the community, the sharply worded critique of Daniel's ill-informed suggestion during a staff meeting, and the ultimate removal of Daniel from the community – illustrate two areas of difficulty. The science department experienced difficulties as it attempted to accommodate and assist a teacher with an alternative background in science. The new teacher faced difficulties in terms of content knowledge and classroom pedagogy. Our analysis of these difficulties is that they are related to three notions of community – subject, relationships and identity.

Analysis of Narrative

Prologue

In matters of the subject, relationships and identity, science teacher communities operate as a powerful context for teacher professional learning. To be a participating member of the community requires the capacity to negotiate the meanings and reifications that a community brings to its practice (Wenger, 1998). The capacity to negotiate meanings within the science department is directly related to the possession of subject knowledge and the relationships necessary to identify with, and be identified by, the community itself. All three precursors of participation, subject knowledge, relationships and identity, are essential in order to access opportunities for professional learning that subject departments offer.

This story of Daniel's short-lived secondary science teaching experience, therefore, raises two issues for teacher professional learning within science departments. First, there is the issue of access by individual teachers to the opportunities for professional learning within that community. To be a participating member of the community is to have the opportunity to develop both the individual and corporate practices of the community. Through participation in the negotiation of meaning, teachers have the capacity to access professional learning that is context specific, collaborative and visionary. Participation in the community allows teachers to develop deep professional relationships with their colleagues, relationships that permit experimentation in practice. The second issue is the danger that science teacher communities may face in assuming that non-science educated teachers can fully participate in the community, raising further questions as to the efficacy of moves towards school or departmentally based professional learning. For a non-science educated teacher to remain on the periphery of a community, unable to participate fully in the community's negotiation of meanings, is to limit the available professional learning opportunities.

Our analysis of the narrative highlights the importance of science teachers being able to negotiate the meanings of science education within their school, and the importance of the subject, relationships and identity in being able to access these opportunities for professional learning. This ongoing process of negotiation constantly shapes the membership boundaries of the science teacher community. Negotiation of meaning involves two interdependent processes – participation and reification (Wenger, 1998).

Participation

The first of the processes, participation, involves the active involvement of the members of a community in a "social enterprise" (Wenger, 1998, p. 55). Participation is a "complex

process that combines doing, talking, thinking, feeling and belonging. It involves our whole person, including our bodies, minds, emotions and social relations" (p. 56). According to Wenger (1998), participation also has a strong link to the relationships and identities developed by the members of a community. There are implications in the notion of participation for this study. Within this particular science department, given the prior experiences of the members and their time together as colleagues, these relationships and identities appear to be well developed. The narrative highlights some of the barriers that these relationships and identities represented for Daniel, the new arrival, in attempting to participate in this community and the professional learning opportunities that it offered.

Daniel struggled with the content and pedagogy of the Year 8 science curriculum. He admitted to this struggle early in the school year. For example:

> Given that I haven't done any science teaching before, I thought I should know what they can do. That's what I'm here to find out ...
>
> Yeah, I'd be happy with that. My weak area is chemistry.

In response to Daniel's struggle, his colleagues offered to work together or to share resources:

> It might be worth, Daniel, if we work together.
>
> I'll give you a hand with that, I've got some resources in that, offered Jenny, who was an experienced chemistry teacher.

However genuine, these responses do not appear to have provided an opportunity for the deep participation with the department, the "doing, talking, thinking, feeling and belonging" that Wenger (1998, p. 56) discusses. There was little conversation with Daniel about the nature of the subject knowledge to be taught, or the most appropriate form of instruction for that content. During the staff meetings, Daniel was not asked explicitly what assistance would be of most value to him, nor engaged in a conversation as to the meaning(s) of science education. Our analysis of the data indicates that the depth of the relationships and identities that the members of the department had developed over a period of years acted as an effective barrier to participation. By failing to recognise the need for full participation, the department limited access to new professional learning opportunities, for themselves as well as for Daniel. As a new teacher, Daniel was effectively on the periphery of the community, unable to participate fully in the community's negotiation of meaning, as this excerpt from the narrative demonstrates:

> In Stuart's class, Daniel made notes about revising the properties of acids and bases and their uses. It turned out that these notes were to form the basis for Daniel's lesson plans.

Daniel's experience illustrates that teachers who do not initially possess the words, arguments and goals required to negotiate a sense of meaning in the subject department are restricted in their capacity of participate in the discourse and reflections of its members. This is not to say that an individual's level of participation within a community cannot grow, but the process would appear to be difficult.

Reification

The second of Wenger's (1998) interdependent processes of negotiation is reification. Reification, or the making of the abstract into a concrete form, contributes to negotiation

by creating "points of focus" (p. 58) around which negotiations can develop. In this study, the subject acts as a "point of focus" as teachers' academic disciplines are fundamental to their often subconscious, "choice of words, the structure of their arguments, or the goals that they hold" (Siskin, 1994, p. 153). Our data suggest that this science department, comprised largely of teachers with an academic orientation to their own education, mistakenly assumed that Daniel, the incoming, non-science educated teacher would automatically understand, or accept, the reified beliefs and practices of the department.

The evidence from the narrative is that this department reified a strong view of the nature of science. This view was not adequately articulated to Daniel as illustrated, for example, in the rather strongly worded response to the proposal about the creation science van:

> Have you heard about the creation science van that travels around schools, to give a scientific presentation of creation?
>
> Scientific presentation would be one definition of it, was Stuart's curt response.
>
> One description of it, was Jack's sarcastic contribution to the discussion.
>
> Stuart continued, The creation science bus is fairly dogmatic. If you disagree with....
>
> At this point Daniel was back-pedalling rapidly from his initial question, "I've never seen one, I just heard about it." The damage had already been done.
>
> Stuart finished his sentence. "It's not terribly scientific, if you don't go along with them, then, you're wrong. There is no space for disagreement with those people." The meeting moved on to the next agenda item.

The effect of such a response may have been ameliorated if Daniel's colleagues had also explicitly informed him about what the department considered to be 'science'. Given his background, it is likely that Daniel had a limited understanding of the nature of science, or the debates surrounding creation science. The members of the department failed to use this opportunity to share with Daniel what they, as a community, meant by 'science'. Unintended or not, there was little space for disagreement with the department's reification.

This study points to the importance of science departments being aware of both participation and reification in their dealings with new, non-science educated teachers. To give precedence to participation over reification, and *vice versa*, is to risk endangering the entire enterprise. As Wenger (1998, p. 65) states:

> If participation prevails – if most of what matters is left unreified – then there may not be enough material to anchor the specificities of coordination and to uncover diverging assumptions. If reification prevails – if everything is reified, but with little opportunity for shared experience and interactive negotiation – then there may not be enough overlap in participation to recover a coordinated, relevant or generative meaning.

In this study, reification prevailed. Members were, with one exception, university educated in both science and education, and several had taught together for many years. For these reasons, the negotiated understandings of science education were so tightly held that members failed to recognise that Daniel was excluded from an opportunity for "shared experience and interactive negotiation" (Wenger, 1998, p. 65). We suggest that science departments need to be aware of the risks involved in limiting these experiences for new teachers, as well as the need for continual (re)negotiation.

Discussion

The development of a context in which a non-university science educated teacher such as Daniel could access an opportunity to participate would appear to lie in the development of relationships that recognise the needs of all individuals to be able to engage in reflection and discourse around the meanings of the community. Effective science departments, according to Harris et al. (1997), develop robust relationships within themselves that allow for the development of contextually based solutions. The methods deployed in developing these relationships centre on taking sufficient time to constantly interchange "professional information at a formal and informal level" (Harris et al., 1997, p. 151). The result is that these departments, through their recognition of the importance of participation and reification in the negotiation of meanings, open new possibilities for learning for all members.

These negotiations are vital if teachers are to improve their practice. Strong professional cultures require teachers to "examine assumptions, focus their collective experience on solutions, and support efforts on the part of everyone to grow" and develop "skills and dispositions towards inquiry, norms that recognise and support failure, and ideas with which to experiment" (Loucks-Horsley, Hewson, Love, & Stiles, 1998, p. 195–196). Underpinning these efforts at improving practice is the need for teachers to be involved in "challenging discourse" about their own practice, and the practice of others, with the aim of improving learning for both teachers and students (Loucks-Horsley et al., 1998). Such discourse should involve teachers in "applying standards of effectiveness to their and others' practices; in gathering, analysing and explaining the evidence for their convictions, and in communicating criticisms to each other both positive and negative" (Loucks-Horsley et al., 1998, p. 198).

Daniel's lack of university education in the sciences made it difficult for him to access the professional learning opportunities presented by the science community. This difficulty of access was compound by the science department's lack of an appropriate support mechanism for encouraging Daniel's participation in the negotiation and reification of the meanings and practices of science teaching within the school, and the development of his identity as a teacher of science.

Conclusion

It is difficult to disagree with the premise underlying the proposition that "professional learning must be school based and directly related to the classroom" (Goodrum et al., 2001, pp. 175). However, our research indicates that, for non-university science educated teachers in particular, participation in school based learning cannot be assumed. We conclude that, for these teachers, school based professional learning is a tricky business involving a complex interplay of issues related to subject matter, relationships and identity.

The first issue concerns the important role of subject knowledge in restricting (or facilitating) access to school or department based professional learning. As Shulman (1986) reminded us, subject matter knowledge is an often overlooked and, consequently, taken for granted teacher attribute. Subject specialist teachers shape their attitudes, values, identities and practices around their subject. Without a deep understanding of the subject, non-science educated teachers may struggle to participate in the negotiations regarding the meanings of these attitudes, values, identities and practices for science education. These negotiations are of increasing importance, given contemporary shifts in education policy and practice. As the focus of science education shifts towards science as inquiry, for example, a deep understanding of the subject content becomes crucial to the teaching and learning of the

subject (Loewenberg Ball & Mosenthal, 1990). If the practices of the department are the experience of these meanings, then those practices may be relatively inaccessible to the non-science educated teacher. This issue of inaccessibility has implications for both the short term quality of science teaching and the longer term reform of science teaching. Consequently, in an era of declining numbers of science educated teachers, it is important for the science education community as a whole to address the issue of how to enhance accessibility to professional learning for all.

The second issue concerns how limited capacity to engage in the negotiation of the department's work may also diminish a teacher's opportunities to develop the robust professional relationships needed for professional learning. Teacher learning involves both cognitive processes and learning opportunities. Learning opportunities include both the context of the learning, in this instance the science department, and the social interactions within that context (Wenger, 1998). As a learning context, the subject department offers opportunities to learn from the experiences of others, to allow others to learn from one's own experiences and to critique one's own practice. That context relies heavily on the quality of the relationships in the department. It is important for department members to be mindful of the conditions and opportunities necessary for teacher learning, particularly with respect to the learning needs of non-science educated teachers.

Finally, we consider the issue of how schools and departments can assist the non-science educated teacher in the long term task of developing an identity as a teacher of science. Identity is a paradox for the beginning teacher because "one needs an identity of participation in order to learn, yet needs to learn in order to acquire an identity of participation" (Wenger, 1998, p. 277). Building identity, therefore, is a slow and respectful process, proceeding through a gradual extension of "horizons of understanding" (Wallace & Louden, 2000, p. 24) rather than through sudden leaps of insight. It follows that building identity should involve the teacher in a mix of learning settings (principally the classroom and the school, but also out-of-school), discourse communities (classroom, department, school, profession, system) and foci (theory, practice, tools). In short, the department and the school should see identity building as a long term rather than a quick fix strategy, providing rich and multiple opportunities for new teachers to build their confidence, capacity and sense of community over time.

We suggest that these three issues – about the critical role of subject matter knowledge, about the importance of negotiation and relationships in communities, and about identity building – lie at the heart of attempts to induct non-science educated teachers into the profession. In this era of a rapidly changing science teacher demographic, Daniel's experience helps us understand the practical difficulties faced by non-science educated teachers and their science department colleagues as they confront these issues. We also hope that we can learn from Daniel's experience about positive ways of building learning communities in schools, thereby improving the standard of science teaching and learning.

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