CHAPTER 1

COUNTRIES NOT OFTEN HEARD FROM

> I was interested in other countries not often heard from.
>
> — Studs Terkel, *Working*

I have argued elsewhere (Emerson, 2012) that scientists are, to a large extent, a lost or forgotten "tribe"[1] of academic writers—that they are, in Terkel's words (1997), a country "not often heard from." This is, of course, something of an exaggeration. Researchers from the humanities may watch scientists from a distance through the body of literature in the field of the rhetoric of science, which examines their cultural artefacts, that is, their textual products (Montgomery, 1996). Sometimes we get a little closer. Like early anthropologists who visit the tribal village, we might get as far as the lab to observe and document their textual practices and the social and cultural contexts in which these practices take place (Bazerman 1988, 1998; Doody, 2015; Graves, 2005).

But we know little of how scientists think as writers—about their beliefs, attitudes and experiences of writing—even though learning to adopt the attitudes and beliefs of their seniors will be essential to our science students in the future as they develop both their professional identity and their fluency as disciplinary writers (Beaufort, 2007; Dall'Alba & Sandberg, 2006; Gee, 2005; Harding & Hare, 2000; Poe et al., 2010). Learning to write as a scientist involves far more than imitating behaviour; for example, as many authors have shown (Alexander 2011a, 2011b; Bereiter & Scardamalia, 1993; Blakeslee, 1997; Brown et al., 2005; Dall'Alba & Sandberg, 2006; Geisler, 1994; Poe et al., 2010; Roth & Lee, 2002), beliefs (about writing, about the aims of science, and about the relationship between writing and science) may have a stronger influence on emerging scientists' capacity to gain disciplinary fluency than learned behaviours.

For many years now, I have observed a discrepancy in the way science writers are anecdotally represented as writers by those outside the scientific community, and the way they perceive themselves as writers. For example, Laura Martin, writing in *Scientific American*, comments, "professional scientists do not consider themselves writers. Some even brag about hating writing or being poor writers" (2012 para. 16). With a few exceptions, this has not been my experience within my professional life or in my research. Indeed, in an earlier Australasian

study (Emerson, 2012), a majority (18 out of a sample of 20) of senior scientists reported very positive feelings about writing:

> I love writing. It's probably the part of the job that I love the most.
>
> I love to write—and to convey the passion I feel for my work.
>
> If I had the option, I would sit in my office all day and write.

Furthermore, of this group of 20 senior scientists (Emerson, 2012), 16 classified themselves as confident writers of science, who, even when they experienced the anxiety of writing for new audiences, nevertheless relished the challenge of doing so. Many of these senior scientists speak passionately and with insight about their work as writers of science and most of them see writing as integral to the construction of scientific knowledge. They hold complex views about audience, persuasion and the writing process.

My observation has been that some of our colleagues in the sciences are amongst the most sophisticated and flexible writers in the academy, often writing for a wider range of audiences (their immediate disciplinary peers, peers in adjacent fields, a broad scientific audience, industry, and a range of public audiences including social media) than most other faculty. And, since their writing is most often collaborative and multidisciplinary, their practices may be more socially complex, and require more articulation, mediation, and interpersonal communication, and more use of advanced media and technology than those of faculty in other disciplines.

And yet scientists' voices seem curiously absent when we talk about writing in science. With the exceptions of Burton and Morgan (2000), who conducted a survey and interviews with 70 mathematicians, and Yore and associates (2002, 2004, 2006; also Florence & Yore, 2004), who provide scientists' perspectives based on a relatively small sample, and a set of recent studies coming out of the literature on higher education related to graduate students' experience of writing a doctorate and co-authorship (e.g., Austin, 2009; Cuthbert & Spark, 2008; Golde, 2010; Kamler, 2008; Maher et al., 2008; Maher et al., 2013; Maher et al., 2014), research into scientists as writers focuses primarily on the observations and analyses of scholars outside STEM disciplines.

In my more pessimistic moments, I fear that our attitudes to scientists as writers have more closely resembled those of 19th century missionaries rather than anthropologists (Segal et al., 1998). In the context in which I write, Aotearoa New Zealand, the indigenous people, the *tangata whenua,*[2] are very cautious about *pakeha*[3] New Zealanders speaking about/for or interpreting Maori culture. The Maori people, like indigenous people elsewhere, see their culture as a

taonga, a treasure, and only those in possession of this treasure, who own it as an integral part of themselves, are considered appropriate speakers for their culture. Anything else is cultural appropriation. Yet it has seemed to me, at times, that we in the humanities, who consider writing and rhetoric to be our own field, have no such qualms about the cultural appropriation of scientific writing and the experience of writing science.

This book is a partial attempt to address what we might see as the humanities' cultural appropriation of science writing. It invites scientists to speak of their beliefs, attitudes, processes, development and experiences as writers of science through the development of literacy narratives—and it invites those of us in the humanities to listen. By presenting science writers through oral history/literacy narrative, and as extended texts, rather than solely as interpreted by a writing researcher, this book provides a rich resource for scholars, teachers, and students, in both the sciences and the humanities.

ADDRESSING THE NEEDS OF UNDERGRADUATE STUDENTS

We need to hear these voices because the literacy aims of many of the undergraduate students in our writing classrooms include joining a scientific community of writers. Corkery (2005), following Shaughnessy (1979) and Bartholomae (1985), discusses student distrust and scepticism of the writing teacher's role of privileged gate keeper into the academy. But that scepticism may also arise—perhaps primarily arise—from a science student's perception that the writing teacher's knowledge of the genres, language, aims, and cultural practices of science, is limited. Why would any science student—some of whom may have a deep fear of or resistance to writing and who may fight away their fear by describing writing as irrelevant to a career in science (Poe et al., 2010)—trust a humanities professor who says "you can do this—and I can show you how"?

The Writing across the Curriculum (WAC) and Writing in the Disciplines (WID) movements have made considerable progress in repositioning the teaching of writing within the context of a specific discipline, giving cultural credibility and disciplinary relevance to the teaching of writing (Bazerman & Russell, 1994; Carter, 2007; Deane & O'Neill, 2011; McLeod & Soven, 2000). Yet still, what remain missing are texts written by scientists or mathematicians exploring their own pathways to competency in writing in their discipline. Corkery (2005) and Soliday (1994) argue that texts which present this kind of developmental narrative, such as literacy narratives, provide models of individuals transitioning into specific forms of literacy and thus provide motivation and models for students struggling to see their own transition into academic writing. This may

be especially important to undergraduate science students, whose confidence in their own abilities as writers may have been damaged by experiences with writing in the classroom during their schooling (Choi et al., 2010; Shanahan, 2004). Several of the scientists and mathematicians in this study discuss damaging experiences with school and English teachers in particular. The anxious mathematics student, sitting in a writing class, who reads this comment by a successful applied mathematician,

> What's interesting is I did mathematics, I think, because I found English so difficult . . . I failed . . . on English and I was fine on mathematics. I was top in maths but I was desperate in English. I can remember the essay. The title was "Your House." Now as a mathematician . . . I've got to write about my house. What is my house? And I went to numbers straight away. It's got five windows, it's got one door—this is age 10 or 11. I knew it was a disaster when I wrote it. But I was incapable of doing anything better—Timothy, Chapter 3.

may recognise a similar incident of their own, and may never have realised that the successful science or mathematics professor in their writing classroom may have experienced this kind of setback. Reading of the way this senior professor worked his way to a position where he could ask for help (many times) and learn to write fluently in a range of genres, and finally say, "I'm pleased that I've got a job where I have to write," may provide the motivation to persist with writing in their discipline.

ADDRESSING THE NEEDS OF GRADUATE STUDENTS

For graduate students, who are beginning their apprenticeship within their disciplinary environment, these voices are also important. Research shows that novice science writers' induction into scientific writing is often poorly articulated, and dictated by the capacity or inclination of specific thesis advisors or peers to engage with writing (Florence & Yore, 2004; Kamler, 2008; Paretti & McNair, 2008) or the student's capacity for imitation (Alexander, 2005). Burton and Morgan (2000, p.450) comment that:

> Current practice in the training of mathematicians and in mathematics education more generally does not explicitly involve teaching and learning about mathematical writing. The novice may learn through using the existing models of published writing, through an apprenticeship of collaboration

> with more experienced writers, or through the often harsh process of peer review. None of these methods is designed to help learners to acquire the kind of knowledge about language that might enable them to be aware of what they might achieve by choosing to write in different ways.

While graduate students might turn to resources on how to write scientific and mathematical documents (e.g., Penrose & Katz, 2010; Blum et al., 2006; and Day & Gastel, 2006), Morrs and Murray (2001) and Bishop and Ostrum (1997) both comment on the scarcity of research exploring the writing process of academics in general, suggesting that there is a gap between the writing processes described in such texts and "the real contexts and practices of [academic] writers" (Morrs & Murray 2001, p. 37). Similarly, Burton and Morgan (2000) show that specific directions relating to style provided by mathematical journal guidelines are seldom followed by mathematical writers who are published within those journals, suggesting such guidelines do not provide sufficient or appropriate direction for the novice writer.

Mutnick argues that literacy narratives are "a potential source of knowledge about realities that are frequently misrepresented, diluted, or altogether absent in mainstream depictions" (1998, p.85). Because narrators in a literacy narrative construct the past from the vantage point of present cultural knowledge and practice (in this instance, because the senior scientist constructs their narrative of their development as writer from a position of having developed rhetorical fluency), they are able, at the prompting of a skilled interlocutor, to reflect on, and draw attention to, the difficulties of making the transition to disciplinary literacy (Soliday, 1994), while presenting solutions that they know are successful. Thus they are invited to examine a process that is largely unarticulated within scientific and mathematical communities.

One final point in relation to graduate students: Corkery (2005), following Couture (1999), argues that the voices of disciplinary experts, portrayed through literacy narratives which show how someone, like the student, outside of academia brought themselves into it, "suggest different ways to bring the student's particular circumstances into an academic forum" (p. 57). Furthermore, as Couture argues, they provide a model or a vehicle for achieving community:

> Writers need to know . . . what it is that others *do* when they communicate in writing . . . and perhaps equally important, [so they can] *be* like them in order to occupy a common field within which each other's communications are heard and understood. (p. 42)

Voices portray more than strategy; they portray shifting beliefs, attitudes and character. A constructed character, yes—but nevertheless, a distinctive and individual character that conveys specific difficulties, struggles, triumphs and successes. One of the features of the narratives in this text is that many of the most successful writers (for example Elizabeth in Chapter 4 and James in Chapter 2) still struggle with writing issues and yet exhibit tenacity and determination (Daley, 1999; Florence & Yore, 2004), continually inventing and engaging new strategies to enable them to overcome these difficulties. A student confronted with a senior scientist sees only the successful present; a literacy narrative can reveal a more complex and conflicted image—an image which the student can meet on common ground. One of the most vivid examples of this is Lizzie, in Chapter 5. Her graduate students, struggling with their own writing, who are likely only to encounter her bright, capable and forceful professional presence, may learn more about how successful scientists also struggle with writing for a complex audience and be encouraged into resilience by hearing the story of how she spent a week in her pajamas wrestling a paper into shape.

Bereiter and Scardamalia (1993) argue that expertise emerges from learning communities that engage not just with the how, but the *why* questions in the field of expertise. Literacy narratives invite scientists to engage with the *why* questions of writing (for example, linking distinctive disciplinary genres to the aims of science), providing a starting point and a language for research communities to engage with the deeper questions relating to writing in their discipline.

For both undergraduate and graduate science students, then, hearing the voices of scientists is vital, in terms of motivation and resilience, providing models, and becoming part of—and developing—a scientific community that has a language to speak about writing.

DISCIPLINARY DIFFERENCES RELATING TO PROCESS

For teachers in composition and WID, these voices may teach us something new about disciplinary *process*. While writing teachers are acutely aware of different disciplinary genres, there is a danger of assuming that process is process; i.e., that while genre, style, structure, and audience may differ across disciplines, process is transferable. It's possible that this is incorrect (Driscoll, 2011; Melzer, 2014). Several of the participants in this text distinctly highlight the differences both in context and process between humanities-based writing processes and scientific writing processes, largely around the issue of collaboration and co-authorship (Austin & McDaniels, 2006; Jacoby & Gonzales, 1991; Maher et al., 2013; Maher et al., 2014). Kamler (2008, p. 288), in a study which compares the publication processes of graduates in different disciplines, comments: "For [the]

science students, co-authorship was a given . . . a crucial part of learning the ropes of academic publishing . . . [a] well-established expectation of the discourse community." And while collaboration, conversation and peer review are very much part of the language of composition, the context in which they take place in the sciences (co-authorship, the hierarchies of disciplinary or interdisciplinary teams, the drafting process, and the use of technology such as the use of LaTeX) are rarely discussed. There are few parallels in the humanities for the following activities:

> Much of my writing now is first drafted by or with someone else: all of the team will create the story. Someone has to start with a draft. What I will do, particularly with my graduate students . . . [is ask] "now, look, what is the story? What are the pictures and so on?" . . . So . . . I'll say . . . "we agree on the story" (that's a discussion, right . . .) but when the writing actually starts I'll say "look, here's an introduction. I want you now to go away and write the rest of the paper." So, they will start, and the next thing will tend to be what was the experimental method?, what were the results? and so forth. Then we'll start getting the more difficult stuff about the interpretation of that story, and how we would end it off. In the process, it will go backwards and forwards. We don't sit down and write together. I write something, they add something on, I will correct that or make suggestions, sit and talk with them, they'll have another go. We'll go backwards and forwards—Richard, Chapter 2.

In our search for common ground between writing and STEM faculty (Poe et al., 2010), and in the relief of finding common terminology, such differences in process may be overlooked. For writing teachers, these voices provide us with new perspectives of what writing in the sciences involves, and how process works in a scientific context, and perhaps suggest new approaches to curricula that will meet the needs of our students more effectively.

THE GOALS AND METHODOLOGICAL BASIS OF THIS BOOK

> The goal and responsibility is to evoke and bear witness to a situation the researcher has been in or studied, inviting the reader into a relationship, enticing people to think and feel with the story being told as opposed to thinking about it.
>
> — Smith & Sparkes, 2006, p. 185

The principal aim of this book, then, is to break down the science-humanities and senior researcher-student divides in a way that speaks to the idea that we are all writers and that we are all engaged in a journey to rhetorical fluency within our disciplines. By conveying, in their own voice, scientists' stories as writers—their beliefs, attitudes, and experiences—my intention is to invite readers "into a relationship" with the storytellers. I'm primarily concerned, not just with the generalizable, but with the particular experience. Hence, the voices in this book are not intended as a representative sample, but as indicative of the wide range of university scientists' voices, in terms of discipline, experience, seniority, institutional type, and geographic location.

Method follows aims, and so the following sections outline how participants were identified, how the stories were collected and managed, and why the stories are conveyed as the hybrid oral history/literacy narrative genre.

THE PEOPLE IN THIS BOOK

The narratives presented in Chapters 2–6 of this book are developed from a selection of interviews conducted with university scientists between 2009 and 2014. In all, I conducted 106 interviews with scientists in a range of different scientific disciplines from 17 universities in North America, the UK, and Australasia. These 106 comprised 62 senior scientists and 44 junior scientists (made up of 26 emerging scientists no more than seven years out of their doctorate and 18 Ph.D. students in science). The scientists in this sample came from a wide range of disciplines, but a decision was made to exclude pure mathematicians in the sample, since preliminary analysis of early interviews suggested that their experiences of writing were so distinctive that they would need to be explored in a separate study.

In terms of demographics, 37% of the sample (a total of 39) were women (16 senior scientists, 13 junior faculty/postdocs, and 11 Ph.D.s)—reflecting the demographic trends of women in science (Bentley & Adamson, 2003; Hill et al., 2010; Maher et al., 2014). Of the sample, 35% was working in North America at the time of interviewing, 41% in Australasia, and 23% in the UK, although these figures do not fully represent the diversity of the sample: as we might expect of an international community, many were working and/or had studied outside their country of origin. The majority had English as a first language—only 10 of the participants identified English as a second language and, of this group, only two (one from China, one from Argentina) were not fully fluent. The choice of primarily participants who had English as a first language was intentional: English is the language of science (Gordin, 2015; Montgomery, 2013), which means that non-English speaking scientists must learn to write

science in English, but exploring the difficulties inherent in scientists acquiring or refining a second language while learning to write science would be a major study in its own right and is beyond the scope of this text.

The process of choosing participants for this research was multifaceted and based on the concept of purposeful sampling (Leydens, 2008). In each institution I identified the senior scientists first. In some institutions, my contacts in the writing program made recommendations or arranged interviews. Beyond these recommendations, I looked for participants from three groups within a range of science disciplines: those with an extensive publication record in their field, those who showed a particular interest in cross-disciplinary writing or writing for a public audience, and those with a moderate publication record. There was a snowball effect: some participants recommended other people they thought I should interview; other participants heard of my research and contacted me to volunteer. My experience was that if I found the senior scientists in an institution to engage with this study, they would help me to locate the emerging scientists or the doctoral students in their discipline. The sample, therefore, was not random, and was, to some extent based on self-selection. It is important to say again that the scientists whose voices appear in this book are not a representative sample of the scientific community—but then I never set out to achieve that. Instead, what I have collected here are a range of voices that are intended to show a wide variety of perspectives within the context of the university-based scientific community.

COLLECTING THE STORIES

Information was gathered from each participant using two methods. Once a participant had agreed to take part in the study, a short survey (Appendix A) was sent by email to the participant to collect demographic data and task-related information. Following this, a time was scheduled for a semi-structured interview which would form the basis for the participant's narrative: this was the central data collection method.

A number of different methodologies could have been used to fulfil my aim of allowing scientists to speak into the literature about science and writing. Attitudes and beliefs can be collected through quantitative and qualitative survey data. Even experiences and writing development themes could have been collected through written data collected in response to directive questions.

Nevertheless, such approaches would provide only a fragmented and limited picture of participants' perceived experiences of scientists as writers (O'Shaughnessy et al., 2012). Anxieties and doubts are unlikely to be explored using such methods, and participants may provide what they view to be the "correct" or

socially acceptable answer to questions, rather than relating their lived experience and perceptions, without the intervention of follow-up or probing questions. Given that writing was likely to be a difficult or contested topic for some participants, a method that allowed them to gradually explore their experience, prompted by appropriate questions that emerged from their discussion, was likely to produce richer and more valid data. The choice to use semi-structured narrative interviews was based on a desire to elicit rich, complex data about scientists' perceptions of their own experience as writers of science.

A further issue relating to data collection was motivated by a desire to focus on what is often a forgotten backstory of scientists' professional lives. O'Shaughnessy et al. (2012, p.44) observe that participants may have both dominant and subjugated stories about their lives, and that narrative interviews are an effective way "to make more conscious aspects of their lives which have been dismissed as not important." My participants' dominant professional story relates to their primary identity as scientists. Focusing on a subjugated story, their story as writers of science, was the central focus of this study. Scientists may not always identify as writers, and some scientists may not consciously recognise that their professional lives are constructed on written texts; the interviews in this study showed that most had never discussed their writing practices and experiences. A narrative interview allows the participant to become more self-aware during the interview process, to see aspects of themselves and their own practice to which they had not previously paid attention (Bleakley, 2005; Rich & Grey, 2003). This was undoubtedly the case for some of the participants in this study. Several reflected on the unexpectedness of their own answers. One participant commented, "you are doing a very hard thing. You are asking us to be self-reflexive about things we don't normally think about. I'm glad to have talked to you today." By having someone ask questions about their writing, listen attentively to their responses, and ask challenging questions, some participants were able to discover things they didn't know they knew or thought.

Sometimes this thinking went on well after the interview. Participants sent me follow-up emails, clarifying or changing the points they had made after further reflection. One emailed me several weeks after the interview, to explain how she'd been thinking about the interview and how it was changing her perceptions of her own work:

> I've been intending to follow up on our meeting for weeks now. I just wanted to say what a profound conversation it was for me. I had several interesting "aha!" moments in talking with you that I've shared with others since then. One was in acknowledging that I enjoy writing but, having said that, how

> difficult I find it to be. . . . The second was in articulating how much writing I do for others . . . letters for people, reviews of papers and grant applications, editing my students' work, etc., and the recognition that it's as legitimate a part of my work as writing a first-authored paper (even if I don't believe that in my heart of hearts yet). (Senior Scientist, Conservation Ecology)

Others sought me out to do a follow-up interview (sometimes after a discussion with others) or to tell me how our discussion had affected their teaching or graduate supervision due to an increased awareness of the relationship between writing and science which had emerged through their own thinking. Data from these follow-up conversations were also collected and recorded if appropriate.

The interviews were semi-structured around themes of writing process, attitudes and beliefs about writing and science, and learning to write science (Appendix B and C). Interviews were scheduled for one hour, but lasted between 40 minutes and 3 hours (the latter conducted over three sessions). Most interviews were conducted face-to-face, but three were conducted by telephone and one by Skype. The interview question sheet was continually adapted as new issues arose with the participants. New questions were added, such as a question about the writing lifecycle, after it emerged from one early interview, while other questions were dropped if the answers to them seemed unreliable or if they consistently failed to contribute to the overall story. Where possible, I encouraged participants to tell specific and detailed stories about their experience of writing in science. I researched each individual prior to the interview, read some of their work where possible, and included specific questions about each person's writing history.

Participants responded differently to the interview process. Some participants gave concise answers to each question, some were ready to speculate and self-reflect at considerable length, while others resisted the interview format and/or the questions and took control of the interview from the start. Richard, for example, whose narrative is provided in Chapter 2, blithely batted aside many of my questions and discussed issues that he considered important that were not covered by the interview plan. In instances like this, I felt it important to respect those choices, and to engage spontaneously with the participant's narrative, adding in my questions, where possible, in whatever order seemed most relevant to the discussion. If some questions therefore weren't addressed, I did not push the issue. Mason (whose narrative appears in Chapter 3) objected to most of the questions I asked, on the grounds that they made assumptions that were not consistent with his experience and beliefs. Again, it was important to respect

those choices and reflect on his objections, but also to probe the resistance in an effort to gain more understanding of the perceived disjunction.

One difficulty which emerged was that many participants volunteered information or asked questions after the recording device was switched off. In this situation, I would write notes on the additional discussion after I left the office, add these to the transcript and, if the interview was to be revised into a narrative, ask participants to check my interpretation and documentation of the discussion and approve the addition.

MANAGING THE DATA

The data were gathered and then initially processed using a two-stage process: transcript correction and analysis, and (for some interviews) construction into narratives. All the interviews were transcribed and checked, adjusted for anonymity, and then edited for comprehension. Digressions (for example, long discussions of their field, unrelated to writing and science) were removed or compressed, and the transcripts were then revised.

Of the 106 participants in this study, only 19 full or extended narratives are included in this text. The interviews selected for development into narratives were chosen primarily to represent a range of themes while giving some consideration to geographical and disciplinary breadth. The procedure for narrative construction was that most of the interview questions were removed and integrated into the narrative as needed for sense, and repetitious phrases which didn't add to the meaning (e.g., repetitious use of "I guess," "sort of," "kind of") were reduced. However, since my aim was to retain the participant's "voice," some phrases used regularly by the interviewee were retained in the narrative.

The finalising of the narratives was an iterative process. It was important that the participants felt ownership of their narrative. Narratives were sent to the participant for checking and approval. Track changes were used to direct the participant's attention to areas that needed clarification or to acronyms or names that would not be accessible to the general reader. Once the participant had returned the narrative, their changes were incorporated into the text and sent back again for re-checking. Occasionally this happened several times. When the narrative had been finally approved, I added a theme, taken precisely from the narrative, and an introduction to the speaker.

Finally, I asked each narrator to provide a pseudonym. Some were happy for me to choose a random name; others chose names that were in some way significant to them, which is why some narrators have one and others two names. Choosing a pseudonym was an important process for some of the narrators, leading to much discussion; some chose names related to a childhood memory,

names given to them by significant (personal or professional) others, or names that represented someone who was significant to them.

One narrative needed special care. Richard died between the interview and the completion of the narrative. I contacted Richard's family and asked for permission to use the narrative. I invited them to make any adjustments they felt were appropriate (they made none), choose a pseudonym, and recommend another scientist to check the narrative for technical correctness. They suggested that Cameron, who worked closely with Richard, be invited to take on this role. Both the family member I worked with and Cameron remarked that it was a bittersweet moment to hear Richard's voice speak so distinctively through this narrative.

PRESENTING THE NARRATIVES

> Stories are knowledge.
>
> — Moana Jackson[4]

In determining how these voices were to be portrayed in the text, the options I considered were *story analysis* and *storytelling* (Smith & Sparkes, 2006). Story analysis is the more conventional approach, leading to a scholarly text based on thematic analysis. In a scholarly analysis of narratives, the researchers step "outside or back from the story, employ analytical procedures, strategies and techniques in order to explore certain features of the story" (Smith & Sparkes, 2006, p. 185). Story analysts write *about* the stories (Frank, 1995) and approach the narratives from a methodological standpoint, seeing narratives as reliable (or unreliable) forms of data (Atkinson, 1997; Smith & Sparkes, 2008). In story analysis, the primary voice is the researcher's, and the researcher controls the narrative and analysis, moving from the particular to the generalised.

Such an approach proved problematic for me, both in terms of my own ethical position as a researcher and the aim of the text as providing a bridge between disciplines and between writers. I felt a text based primarily on the product and process of a story analysis to be a form of cultural appropriation. Furthermore, a story analysis would limit the immediacy of the narratives and the readers' capacity to engage, rationally and empathically, with the narrators' lived experience as writers. While story analysis is included in this text (in the introductions to Chapters 2–6, and the final chapter, which takes a broader perspective on the data set as a whole), another approach to working with the data was needed to achieve my goals.

Storytelling, by contrast, sees the story as the product of the enquiry, and invites the reader *into* the story, to engage at both emotional and rational levels with the narrator's experience (Frank, 2000). The researcher-as-storyteller

understands the story itself as containing analytical techniques, theory, and dialogical structures (Bleakley, 2005; Ellis, 2004) which can speak for themselves:

> In a narrative analysis, storytellers emphasize that participants' stories of the self are told for the sake of others just as much as for themselves. Hence, the ethical and heartfelt claim is for a dialogic relationship with a listener (including the researcher) that requires engagement from within, not analysis from outside, the story and narrative identity. Consequently, the goal and responsibility is to evoke and bear witness to a situation the researcher has been in or studied, inviting the reader into a relationship, enticing people to think and feel *with* the story being told as opposed to thinking *about* it. (Smith & Sparkes, 2006, p. 185)

The decision to include extended narratives as the primary structure of this text was motivated by these attributes of a storytelling approach to narrative: the invitation of the readers into the story, the possibilities provided by a dialogic relationship in evoking changed attitudes in the reader, the goal *and responsibility* to "bear witness" to these conversations (Bleakley, 2005). This is the primary motivation of this book: to invite the reader (whether that is a teacher/writer from the humanities, an undergraduate or graduate student of science, or a senior scientist) into the story of scientists' experiences as writers of science.

Perhaps the key feature of storytelling for this study is its view of the construction of the narratives as dialogic (Stephens & Breheny, 2013). Interviewing is not a "transparent process of information gathering" (Bleakley, 2005) and it is important to acknowledge the impact of the researcher on the construction of the stories (Mishler, 1995). The narratives in this text were co-constructed by myself and the participants. I provided both the opportunity to dialogue and the initial questions, responded spontaneously to their answers, occasionally engaged in argument, and eventually shaped the narratives through the editing process. Despite the iterative consultation, my hand is on the narratives at every step, and it is important not to minimise my contribution to the final story. My own story, as an outsider (I am not a scientist) means that participants may have simplified their process for the sake of a non-scientist.

Nevertheless, the role I took, of a naïve interviewer, as someone outside of the experience of the participants, is appropriate to the readership of this book, which includes writers and writing teachers from other disciplines, and emerging scientists, who also stand on the edge of the experiences of the narrators in this text. This issue of the role of the interviewer is explored further in the following section.

AN IMPORTANT ISSUE: RELIABILITY

Because the interviews investigated a subjugated and emerging story, some of the narratives in this text contain internal contradictions, even among participants who appeared to have the clearest and most well-rehearsed story about writing. Examples of this can be found in Richard's discussion in Chapter 2 of whether a bad writer can be a good scientist, and Timothy's portrayal of himself as both a confident and struggling writer in Chapter 3. I have made no attempt to remove these contradictions. While cohesion is often seen as an essential form of validation in narrative theory (Harvey et al., 2000; Holstein and Gubrium, 2000), I was aware that participants were telling a new story, struggling to find coherence about a topic they rarely thought about, and that this meant that emerging thinking could lead to apparent lack of cohesion (Baerger & McAdams, 1999). Sometimes my questions broke through a carefully constructed narrative; Timothy, again, indicates that he hadn't expected to talk about his experiences of writing in childhood and these questions led to the emergence of a new story. In most instances (but not all) the participant became aware of the contradiction within their narratives and attempted to achieve cohesion.

Nevertheless, the issue of reliability is important in considering the nature of these narratives. Clearly there was no need to objectively verify described events, since our focus is on the subjective experience of participants and the meaning they attributed to those experiences. For example, Jane, in Chapter 3, describes her graduate advisor as hostile and unhelpful during an oral examination, but no external verification of her experience is provided. It is possible that others at this meeting may have experienced his behaviour differently (although she does provide some evidence of other people's experience of his behaviour in other contexts), but our interest is in how Jane experienced her advisor's behaviour and the way she portrays its impact on her confidence as a writer.

One of the challenges of the interviewing process was to somehow break through real barriers to describing personal experience: people forget or minimise painful past experiences in the more confident present, and professional personas are valuable public shields against personal insecurities or uncertainty. I knew that, for some participants, writing would be an area of personal and professional insecurity (Florence & Yore, 2004; Yore et al., 2006). Being aware, as an interviewer, of strategies to avoid personal disclosure was essential throughout each interview. For example, a common strategy used by the participants to avoid personal engagement was presenting a generic or "correct" approach to writing rather than recounting their actual experience or strategies. When asked about writing a scientific paper, some participants would speak in the second person ("well, you write the method, and then then you look at the figures")

or use indefinite pronouns ("mostly one starts with the pictures"). The use of a second person or indefinite pronoun usually (but not always—some participants spoke predominantly in the second person) alerted me to the possibility that the participant was not discussing their own process but rather the process they believed to be correct. Such a response also often lacked the detail I was looking for. To counter this, I did not challenge their approach but later in the interview asked participants to think about a recent writing project and then to walk me through each step of the writing process—or I asked them to tell me a story about their first paper or their most challenging writing task. The latter was especially effective for talking to people who insisted that learning to write science was "effortless"—more often than not, a question about a specific writing experience elicited a quite different response. It was also sometimes necessary to ask detailed questions to bring participants back to their actual lived process, to ensure that the details of the process were captured.

While it is important to see the reliability of the stories in relation to the subjective experience of the speaker, and in terms of an emergent, subjugated story, internal contradictions in some narratives invite the reader to question the reliability of some central ideas within the narrative. Jane's story, for example, contains a central theme that she is alone, unsupported, and courageous in her attempts to find ways forward as a scientist and as a writer. However, there are elements in the story that bring this theme into question. Various people offer her support—an editor provides meaningful feedback, a colleague sets up a writing group, a scientist from another country with whom she has no previous professional relationship volunteers to visit her and works with her over several years, two colleagues help her write a significant grant proposal—which suggests she is not entirely alone and unsupported. Some of her comments ("I have a fear of the blank page and I'll do anything to procrastinate my way out") suggest that her limited publication record is caused by internal rather than external factors, while her discussion in the penultimate paragraph of her chair's proposed initiative to get groups and peer support strategies in place in the department suggests a lack of agency on her part. This does not suggest, of course, that Jane does not experience herself as alone, unsupported, and courageous, nor that she has been denied supports (e.g., the support of a helpful advisor and an effective research team) that she was entirely justified in expecting within the cultural context of her professional life. But it does suggest that there may be elements in the story that the narrator is, to some extent, unaware of, and that we should read the stories carefully.

One final issue concerning reliability: in any interview situation, the interlocutor is in some sense constructed by the participant, and this may affect the participant's responses to questions. In this case, the participants may have at

times provided answers in terms of their expectations or assumptions of the interviewer based on such issues as gender, nationality, or disciplinary-allegiance. The latter was most clearly evident in one particular question about reading for pleasure: those who did not read outside of a professional context, or those who read only news and non-fiction, were sometimes reluctant to admit this, or apologetic about what they feared I might perceive as a personal shortcoming. On the other hand, this also opened up possibilities. For example, one participant told me about a piece of creative nonfiction he had been working on for years, and commented with pleasure, "I've never told anyone about this before!" While the impact of the constructed interlocutor can never be eliminated, or even entirely measured, and may be different for each participant, my aim was to offer a non-judgmental, interested, curious, and naïve presence, and to be alert to the signs of its impact (positive and negative) on the stories being constructed.

In some essential ways, then, such as the narrative technique and the constructed interlocutor, these stories are dramatic monologues. As such, they invite the reader into an experience that is both empathetic and critical.

Chapters 2–6 of this study are focused on storytelling. Each chapter presents 3–5 participant narratives based around central themes: public-focused writing, the reluctant writer, the writing community, the development of the scientific writer, and creative writing. The aim of these chapters is to invite the reader into the scientists' experience of writing and learning to write within a disciplinary context. While each chapter gathers narratives with a particular focus, I have not edited the narratives solely to illustrate that theme. In Chapter 2, for example, while the narratives have been chosen to illustrate the theme of public engagement/writing, the narrators also discuss more fully their experiences of writing and learning to write. My intention here is to convey a scientist's interest in public writing *within the broader context of a scientist's perspective on writing.* This approach is central to a storytelling methodology: a scientist's choice to engage with public audiences emerges out of—and needs to be seen within—their beliefs, attitudes and experiences of writing, the way they learnt and were mentored into writing. For this reason, we need to hear not just disembodied segments of narration but a contexualised theme embedded in a full and rich discussion of the scientist's experience.

READING THE THEMES

Beyond this interest in the particular lived experience, however, there is also obvious value in considering the themes that emerged from such a substantial data set, and these themes are addressed in Chapter 7, using a story-analysis approach. Using themes that emerged from the literature and from a preliminary

Quadrant 1: Early influences	**Quadrant 3: Attitudes**
Childhood attitudes/experiences of writing	Enjoyment
Undergraduate attitudes/experiences of writing	Motivation
	Resilience
	Self-efficacy/purpose
Quadrant 2: Learning to write science	**Quadrant 4: Beliefs**
Advisor	Function of writing
Community	Audience
Rhetorical reading	Persuasion
Ongoing support post-Ph.D.	Beliefs about identity/role as a scientist.

Figure 1.1: Model of a scientific writer

analysis of the data, the analysis of the entire data set is based on the following model (Figure 1.1).

The remainder of this chapter focuses on these central themes and, in particular, research to date relating to each theme, and the gaps that this study will address.

EARLY ATTITUDES

Much of the current research on scientists' perceptions of themselves as writers is narrowly focused in three areas: experiences of undergraduates as disciplinary learners, primarily through the literature on WAC and WID; experiences of doctoral students, through the literature on graduate supervision; and research which examines the doctoral/post-doctoral (or novice/expert) divide. A consequence of this narrow focus is that the picture that has been drawn of scientists' development as writers is a relatively simple one: scientists may begin to learn to write science as undergraduates through writing-intensive classes, but the graduate years are a central place in which scientists learn the craft of disciplinary writing, through a process of cognitive apprenticeship and mentorship (Burton & Morgan, 2000; Cummings, 2009; Cuthbert & Spark, 2008; Florence & Yore, 2004; Maher et al., 2013; Poe et al., 2010).

We will return to the issue of undergraduate/graduate experiences later in this chapter, but pause here for a moment to observe one limitation of the current narrow research focus on scientists' perceptions of themselves as writers:

what of scientists' earlier experiences? How do they impact scientists' development as writers?

In the preface to this study, I noted that my undergraduates are surprised—and perhaps somewhat dismayed—to find writing is part of their science curriculum. Similarly, Poe at al. (2010, p.1) begin their study by commenting "MIT students, by and large, do not love to write . . . the science and engineering orientation of MIT undergraduates can often lead them to believe that in their professional careers, the search for engineering solutions or scientific phenomena, not the seemingly tedious process of communicating those findings, will dominate." If such observations are correct, these attitudes and beliefs—including a reluctance to write, and a belief that writing is somehow separate to and unnecessary for science—come from somewhere.

And yet, the early educational experiences of scientists in relation to writing appear to be largely unexamined. Instead, as with the two examples cited above, the evidence seems to be largely anecdotal. Laura Martin (2012, para. 9), for example, suggests that the division between science and writing begins at elementary school, and that, consequently, children with an interest in science are separated from writing-rich subjects at an early age:

> On top of rigid conventions, scientists must contend with the pervasive myth that scientists can't write. We begin differentiating scientists and writers in elementary school. One "likes math" or "likes English." Our academic system, from pre-K through graduate school, contrasts science and literature—objectivism and subjectivism, reductionism and holism.

Martin provides no empirical evidence for such a view, and in some countries there is evidence that contradicts such a perspective. In New Zealand, for example, the national curriculum embeds writing and communication into every discipline at both elementary and secondary school (although how that works in practice may be another matter), and the pedagogical value of integrating writing for learning in science in schools has been extensively researched (see, for example, Bressler, 2014; Chinn & Hilgers, 2000; Choi et al., 2010; Holbrook & Rannikmae, 2007; Prain & Hand, 1999; Shanahan, 2004; Rowell, 1997). Nevertheless, anecdotal evidence suggests that, somewhere in their education, students with a science orientation adopt—or may be encouraged to adopt—particular attitudes and beliefs about the nature and purpose of writing and its relationship to science which need to be challenged if they are to become proficient writers of science (Shanahan, 2004). Beliefs and attitudes inform praxis and are resistant to change (Brady & Winn, 2014; Martinez et al., 2001; Tobin & Tippens, 1996), as we discuss more fully later in this chapter.

Beyond the experience and impact of schooling, the undergraduate years have recently been seen as a significant opportunity to embed writing into the curriculum, and writing or communication-intensive courses as they pertain to the sciences have been extensively researched, including students' experiences of those courses (Bayer & Curto, 2012; Bayer et al., 2005; Hand et al., 2001; Reed et al., 2014; Reynolds et al., 2009; Reynolds et al., 2012; Stanford, 2013). However, the long-term impact of these programmes on scientists' attitudes to and beliefs about writing, and their impact on praxis, remains largely unexamined. The extent to which these learning initiatives are reaching the majority of undergraduate science students is also something of an unknown (Thaiss, 2012).

By taking a broader approach to the question of influences on scientists' development as writers, this study intends to examine these early years: to what extent did early learning experiences and early attitudes to writing, formed during the K-12 years, impact on scientists' later development as disciplinary writers? And how do scientists perceive the impact of their undergraduate education on their development as writers?

LEARNING TO WRITE SCIENCE

Learning to write within a disciplinary academic context is part of the process of being socialised into a disciplinary community (Bazerman, 1992; Kelly, 2007; Lee & Aitchison, 2009; Maher et al., 2013; Maher et al., 2014; Norris & Phillips, 2003). Austin and McDaniels (2006, p. 400) describe this socialisation process broadly as "internalising the expectations, standards, and norms of a given society," including relevant skills, knowledge and behaviours, attitudes, beliefs, and values. In examining how scientists become writers, therefore, we must consider both the individual and the social context, especially given the collaborative nature of much scientific writing (Cummings 2009; Golde, 2010; Maher et al., 2014).

Bereiter and Scardamalia (1993) suggest a nurturing and challenging learning community, or "community of practice" (Dunbar, 1996; Riel, 2000) is essential if writers are to develop the flexible writing skills required in the sciences (Hatano & Inagaki, 1986; Holyoak, 1991). The ability of the scientific writer to demonstrate an interest and capacity to engage with a range of discourse communities in a range of genres should, they suggest, emerge from a deeper conceptual understanding of the domain borne out of a community of practice which favours deep engagement and learning. Such a conceptual understanding is effected by a learning context or community in which understanding is favoured over goal completion, where tasks are variable and to some extent unpredictable, and where there is social support which encourages exploration, experimentation, and

deeper comprehension through discussion of *why* questions rather than simple *how* questions. Poe et al. (2010, p.10), following Riel (2000) and Smith et al. (2005) build on this concept of the learning community, describing it as:

> A setting in which the community is organized rather than disciplined; characterized by collaboration rather than competition; focused on knowledge construction rather than knowledge delivery from one central source; student centered rather than teacher centered; interdependent rather than independent. Instead of expertise flowing from the teacher to many students, expertise flows in many directions . . . leaders are people who inspire others to work towards common goals.

Broadly speaking, the research to date suggests that the cultural context of science is not wholly conducive to the development of its emerging members as scientific writers. Maher et al. (2013) comment that enculturation into any disciplinary discourse practices is no simple matter, but that there may be additional challenges in the sciences related to social context and cultural and pedagogic expectations (Collins et al., 1989). While the cognitive apprenticeship model, embedded within a learning community (Austin, 2009; Collins et al., 1989; Poe et al., 2010) is central to the doctoral process, its success as a model of teaching writing is open to debate. Within this model, reading and imitation (Burton & Morgan, 2000) and feedback from doctoral advisors, lab partners (Florence & Yore, 2004; Kamler, 2008), collaborators and peer review (Austin 2002; Burton and Morgan, 2000; Gardner, 2009; Sweitzer, 2009) are the primary ways in which students learn to write, with faculty-student co-authorship (Kamler, 2008; Maher et al., 2013) the "signature pedagogy" (Maher et al., 2013, p.128) of learning to write in the sciences.

While such approaches to learning disciplinary writing clearly can be successful (see, for example, the discussions of co-authoring in Florence & Yore 2004; Kamler, 2008; Maher et al., 2013), they may also be fraught with difficulty (Lee & Aitchison, 2009; Paré, 2011; Starke-Meyerring, 2011). There is evidence, as we have already observed, to suggest that some resources available to support emerging scientists as writers, such as style guides and journal guidelines, do not provide accurate or appropriate direction (Bishop & Ostrum, 1997; Burton & Morgan, 2000; Morss & Murray, 2001). Lerner (2007, p. 215) comments on one particular example (Knisely, 2005) where the author is explaining how the structure of a scientific paper facilitates reading:

> Although scientists' act of reading research articles might resemble this process to some degree, the emphasis on reading

> as information gathering, and thus writing as information conveyance, captures none of the dynamism of the experimental process and largely ignores the complexity of the rhetorical choices open to a scientific writer.

Further, the process of writing collaboratively with a mentor is socially complex, incorporating hierarchical structures (Jacoby & Gonzales, 1991) that may or may not be open to revision (Florence & Yore, 2004. Co-authors may bring (sometimes unarticulated or even subconscious) expectations to the collaborative process; Maher et al. (2013), for example, list a series of advisor and co-author expectations related to writing skill level, prior experience of writing and reading, and beliefs about the purpose and process of writing and co-writing, which senior scientists describe as commonly not shared by the emerging scientists with whom they are co-authoring. Learning by imitation (e.g., by reading in the discipline) may be a hit-and miss affair. As Collins et al., (1989, p.7) observe, "students are unable to make use of potential models of good writing acquired through reading because they have no understanding of the strategies and processes required to produce such a text." Without access to these cognitive and metacognitive strategies, students must learn intuitively, and thus lack a capacity to articulate their rhetorical choices.

The current context of science, then, appears to offer limited, and largely unarticulated and unsystematised, support for emerging scientists as writers, with none of the methods currently available "designed to help learners to acquire the kind of knowledge about language that might enable them to be aware of what they might achieve by choosing to write in different ways" (Burton & Morgan, 2000, p. 450). While science is formed within the investigative learning communities that Bereiter and Scardamalia (1993) identify as essential to the formation of new knowledge, there is little evidence to suggest that these communities reliably work to articulate and support the advanced, flexible writing expertise that emerging scientists need. For some researchers, the co-authorship relationship is a potential strength that needs reframing:

> Co-authorship with supervisors is a significant pedagogical practice that can enhance the robustness and know-how of emergent scholars as well as their publication output. There is a need, however, to rethink co-authorship explicitly as a pedagogical practice. (Kamler, 2008, p. 283)

Others have suggested the need for a new approach, querying whether faculty mentors are the best people to support emerging writers (Maher et al., 2008), and whether a workshop (Maher et al., 2013), or writing groups model

(Cuthbert & Spark, 2008; Kamler, 2008; Maher et al., 2008) would be more effective ways of enculturating emerging scientists into disciplinary writing.

All this is to assume that the primary—or perhaps only—context in which scientists learn to write is during the years prior to the completion of a doctorate. It is possible, however, that the process of learning to write in the sciences has a longer duration, and that different factors may impact on scientists' development as writers post-Ph.D. Since it is unlikely that scientists could be considered fully fledged disciplinary writers when they hand in the dissertation, how do they continue to learn and develop as writers within the cultural context of science? For those who move into cross-disciplinary writing or writing for public audiences, and thus into writing in new genres, what support is available and how is that support accessed?

This study, then, investigates scientists' perceptions of their own development as writers within the cultural context of science. To what extent do they perceive the different aspects of the cognitive apprenticeship (reading and imitation, mentorship and co-authorship) to be successful? What do they perceive to have been the key influences on their development as writers of science? Is the post-Ph.D. period important to their development as writers—and, if so, what forms of support are available?

ATTITUDES

As stated earlier in this chapter, learning to become an effective disciplinary writer requires more than the acquisition of a set of skills and knowledge (Blakeslee, 1997; Dall'Alba & Sandberg, 2006; Gee, 2005; Poe et al., 2010); writing takes place within a social and cultural context (Collins et al., 1989; Doody, 2015; Maher, 2008) and in the context of forming disciplinary identity (Brown et al., 2005; Gee, 2005). For this reason, investigating the attitudes and beliefs of scientists and emerging scientists is vitally important (Kagan, 1990).

While, as we have discussed earlier in this chapter, scientists are sometimes anecdotally portrayed as reluctant writers, the broader limited literature on scientists' perceptions of writing calls this into question. Florence and Yore (2004), following Daley (1999) suggest scientists are driven, passionate about their field, continually dissatisfied with current understandings (Bereiter & Scardamalia, 1987, 1993), and therefore driven to write by their desire to contribute to a continuing disciplinary debate. Hartley and Branthwaite (1989) in a study of academic psychologists noted that the most productive writers had positive attitudes to academic writing and felt that their writing was important to them (see also, Hartley & Knapper, 1984). They noted that writing anxiety decreased with experience and productivity, and individuals who enjoyed writing were

less anxious and most productive. Within the broader literature on academics' writing, Rodgers and Rodgers (1999) suggest that prolific academic writers are likely to enjoy writing, be energised by writing, and respond constructively to reviewer criticism. A sense of personal accomplishment and dedication (Fox & Faver, 1985; Jones & Preusz, 1993), resilience (Boice, 1994), confidence (Morrs & Murray, 2001; Shah et al., 2009), and intellectual curiosity (Veronikas & Shaughnessy, 2005) have also been identified as key characteristics of successful academic writers.

In the broader literature on expertise, attitudes are described as critical in the shift towards competency in any discipline (Alexander, 2011a, 2011b; Brady & Winn, 2014; Dreyfus & Dreyfus, 2004, 2005), with Dreyfus and Dreyfus (2005) and Benner (1984, 2004) describing emotional engagement as the starting point in the move towards expertise. Alexander argues that emotional engagement is as important as cognitive capacity in the development of academic expertise, with both competent and expert practitioners showing deeper affective engagement and more investment in their work than those who are at earlier stages of development within a discipline. Bereiter and Scardamalia (1993) suggest that experts are more curious, more likely to pose new questions, more robust and more tenacious and determined than experienced non-experts.

Alexander (2003, p.10), in her Model of Domain Learning, sees motivation as one of the central attitudinal features of academic expertise:

> individuals' motivation and affect are significant contributors to the development of expertise . . . without understanding those motivational/affective dimensions, educators cannot explain why some individuals persist in their journey to expertise, while others yield to unavoidable pressures.

She notes that motivation and interest have been largely overlooked in studies which have concentrated on the cognitive abilities, behaviours and skills sets of experts (such as those by Dreyfus and Dreyfus, 2005). But multiple studies (see, for example, Bloom, 1985; Dorner & Scholkopf, 1991; Ericsson, Krampe & Tesch-Romer, 1993; Holyoak, 1991; Hidi, 1990; and VanSledright & Alexander, 2002) have pointed to the importance of motivation and interest in the development of competence in any field, while Bereiter and Scardamalia (1993) see motivation as one of the key factors that pushes experts to work harder and more strategically than non-experts at both simple and challenging tasks within their domain of expertise.

This study examines four specific attitudes to writing: the extent to which scientists enjoy writing, their motivation to write, their resilience as writers, and their self-efficacy in relation to writing.

BELIEFS

> Further inquiries into scientists' . . . beliefs about writing are needed.
> — Yore et al. (2002)

Harding and Hare (2000) suggest that we have insufficient information concerning scientists' beliefs about science—and, we might add, their beliefs about the nature and purpose of writing (Geisler, 1994; Yore et al., 2002, 2003, 2004). In this study we focus on scientists' beliefs concerning the purpose of science and, more specifically, the role of the scientist in communicating scientific findings.

One of the major debates in the literature on scientists as writers concerns scientists' beliefs about the purpose of writing. Florence and Yore (2004), Bereiter and Scardamalia (1987) and Keys (1999) suggest that there is a distinction to be made between emerging and experienced writers, that emerging scientists see scientific writing as knowledge reporting, while more senior writers see writing as knowledge construction or transformation. In contrast, Yore et al. (2002), Yore, Hand, and Prain (2002), and Yore et al., (2006) found that senior science writers as well as emerging writers are likely to see writing as knowledge reporting. Yore et al. (2004) conclude: "the [beliefs of the] prototypical science writer . . . did not match the literature-based image. These [senior] scientists perceived writing as knowledge telling not knowledge building" (p. 346). Nevertheless, their findings are somewhat conflicting, and in their concluding observation in their 2004 study (p. 359) they note that the issue may be one of awareness:

> These scientists recognized the dynamic nature of writing as they applied the discursive movements to address the demands of the written discourse and the science technology content, but they did not explicitly use the language associated with the knowledge-building model of writing.

Other significant questions concerning beliefs relate to the persuasive quality of scientific writing and the significance of audience. Yore et al.'s findings (2002, 2004) suggest that scientists are highly cognizant of audience and the need to adapt their style and content to specific audiences. However, their findings relating to persuasion are again somewhat ambiguous:

> The respondents wrote to inform and share new ideas, unique innovations, and novel findings. Although none used the word "persuade" in their questionnaire responses, some scientists realized the rhetorical demands and the pragmatic need for writing grant proposals . . . [which] unlike research reports in which editorial referees can be persuaded by compelling

> evidence, must convince review panels by their use of linguistic devices in the description of the research proposed and its significance without the support of evidence (Yore et al., 2004, p. 357).

This observation is an interesting one since it distinguishes between persuasion which is achieved through "compelling evidence" and persuasion which is achieved through linguistic devices. This is a distinction which we will return to in Chapter 2.

One of the reasons why Yore et al. (2004) may have experienced difficulties in examining scientists' beliefs related to persuasion and the function of writing is that beliefs are often held tacitly, and therefore may not be easily identified through direct interviewing techniques (Benner, 2004; Dreyfus 2004; Tobin & Tippens, 1996). In other words, scientists may not consciously know what they believe about persuasion or the function of writing. This may be especially the case in a study such as this, where participants are answering questions about an aspect of their work that they do not consciously analyse themselves and where they have learnt a praxis intuitively (Florence & Yore, 2004; Jacoby & Gozales, 1991). While it might be argued that interviews and surveys are not as effective as other methods (e.g., observation studies) in eliciting attitudes and beliefs, I would argue that beliefs can emerge implicitly through narrative in response to indirect questioning and can be identified through close analysis of narrative texts. In this study, attitudes and beliefs were collected through direct questions (e.g., do you think scientific writing is persuasive?) and indirect questions (e.g., how would you describe the relationship between writing and science?), and identified through textual analysis.

Two final points about attitudes and beliefs: research suggests that they are developed early (Raymond, 2013) and they are resistant to change (Alger, 2009; Leavy et al., 2007; Martinez et al., 2001; Tobin & Tippens, 1996). This study therefore included questions about childhood attitudes and learning experiences related to writing and science: did scientists' early experiences, beliefs and attitudes to writing relate in some way to their relationship with writing within their professional life?

In this study, we examine four sets of beliefs—the importance of audience, the nature of persuasion, the perceived function/purpose of writing, and scientists' beliefs about their communication responsibilities as scientists.

The final chapter of this study, then, focuses on a model of the scientific writer which builds on current research into scientists as writers within the four quadrants of our model (learning to write, learning to write science, and the beliefs and attitudes of scientists as writers) to investigate scientists' perceptions

of these issues. But should our focus be on the sample as a whole, or on the novice/expert divide (emerging vs. senior scientist), or should we be differentiating the sample in other ways?

DIFFERENTIATING THE SAMPLE

The current primary focus in the literature on the pre-post doctorate divide is perhaps understandable and in some respects desirable because, from the point of view of the writing community, the graduate years (and the undergraduate years preceding them) are the time when we can make a difference. As the doctorate is handed in, formal education is completed and there are fewer opportunities to engage across disciplinary divides. From the perspective of the scientific community, too, the handing in of the doctorate is the point at which a scientist's formal training as a writer, such as it is, ends (while post-doctorate positions do include opportunities for mentoring, the relationships between the senior and emerging scientists are generally less formal than that between the doctoral candidate and advisor). Focusing, therefore, on the final stages of the apprenticeship, where any formal influence is completed, makes pedagogical sense.

But while the current primary focus on scientists' perceptions of writing pre and post Ph.D. (novice and expert) scientific writers has pedagogical value, it also has limitations beyond those of disregarding scientists' learning experiences pertaining to writing prior to and following doctorate. A narrow focus on the differences between the two groups (novice/expert) may fail to recognise variation within each group (Carter, 1990; Dall'Alba & Sandberg, 2006): "Variation within groups could be considered an important research result, but in each study it was veiled by an emphasis on exploring differences at two distinct stages of development, namely novices and experts" (Dall'Alba & Sandberg, 2006, p. 390). The literature on doctoral supervision and co-authorship in the sciences does not distinguish the scientists who are engaged in supervision by experience, seniority, discipline or gender, or by attitudes and beliefs.

Yet even a casual engagement with the scientific community reveals that the writing tasks scientists engage with post-Ph.D., and the attitudes and beliefs they hold in relation to those tasks, are highly variable—though whether that is due to individual preference/attributes, disciplinary conventions, beliefs and attitudes to either writing/research or the responsibilities of the scientific community, professional life stage, or some other factor, cannot be established without empirical investigation. There are suggestions in the broader literature on scientific writing to support this observation of heterogeneity. Bazerman (1988, 1998), for example, suggests that competent academic writers in general are more inclined to write across disciplinary boundaries rather than focusing narrowly on

the requirements of a single discourse community, and Yore et al. (2004) speculate that senior scientific writers may engage with a wider range of audiences, within the scientific community and in terms of the public discourse of science. Further, the preliminary analysis of the data for this study showed patterns of variation within the senior scientists which became an emergent theme of this research and warranted further analysis.

One of the questions explored in this study, then, is whether—and how—we might distinguish between categories of scientific writers. In particular, are post-Ph.D. scientific writers a single group, or can we distinguish between them in terms of tasks, attitudes and beliefs? And, if we can make such a distinction, what are the implications for both the scientific and writing communities?

The simplest approach to addressing the first of these two questions is demographic: can we differentiate the sample by discipline or gender? Differentiation by discipline was not undertaken in this study, since the sample was not structured in such a way as to facilitate comparative analysis.[5] Differentiation by gender, however, was possible—although any results must be tentative, given the smaller number of female participants. While the few studies that have examined scientists' or mathematicians' perceptions of writing (Yore et al., 2002, 2003, 2004, 2006; Burton & Morgan, 2000) have either specified gender when discussing participants' comments or included intentional sampling in relation to gender (for example, Burton and Morgan went to considerable lengths to find equal numbers of male/female participants), none of them have drawn any gender-based conclusions. Given that the role of women in science, and women's access to career positions in science are matters of some interest, this is perhaps a surprising omission.

A more complex approach would be to consider differences not simply by a novice/expert distinction but by "professional life stage" (Bent et al., 2007). Such an approach would be supported by the stage models of expertise (Dreyfus, 2005; Benner, 2004) which differentiate five stages on the path to expertise, each of which incorporates a differentiation in terms of skills, knowledge and affective factors such as motivation and self-confidence. Interestingly, such a model was raised by one of the participants in this study:

> So, at the beginning, when you start writing science, first of all, you're learning to write. Then you go through a phase where you are writing to discern what your ideas are as well as to understand your field and learn to write about science more effectively. And from there, you go on to writing reviews, where, in a way, you know what the ideas are at the outset. You know the field so well that you write and your

> ideas are already formed. It's simply a matter of putting them out there. And then finally you get to a stage—or maybe not finally, maybe there is another stage after that—where you are providing a platform for something that has huge implications in lots of different ways. (Lemrol, Chapter 5)

While drawing only the broadest strokes, Lemrol's model is interesting, not least because it gives credence to the idea that learning to write science has a longer gestation period than has previously been assumed in the literature, but also because it suggests diversification of writing activities by professional life stage once a scientist has established themselves as a researcher.

Thus, one way to read the data in this study is to consider whether such stages can be identified in the "lifecycle" of the scientific writer and whether these stages can be further nuanced according to *affect*, i.e., attitudes, beliefs, and emotional investment, as well as behaviours and practices. This question of life stages was addressed in two ways in the study: the inclusion of a direct question within the interviews and an analysis of the complete data set into three categories (doctoral, emerging and senior scientist) according to tasks, beliefs and attitudes.

One final model was investigated to potentially differentiate the senior scientists. Based on a preliminary analysis of the data, which suggested that at the senior level we could distinguish two, if not three, groups according to task choice, I adapted Holyoak's (1991) model of routine and adaptive expertise to the question of scientific writers (Verschaffel et al., 2011). Holyoak (1991, p.310) defines routine experts as "able to solve familiar types of problems quickly and accurately, [but having] only modest capabilities in dealing with novel types of problems." Routine experts ("the artisans," Bransford, 2004) learn complex and sophisticated routines which they skillfully apply in familiar situations and, while they may continue to learn through their professional life, their focus is on increased efficiency at applying familiar routines. Adaptive experts ("the virtuosos," Bransford, 2004), by contrast "may be able to invent new procedures derived from their expert knowledge". For the adaptive expert, learning is about reaching beyond their skill set, embracing even uncomfortable challenges which will stretch their beliefs, and entertaining new possibilities.

Using this classification, routine writers might be seen as scientists who write consistently well in a specific genre to a specific audience (e.g., the physicist who writes consistently and exclusively for a narrow range of journals targeted at his or her disciplinary peers) within the established expectations and conventions of their discipline; someone who may, indeed, learn most, if not all, they need to know about writing during the postgraduate period apart from issues

of efficiency. Many of the scientists in Yore et al.'s (2002, 2004) studies, who write for a narrow range of audiences, appear to fit this model. Adaptive writers, by contrast, would be continual learners, choosing to step outside of conventional disciplinary expectations and norms, adept at problem-solving strategies for discourse problems within and beyond their domain. Such a writer would need to continually adapt and renew their writing skills as they sought out new audiences and extended their skills to write in a range of genres to a variety of audience (for example, extending out into popular writing or social media), something for which their Ph.D. couldn't prepare them.

Holyoak's model therefore goes beyond stages differentiation, suggesting instead that there are different pathways *within* the senior scientific community. One of the questions for my investigation, then, was to consider whether we could distinguish these two groups within the senior scientist sample and, if we could, whether there we could identify distinct attitudes, beliefs and influences for each group. The preliminary analysis of the data set suggested a differentiation into three groups according to writing choices:

- Routine scientific writers. This group comprised those who wrote exclusively within the expectations of their discipline. This did not equate with those who wrote peer-reviewed papers only; an extension scientist, for example, might write in public-facing genres, but this would be within the expectations of their discipline. It also did not equate with people who avoided cross-disciplinary work; again, in some disciplines this is expected or unavoidable. The key differentiating feature of this group was that they stayed within the confines of their disciplinary *expectation*s. An example of the routine scientist is Mason in Chapter 3.
- Adaptive scientific writers. This group was defined as those who had intentionally developed opportunities to extend beyond disciplinary expectations through writing for public audiences, attracting cross-disciplinary colleagues as research partners or creating/finding opportunities for engagement in creative projects. The key defining feature of this group was that they had intentionally sought out research and/or writing opportunities that went beyond disciplinary expectations. Examples include the scientists in Chapter 2, or Gao and Elizabeth in Chapter 4.
- Transitioning writers. Although I had originally identified just the two groups discussed above, a third group emerged from the preliminary analysis: researchers who were either transitioning from routine to adaptive, or who wished to make the transition but were unable to do

so for some reason. Paddy in Chapter 5, although an emerging rather than senior scientist, exemplifies this type of writer.

In the final chapter of this study we engage with the story of the data set as a whole, focusing on the model of the scientific writer as outlined in this chapter, and investigating the question of differentiation, and the implications of the findings as a whole for the scientific and writing communities. Before we engage with this larger story, however, we return to the idea of the individual story, the lived experience of the scientist as writer.