CHAPTER 7

"WE HAVE TO COMMUNICATE THE BEAUTY AND THE PASSION."

> I tell my students that you may think you're a scientist—you're not—you're a writer who writes about science.
>
> — Senior Scientist, Genetics

The story of scientists as writers is a subjugated story, one that hides behind the scientists' overt identity, their central story of themselves as a geologist, physicist, or evolutionary biologist, etc. Many of the scientists in this study struggled to articulate their understanding of writing, because writing—though utterly central to their careers—was something they didn't think about:

> I'm surprised I was able to say anything at all [about writing]. I thought "I have nothing to offer, nothing to say"—I thought it was going to be a real short interview. I think about a lot of things but how I write, the writing process, is not one of them—I just do it . . . I don't analyse it much at all. Isn't that strange when that's the final product of what I do? I mean, people aren't going to come in and say "let me see those parasites now." They want to read what I had to say. (Senior Scientist, Ecology)
>
> This is such a new concept to me. Yeah, I don't think I've ever thought about my writing thoroughly before; you know, you sort of . . . learn how to structure things and grammar and all that sort of thing, but actually sitting down and considering writing is something a bit more than that, I've never done it before. It's been useful. (Emerging Scientist, Exercise Science)

One of the participants referred to this as "an interesting lack of awareness":

> I guess I've never tried to think about this process of my own writing so much before. It's an interesting lack of self-awareness. Because you spend all your time writing basically, spend your time locked to the keyboard . . . if you're not writing for a journal, you're writing a letter of recommendation or you're writing a grant proposal—writing all the time. (Senior Scientist, Biology)

"Are you a writer?" I asked in some interviews, and mostly the answer came back, in some form, "no, I'm just a scientist." Over and over, I noted this odd discrepancy: scientists were concerned about their students' writing, the majority saw themselves as (sometimes reluctant) teachers of writing, but many hadn't recognised the extent to which their professional identity revolved around their writing, until they began to talk about it. Only a few, acknowledging their professional identity as inextricably tied to writing, made writing central to their work with the next generation of scientists.

The story of scientists' perceptions of themselves as writers is also a subjugated story in the literature on scientific writing, a consequence of which has been an insufficiently nuanced picture of the scientific writer focused primarily on the novice/expert (graduate/undergraduate-senior researcher) divide.

And yet, "effective writing comes sometime after the Ph.D." says Timothy in Chapter 3. "Everything I write, I still learn something new. There is always another way of putting an idea, or a fresher way" says Lemrol in Chapter 5. And writing teachers know this—that learning to write is never complete, that there are always new challenges to meet if we are to grow as writers. But if scientists too perceive that writing development occurs post-Ph.D., then investigating how it happens, whether it is successful, and the extent of its influence is likely to be of interest to both the writing and the scientific communities. Furthermore, if scientists perceive that writing activities, beliefs and affect change *predictably* over a scientist's professional lifecycle, or that they may be differentiated in some other way (e.g., by demographics) then this is significant information which emerging scientists need to be aware of and perhaps prepared for. Similarly, if this narrow focus on the novice/expert divide has obfuscated possible variations in writing and identity development, beliefs, attitudes and praxis on either side of the divide (Carter, 1990; Dall'Alba & Sandberg, 2006), then understanding those variations is also important for the ways we prepare our scientists as writers. At the other end of the scale—if writing in school or the undergraduate years is a significant influence on scientists' development as writers—then this should be of interest to the scientific and writing communities alike.

The aim of this last chapter, then, is to develop a broader, and more nuanced story of the scientific writer, and the development of the scientific writer, than is currently available, based on the data set as a whole. Can we distinguish between groups, based on beliefs, attitudes and learning experiences correlated with writing activities or demographic features? And if there are indeed distinctive groups, what are the implications for the scientific community or, more broadly, for those tasked with teaching writing to students within the sciences? How might we, on the basis of the findings here, more effectively enculturate our emerging scientists into their community of practice, as writers of science? The answers to these questions must be approached somewhat tentatively, since the sampling method and sample size mean that the range of participants in this study cannot be seen as representative of the scientific population as a whole. However, the aggregated data may shed light on the development of the scientific writer and the diversity of beliefs and attitudes related to writing as perceived by the scientific community.

LOOKING AT THE DATA

A three-step approach was used to investigate these questions in relation to the entire data set. First, a spreadsheet was used to collate demographic data (including stage—senior, emerging, or doctoral scientist) and writing activities. Second, the interviews were processed quantitatively, based on the model outlined in Chapter 1; each transcript was analysed and scored on a scale between 1–10 for each variable and this was added to the spreadsheet. For some variables (e.g., enjoyment, resilience), the scale simply measured a level, as indicated throughout the interview (where 1 was low and 10 was high). For others, particularly the beliefs, the scale represented sophistication of thought (see Appendix D for more detail on scales for each variable).

The individual scores for each variable were then averaged by gender, professional stage, and designation as adaptive, routine and transitional writers. Finally, to provide more depth of analysis, the qualitative data were coded according to the variables used in the quantitative analysis.

The model used for this analysis, as described in Chapter 1, can be seen in Figure 7.1.

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

Figure 7.1: Model of a scientific writer

Differentiation by Gender

No significant differences were found in the quantitative data in any of the four quadrants in terms of gender; women overall did not reveal significantly different attitudes or beliefs, or experience stronger levels of support or more positive or negative early learning related to writing, than their male colleagues. This was somewhat unexpected: although the interview included no direct questions related to gender and most of the female participants did not directly address gender issues, several did suggest there was a gender bias that impacted on their written activities.

These female participants focused on two issues which may impact on their writing. First, several women suggested that there were heavier pressures on women to engage in outreach to schools (as a way of making science more attractive to girls) and/or communicate in a public context—which may impact on a female scientists' peer-reviewed outputs. Second, there were suggestions that female scientists saw and developed their career trajectories differently (see, for example, Bentley & Adamson, 2003). One senior biologist, when told that a previous participant in the study had raised the concept of a lifecycle of a scientific writer laughed "he was a man wasn't he?" Later in her interview, in response to a discussion about a scientist's "genealogy," she suggests a sense of being excluded ("othered"), which may have implications for mentorship and sponsorship of women's writing in science (see Donald, 2013):

> It was another man [who suggested that], wasn't it? Boys do. That's part of the club thing that I would rail against. I don't feel part of that. But I know there are people who do. I find it claustrophobic, the genealogy thing. I think it's true of lots of women; they're not part of that club. And the whole knowing everybody's lineage just immediately "others" you if you're not part of it. (Senior Scientist, Biology)

Conclusions about gender in this study must necessarily be tentative, since the sample of senior women was small. We may hypothesise that women receive less support for writing than men, and given that there is a substantial and rapidly growing body of knowledge (in both the academic domain and in the media) revealing gender bias in selection process and peer review (see, for example, *Nature's* 2013 special edition on Women in Science;[10] Bentley & Adamson, 2003; Dweck, 2006; Hill et al., 2010), such a hypothesis is reasonable. While the quantitative data in this study don't support this hypothesis (figure 7.2), it is notable that the three participants who perceived themselves as being in a sus-

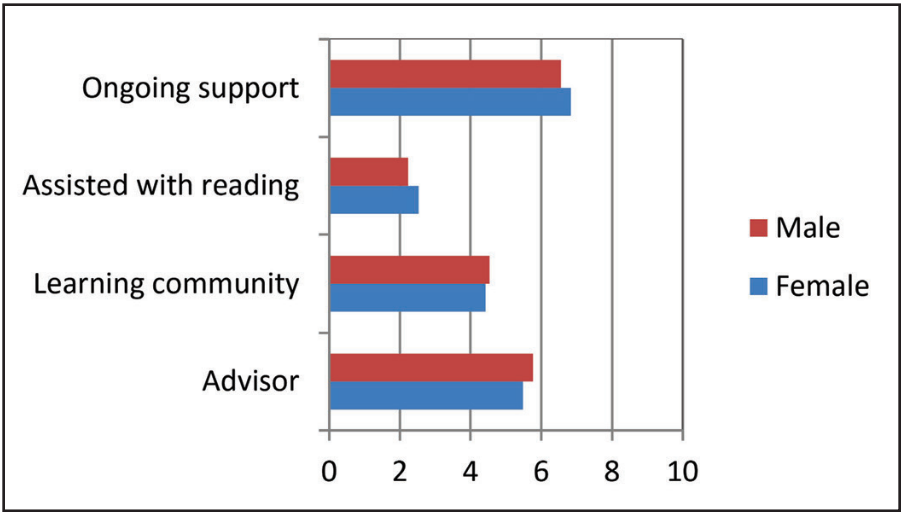

Figure 7.2 Levels of support for scientists as writers by gender

tained, isolated position (both during and following the doctorate) and without community support were all women.

A positive note can, however, be taken away from the gender issues in this study: there were indications that women's support for writing may take a different form from that of their male colleagues. The two writing groups were led by and initiated by women, and were composed primarily of women (Grant, 2006; Grant & Knowles, 2000); both journal clubs (see later in this chapter) were mentioned by female participants. What is encouraging about this finding is that, apart from providing evidence that women are in these ways supporting other women as writers, these initiatives allow writing to be discussed and engaged with explicitly in ways that do not seem to be the norm in the cognitive apprenticeship model.

Given that this study was not designed primarily to investigate gender differences in writing and that the number of women in the sample, particularly at senior scientist level, was small, more research is needed. Fruitful areas of investigation include the impact on women's opportunity to develop as writers of bearing a double burden of being the gender-balanced face of science, gendered differences in career trajectories, and writing support relating to writing (Bentley & Adamson, 2003).

Differentiation by Career Stage

Overall, the data in this study showed support for some aspects of the stages model of differentiation. In particular, two points were agreed by most participants.

The first was that, for most participants in this study, "learning to write science" began in graduate school rather than the undergraduate years. Both the quantitative and qualitative data showed that undergraduate experiences were not significant for developing scientific writing skills for these cohorts. This is perhaps surprising given extensive moves to integrate authentic writing opportunities into undergraduate science education in recent decades through WID and WAC (see, for example, Brieger & Bromley, 2014; Prain, 2006; Reed et al., 2014). While some older participants would have experienced their undergraduate education prior to the impact of WAC, and other participants had been educated in countries where WAC and WID programmes are not prevalent, nevertheless, it might have been expected that many of the younger participants would have experienced some support for scientific writing through their undergraduate years. Those participants who did identify undergraduate education as a significant time in which they learnt to write science again mostly pointed to essay-writing skills, informal writing, or learning to write lab reports—a genre that is dismissed as counter-productive to effective scientific writing by many other participants in this book, a perspective broadly supported by the literature (Driver et al., 1996; Hodson, 1998; Lerner, 2007; Russell, 1991; Russell & Weaver, 2008; Vargas & Hanstedt, 2014; Yore at al., 2002):

> You were taught what a lab report structure was, and aims and methods and stuff [at school], but when I got to doing my Ph.D. I quickly realised that this was just fantasy—there was this myth that lab reports were important, like teaching you for the future! No, it's not! It's not like a scientific paper at all! That's outrageously stupid! I don't even know why we persist with this artifice that lab reports are somehow important. . . . I'd much rather have people fill in boxes with their thoughts that gives them some structure . . . and then later, when it comes to writing papers, they won't have this idea that your paper will be like just a really long lab report. That's just stupid. (Emerging Scientist, Chemistry)

Lerner, (2007, p. 214), commenting on informal writing in the science classroom, suggests:

> Writing in the science[s] often exists in informal modes . . . the kind of writing that is essential for students to do to engage with the material, but not, I would argue, the way for students to learn the relationship between *doing* science and communicating what they are doing . . . And not in a way, in

> Russell's (1991) words, "to engage students in the discovery of knowledge, to involve them in the intellectual life of the disciplines" (p.200).

A rare few discussed a specific teacher who required them to write and to think about writing, and only two (Eugene in Chapter 4 and one other senior scientist) experienced anything that resembled a WAC program or writing intensive course. This particular senior scientist (whose undergraduate education took place over 30 years ago in a country where WAC had not been introduced at that time), like Eugene, sees this undergraduate experience as critical to his development as a scientific writer and as facilitating his writing at advanced levels:

> There was a general awareness of teaching writing right across the degree (across years and across courses). . . . But there's one [professor] who was truly inspirational in teaching us how to write. . . . he actually ran a course which was about how you run an experiment and how you report an experiment in written form. It was really a course exploring the philosophy of scientific methodology and an explanation of how you should report science as a scientific paper. He talked about how you write an abstract, what you do put in and what you don't put in, what you can get away with and what you can't. . . . I think the critical step for me was [that] last year of my bachelor's degree. When I went into my Ph.D., I could write science. I was pretty good. I had my skills honed by my Ph.D. advisor, but it wasn't critical. The critical step was earlier. (Senior Scientist, Nutrition and Physiology)

While this study sheds no direct light on the impact of WID or WAC on the development of scientists as writers, there is nevertheless encouragement from these two scientists. Both encountered few difficulties developing their writing skills at advanced levels and both show the attributes of the adaptive writer, suggesting that intervention in the undergraduate years may have a substantial impact on scientists' future development as writers and may counter some of the inherent difficulties in the cognitive apprenticeship model of writing development at graduate level.

The second point that most participants agreed on was that most scientists did experience a significant shift in their writing activities throughout their careers, which appeared to take place 5–8 years post-doctorate (depending on factors such as the length of the post-doc period and employment opportunities)—but further predictable shifts (as proposed by the lifecycle model) were not fully confirmed. The predictable move identified by the majority is the shift from writing up their own research to overseeing the research and supporting/editing the writing of their juniors. For some this was a partial shift, but for others it was a substantial change in their writing activities:

> I find now that I write less and less. My job as a writer now is to edit other people's writing. (Senior Scientist, Human Biology)

This shift was often discussed as being, in some way, a surprise the scientist felt ill-prepared for:

> I didn't think I was going to be an English teacher, but that's what I am. (Senior Scientist, Seismology)
>
> I don't think of myself as a teacher of writing, and yet I guess sort of that's what I am doing. I think to myself "I'm a scientist, I'm not an English professor and I really don't know how to teach people how to write." And it's been one of the more frustrating things of my career. (Senior Scientist, Ecology)

The following participant hadn't recognised that she was moving from one mode to another until we discussed the lifecycle model:

> But transitioning through those [stages] is hard . . . because I still expect myself to be—so I'm in that stage of now [where] mostly what I'm doing is working with my graduate students to write up their work. And I think "why don't I value that as much as I value writing from scratch with my own work?" Because I have a lot of my own data that still needs to be written up, but I don't find the time and their work always takes precedence over my own. I should be spending time working on a manuscript of my own, but I don't. So I'm not, I haven't found sort of comf—I feel like what I should be spending my time on is writing up my own work. What I *am* spending my time on is helping others and being at that stage of the life history of the scientist, in which I'm more of a mentor than the person who's putting the work out there on my own. (Senior Scientist, Conservation Ecology)

Some, such as Mason in Chapter 3, reluctant to make this shift, minimised it by allocating as little time possible to supporting the writing of their juniors and retaining a primary focus on conducting and writing up original research. This reluctance was attributable to the value they placed on their own research—that's what got them into science in the first place and it remained a key motivation:

> I hope that I'll always be writing my own research stuff right up to the end. . . . I have a post-doc who spends a lot of her time doing that and it really frustrates me because it's what I like doing too and I'm really jealous. . . . As you become more senior, your colleagues and managers . . . start to ask you to produce a lot more kind of meta-level stuff and it's unavoidable, but I'd hope that I'd always stay involved in the practical stuff as well. Because I enjoy it. Absolutely. That's the thing that gets me into the office; it is still the technical achievement and the curiosity-driven stuff that really gets me going. (Senior Scientist, Interdisciplinary Mathematics)

Others embraced the shift despite the difficulties, seeing it as an opportunity to increase publication rates (Mayrath & Robinson, 2005), develop new skills, and help support the next generation in their discipline. But many clearly struggled for years to feel comfortable with this inevitable transition. Those who could most confidently articulate their role as a supporter of others' writing, such as Lemrol in Chapter 5 and Richard in Chapter 2, were most likely to be close to the end of their careers.

It should be noted, however, that this study focused exclusively on university-based scientists; whether this shift also takes place outside in the academic context (in independent or state-funded research facilities, for example) is not clear.

Beyond these two central points, on which there was almost a consensus, responses to the lifecycle model as a whole were more equivocal. Doctoral and emerging scientists were most likely to agree with the entire model based on how they perceived their own position as writers within the scientific community and their observations of the wider community. But generally the response from the senior scientists was more ambivalent. Some strongly confirmed that this was the model that described their career (see, for example, Marama in Chapter 2) or the way they wanted their career to progress, while others were not so sure or were strongly opposed.

Opposition to the model as a whole by the senior scientists came from a number of positions. Some senior scientists suggested that diversification of writing activities, beyond the shift identified above, was not universal. For example, some senior scientists, as discussed above, did not wish to shift from the position they had established early in their careers as researcher/writers. Other senior scientists had broadened their activities but saw colleagues who didn't:

> I can also cite very many people in my field who are phenomenally successful who will continue to the bitter end, and beyond, publishing extremely specialised, high-quality papers in their field because they are the leaders of the field and that is what drives them, totally and utterly—[but] I think the truly brilliant chemists are polymaths who can turn their hand to anything. (Senior Scientist, Chemistry)
>
> I mean there are some people who repeat their Ph.D. research for their whole career. (Senior Scientist, Physics)

Sometimes the move to writing for a broader audience was seen, not as a positive step, but as representing some failure of imagination or intellectual/research capacity:

> I think there's some truth in the idea that you write more broadly as you get older. It might be because you have less time to do research as you get further up in your career. . . . It might be because it's harder to do research—you know there's a tendency to just create a whole lot of stuff in your head so you can't think originally about things. And it can be quite hard to shake off a whole lot of ways of thinking that you become used to. So I think it is generally harder to do research when you've had more experience. But there are positives in that for quite a lot of people, and for me, because you just get opportunities to do things at a broader level. You know, you can influence science policy or government policy. But maybe that's necessity being the mother of invention—I don't know. (Senior Scientist, Physics)

Others, such as Richard and Cameron (Chapter 2), opposed the lifecycle model because they saw it as outmoded and undesirable in terms of the aims of science:

> I would like graduate students, now, to see science communication as an essential part of their youthful role as scientist . . . the face of science is often, I think, perverted by the fact that you see these older people out there who are the famous scientists, and people have this vision of the scientist that way. And in fact science is a youthful game.

Several participants discussed the issue of technology and social media, and how young scientists are more likely to have the technical know-how and famil-

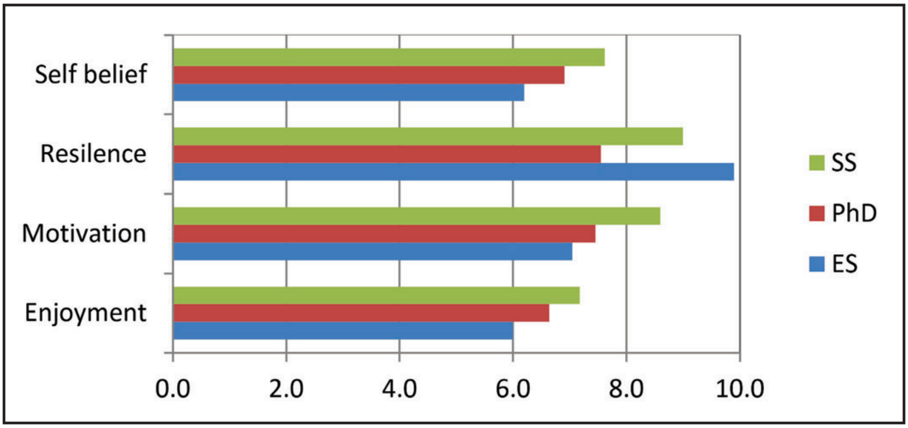

Figure 7.3: Attitudes of senior, emerging, and postgraduate scientists

iarity with social media to reach out to a younger generation—and to be a more attractive face for science.

The results from the direct question in the interviews revealed ambivalence concerning the lifecycle of the scientific writer. But what do the quantitative data tell us—and can we differentiate not just on the basis of praxis but by attitudes and beliefs? To investigate these questions, the data were first analysed by three "stage" categories of participants: senior, emerging and doctoral scientist.

The results suggest that emerging and senior scientists can indeed be differentiated according to attitudes and beliefs. In terms of attitudinal factors—confidence levels, levels of motivation and particularly enjoyment—the senior scientists scored more highly than the emerging scientists (figure 7.3). The only factor on which emerging scientists scored more highly was resilience; as less experienced writers, emerging scientists may be more likely than senior scientists to face criticism and rejection through peer review, and so the need to exhibit resilience may be more important or more uppermost in their minds.

However, the most significant differences between emerging and senior scientists can be seen in beliefs around writing; although none of the rates are high, senior scientists are more likely to perceive writing as knowledge construction and as persuasive and creative, are more cognizant of audience during the writing process, and take a broader perspective on the nature of their role as scientists (figure 7.4).

There was, however, an unexpected finding. According to a stages model (Alexander, 2011a, 2011b; Benner, 2004; Dreyfus, 2005), doctoral students would be expected to exhibit less positive attitudes and less sophisticated beliefs about scientific writing than the emerging scientists. This was not the case: on

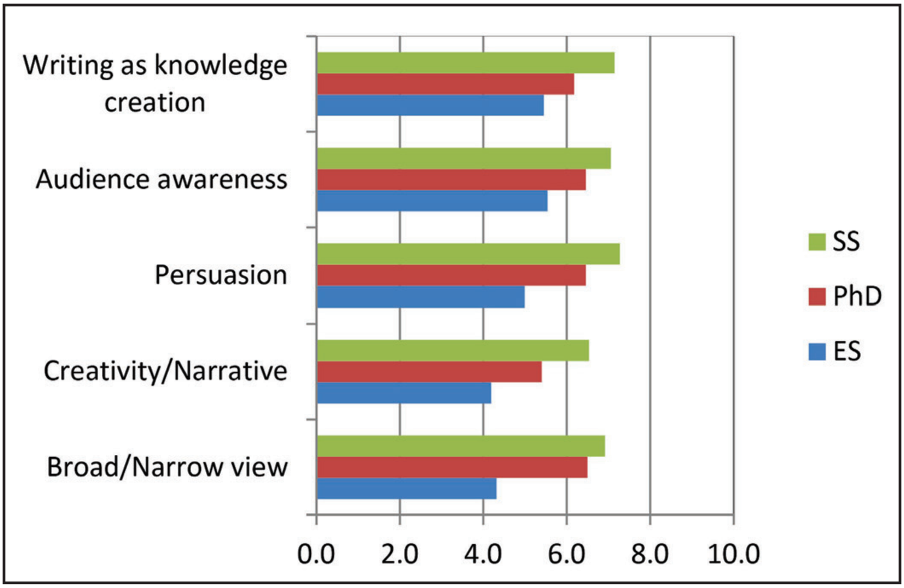

Figure 7.4: Beliefs of senior, emerging and postgraduate scientists

all measures except resilience the doctoral students were closer to the senior scientists than the emerging scientists; they showed, on average, more positive attitudes and exhibited more sophisticated beliefs than the emerging scientists. They were also more cognizant of audience, more likely to see writing as persuasive and to take a broad view of their role as scientists. We will consider this unexpected finding in detail later in this chapter.

Differentiating the Senior Scientists: Routine, Transitioning, and Adaptive Writers

While this study has shown that we can distinguish between the writing behaviours, attitudes and beliefs of emerging and senior scientists, preliminary analysis of the senior scientists revealed this picture to be lacking complexity. Specifically, it didn't account for the fact that the senior scientists exhibited a far wider range of attitudes and beliefs than the emerging or doctoral scientists. Using Holyoak's distinction between routine and adaptive expertise (Chapter 1), the data from the senior scientists was differentiated into three groups: routine (R), adaptive (A) and transitioning scientific writers (A/R).

It should be noted that these three groups did not equate with successful or unsuccessful (or less successful) scientists. Scientists in all three groups could be

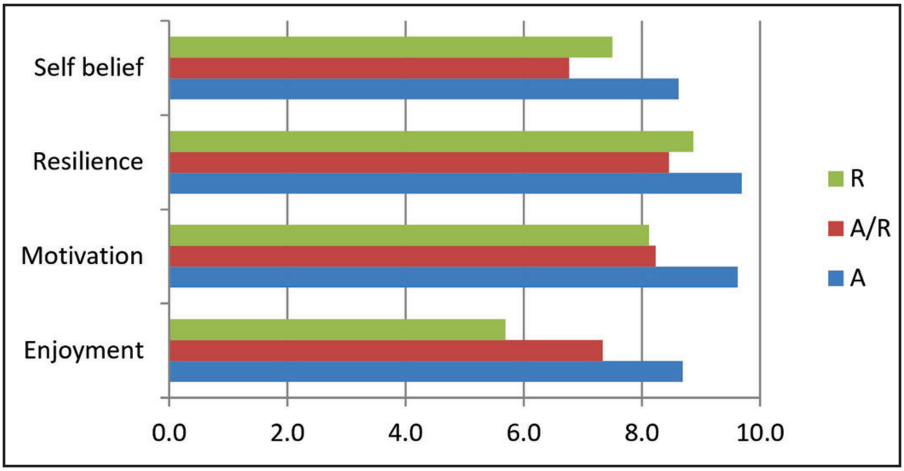

Figure 7.5: Attitudes of senior scientists

equally highly regarded within their professional context. Adaptive scientists did not necessarily, for example, have a more successful career path than the routine scientists, although they were likely to have a higher *public* profile. They did not necessarily publish more, nor were they more likely to have achieved honours in their profession. Adaptive writers published *differently* to the other two groups, i.e., in a wider range of contexts, and they were more likely to be part of the public face of science. In this study, there were equal numbers of routine and adaptive scientific writers (just over 35% in each category), and slightly fewer transitioning writers (29%).

If we examine attitudes and beliefs in relation to these three groups of senior scientists, we find some significant differences. In terms of attitudes (figure 7.5), adaptive writers are far more likely to enjoy writing than routine writers, and are more motivated to write.

Typical comments from adaptive writers included:

> I'd like to write all the time. I'd like to be able to do just writing. I'd like to have the time. And if I have the time, that's what I do. I like trying to write down my opinion about things because that's really hard—because what do I really think? (Senior Scientist, Plant Genetics)

> I think writing, communicating, is very, very important—so I enjoy it. (Senior Scientist, Chemistry)

> I love writing. . . . And I think there is nothing more satisfying than having written a scientific paper or a review, and getting to the end of it and reading it for the last time and being really satisfied that it's a nice piece of work in every way. . . . I think I'll write till I die! And probably post-science I'll be doing some other kind of writing. I love words! (Senior Scientist, Animal Physiology)

However, enjoyment should not be equated with easy: most of the participants in this study, including the adaptive writers, described struggling with writing in one way or another. Even some of the most confident writers struggled when moving to new cross-disciplinary work, or when writing in a new genre. But, for the adaptive writers, this did not take away from the enjoyment, supporting Bransford's (2004) observation that adaptive experts are willing to engage in the emotional difficulties associated with changing their own thinking and praxis. This quote, from a senior mathematician, seemed to sum up the attitude of the adaptive writers:

> I do enjoy writing. It's extremely difficult for me. (Senior Scientist, Interdisciplinary Mathematics)

While routine writers rated enjoyment low, their scores on self-confidence and resilience were ranked almost as highly as the adaptive writers. The following scientist, who identified five journals he writes for routinely, commented:

> I've done the same thing for 35 years. . . . I'm like a little independent contractor. . . . I've turned down more things than I've probably done, so I do the stuff I want to do. (Senior Scientist, Chemistry)

Throughout his interview, this senior professor described ways of making writing easier and more efficient, in line with Bransford's (2004) description of routine scientists' focus on increased efficiency, discussing the use of boilerplate and keeping to similar structures:

> Writing is easiest for me if it's similar to something I've already done before, because then I can grab it, right. I already have a template for it and I already have some stuff so that will be the easiest.

Both the adaptive and routine writers were more confident about writing than the transitioning writers, which is possibly attributable to the uncertainties of transitioning writers endeavouring to move from one type of writing/research into another. While the difficulties in transitioning from routine to adaptive researcher/writer could be attributed to managing external factors such as other pressing commitments with absolute deadlines (e.g., teaching and administration), internal struggles were often also a factor:

> So my big pause is . . . I think yes, I enjoy it, [but] if I really enjoy it why don't I do more of it—right? [It's like] would I love to get out and hike every day? You bet. Would I like to go for four or five miles instead of my two with my dog every morning? You bet. Why don't I? (Senior Scientist, Conservation Ecology)

This was the dilemma faced by many of the transitioning writers in this study: they enjoyed writing, were strongly motivated to extend the scope of their writing, but the difficulties of knowing *how* to make the transition led to struggle and, sometimes, inertia. The distinguishing factor in many cases between those who had or were making the transition and those who had been poised on the cusp for some time was the availability of a supportive mentor or mentoring context (for example, Richard's encouragement of Cameron in Chapter 2). When ongoing support was coupled with broad beliefs about the purpose of science and the role of the scientist that corresponded with adaptive scientists' beliefs, then the transition appeared to occur more quickly.

Beliefs were critical to the distinction between routine and adaptive scientists (see figure 7.6); adaptive writers' beliefs about writing and their own role as scientists and writers were significantly different to those of routine writers. While adaptive writers show more audience awareness in their writing and are more likely to see writing as persuasive and as knowledge creation, what distinguishes them most are their beliefs about both the purpose of text and their own identity as scientists and writers. Their talk about writing is quite different to that of routine scientists; they talk about crafting a narrative, of shaping the story, of working out where a reader needs what information, of enticing the reader or creating suspense, as this participant describes:

> Good papers are papers that at a certain point show you a glimpse of what is to come, what will be relevant, what is the real explanation of the phenomenon, you know. . . . and to tell this to people means that you have to write a good narrative; if you just rely on the formulas and the words as a glue between formulas and plots it's very likely that your paper will be ignored for a long time. Perhaps forever. [Good scientific writing] takes the reader by the hand; you start a journey

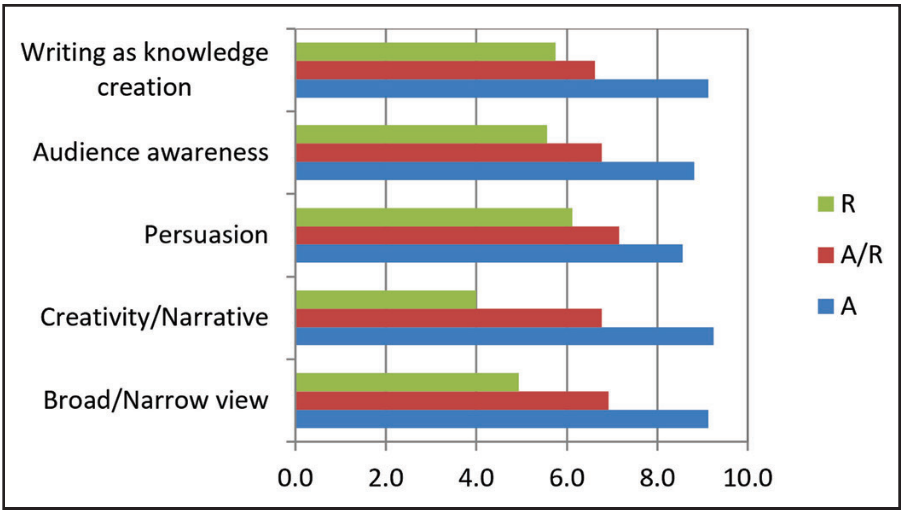

Figure 7.6: Beliefs of senior scientists

> together—even if it's a journey through formulas or topics, it is a journey. And you have to organise this journey; and this journey can be pleasant or it can be a pain in the back and that depends on the writing. . . . So I think this is part of the writing process, creating the story. (Senior Scientist, Biological Physics)

Adaptive writers are more able to articulate issues around style, beyond simple descriptors of clarity, concision; they are more likely to talk about voice than simply the use of pronouns, and to be able to discuss how voice changes and why, beyond issues of perceived objectivity. They are likely to show a complex understanding of the interplay between words and figures, and they are more likely to challenge disciplinary conventions:

> So there do tend to be constraints, passive voice and so forth, but they're not always followed these days. I wouldn't always follow them. It comes with a kind of maturity, knowing what way you can push the boundaries. (Cameron, Chapter 2)

Routine writers, by contrast, are more likely to see writing as mechanistic, to view writing from a more technical perspective of providing information:

> I don't have to be persuasive in my writing. No. I just have to tell facts. But what I do have to be is clear, I have to be a good writer. (Senior Scientist, Chemistry)

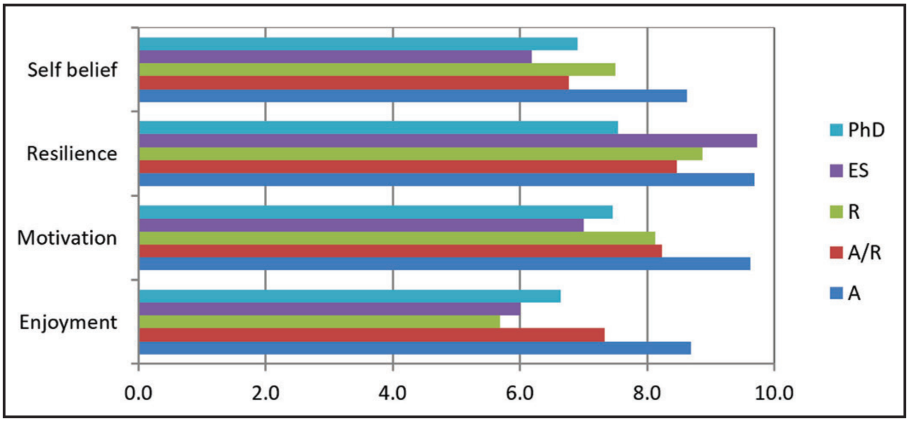

Figure 7.7: Attitudes to writing in all groups

Routine writers stay closer to the model of writing they learned as graduates. For some, the preference would be to dispense with words altogether, and to rely primarily on figures and equations—as they might have done when writing undergraduate lab reports. Routine writers were unlikely to talk about "story"—in fact some saw the notion of story as undesirable:

> And so you have to go back and find the evidence and what does the evidence say? Oh, OK, it actually said this. So when I'm doing strict scientific writing, I keep pulling myself up. I write a sentence and say "oh actually, that's not actually quite right," and reword it according to exactly what the truth . . . what exactly . . . because you get yourself carried away with the story. In fact scientific writing is about presenting the evidence. Not about the story. And I think we've got to be careful not to fall into the trap of telling the story. (Senior Scientist, Plant Genetics)

The transitioning writers were more likely to exhibit similar attitudes and beliefs to the adaptive writers, suggesting either that, in making the move towards a more complex role as a researcher and writer, they must also develop a more complex set of beliefs than they currently hold, or that their attitudes and beliefs are precisely what moves them into a transitioning stage.

If we then put the different groups together—emerging scientists, doctoral scientists and the three groups of senior scientists—we see a more complex picture. The more positive attitudes and complex beliefs of the adaptive senior scientists compared to any other group become much clearer. And while the routine

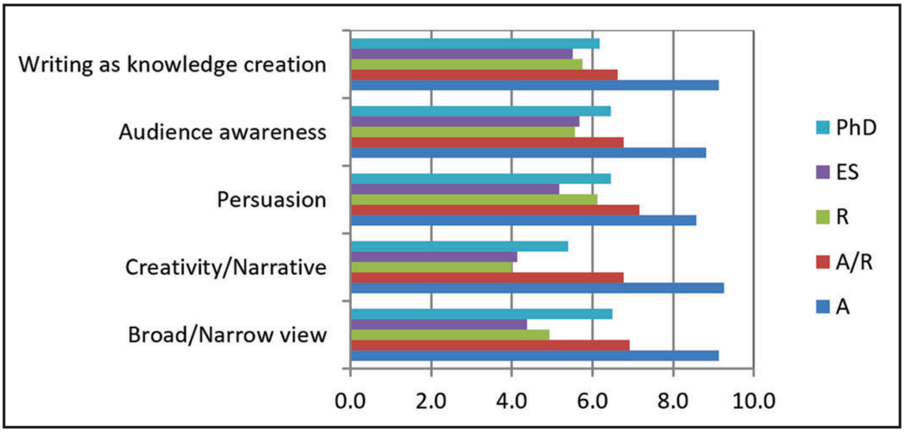

Figure 7.8: Beliefs about writing in all groups

senior scientists remain the most reluctant writers, their scores on self-belief, resilience and motivation remain high in comparison to the other groups.

But in terms of beliefs, while senior scientists clearly have more sophisticated beliefs than any other group, the doctoral scientists' beliefs remain unexpectedly high in relation to every other group.

Setting aside the doctoral students for a moment, what we may be seeing is two distinct yet parallel paths for scientists, predicated on different writing activities corresponding to two sets of beliefs and attitudes: one which follows the lifecycle path hypothesised in Chapter 1 (the adaptive writer), including a sophisticated set of beliefs and positive attitudes, and another path where activities are more consistent (the routine writer), based on more restricted beliefs and less positive attitudes to writing.

An interesting question that therefore arises is whether we can identify those paths in early career, or even early schooling. Do the routine scientists report different attitudes and beliefs in earlier years, and/or did they learn to write differently?

The Growth of the Scientific Writer

The results of this study suggest that childhood influences may be associated with the long-term development of scientific writers. The data show that, while none of the groups rated childhood experiences or attitudes very highly, the adaptive senior scientists and the doctoral scientists had the most positive attitudes and experiences of writing in childhood compared with the other groups, while the routine scientists had least positive experiences and attitudes (figure 7.9).

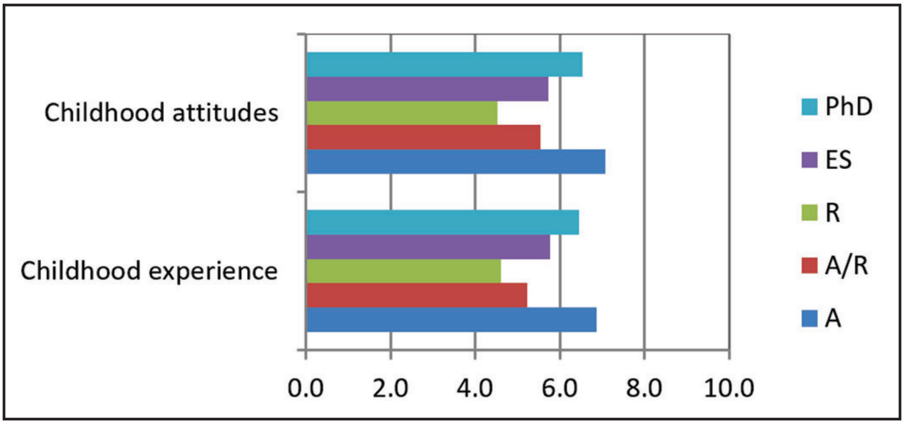

Figure 7.9: Childhood experiences of writing

The routine writers were more likely to have had negative experiences of writing at an early age, most likely to say they struggled with writing in childhood (mostly focusing on the perceived difficulties of creative writing), and most likely to have avoided writing rich subjects in their senior schooling or to see their English teaching as inadequate.

This is not to say that adaptive writers didn't have negative experiences or experience difficulties. Timothy in Chapter 3 is a case in point, but he was not alone—for example, three of the adaptive writers in this study discussed problems with dyslexia at school, and others had had negative experiences with teachers that had undermined their confidence, such as the following:

> I was 8 years old in school in Singapore; I took a cruise with my parents to Hong Kong from Singapore and I wrote a card every day to my class. They were . . . bubbling over with stuff, right, and very messy and, I remember now, the teacher stuck them on the board and said "this is exactly how not to write" because my handwriting was terribly sloppy, so I was obviously creative but I was messy and he made it—he embar—I must have come home and my mother said, "You've stopped writing. What's going on?" (Senior Scientist, Physics)

Some 40 years later, this highly successful adaptive scientist was still apologising to me for the state of his handwriting. But for the adaptive writers these setbacks or negative experiences were overcome—most commonly because they were counter-balanced by some substantial positive support either at school or during the postgraduate years.

Contrary to Martin's (2012) suggestion that scientists are encouraged away from writing-rich subjects at school, most participants *did* take subjects such as English or history right through senior high school, even in countries where taking English (or its equivalent in non-English speaking countries) through senior high school was not required. However, only a small minority said they had learned something about scientific writing in secondary school. Furthermore, those that did suggest that school experiences included the teaching of scientific writing tended to focus on either generic aspects of "good" or "clear" writing, or essay writing (taught in traditionally writing-rich classes, such as history or English), or learning to write lab reports which, as we observed earlier, is not closely related to writing research.

Beyond school, despite the impact of the WAC and WID movements over recent decades, the literature suggests that scientific writing is most commonly learnt indirectly, at post-graduate or doctoral level, through co-authorship, doctoral supervision, and reading and imitation—the cognitive apprenticeship model. This study confirms these factors as important in the development of the scientific writer, but also demonstrates how varied these experiences of learning to write can be for emerging scientists. For some, a doctoral advisor was/is a lifeline in terms of writing and establishing career-long partnerships—for others, not so much. "I think my supervisor might have read my final draft—possibly not" (Senior Scientist, Chemistry) was a sentiment made by more than one participant in this study. For some, immersing themselves in reading in their field made writing a paper feel almost effortless, as if "it just writes itself" (Senior Scientist, Physics); for others it raised questions for which they had no answers and no access to answers. Co-authors' revisions and peer reviewers' comments could be a spur to action or resistance or simply devastating.

More participants had negative or limited experiences of working with a master's or doctoral advisor than those who had positive, constructive experiences. What distinguished most positive experiences was the advisor talking through the changes they were making on a document, but these advisors were a minority. Instead, at doctoral level, if advisors did engage with the writing (and many did not), they were most likely to either rewrite completely, or revise sections without explanation—leaving the student to try to fathom the reasons for the changes for the remainder of the document. This was experienced as highly frustrating:

> I wrote what I thought was an appropriate section in the thesis; it was given to my supervisor and half of it was turned back in red ink as wrong and I felt like I couldn't write anything. So, actually, it was a crisis. . . . I thought I was writing

> better and then I suddenly . . . I thought "what on earth is going on?" I was desperate because I knew I had limited time left to finish the thesis and I thought "that's a huge amount of writing I've just done and it's been shot to pieces." (Emerging Scientist, Food Technology)

Even when advisors did talk the student through the process, as this same scientist found, it was often experienced as highly disempowering:

> I know that the thesis was a reflection of my supervisor's way of writing—it wasn't necessarily my style. I queried my supervisors a lot about it, and I fought the content but I let go on the style. They said "this is how you need to explain it" and so I just, I let them—you know, I had to type it in but they were dictating to me, "this is how you write that sentence out." Somehow through that, I actually learnt something. I think it was just because I did not want to have that happen to me a second time, [that] I was determined to understand what they were saying, not just do what they were telling me to. But that was very difficult. They told me that you are supposed to become independent at the writing, and it's like you are a little child again. I had never had to write that kind of way ever in my life; I have never had to. And I do not resent them for it at all, but I wish that wasn't necessary. (Emerging Scientist, Food Technology)

Perhaps the most significant finding in relation to how scientists perceived they had learnt to write in their discipline was that support post-Ph.D. was the most important factor for all groups, including the routine writers (figure 7.10). Writing with co-authors and in ongoing partnerships, often spanning decades (one senior, award-winning physicist noted that he still sends drafts of his papers to his advisor after 30 years—surely the academic equivalent of never leaving home?), was seen by all groups as the most critical for writing development.

For a small minority of participants (all female), writing groups appeared as a support system at this stage. An unexpectedly large number of participants (almost 40%) had attended a writing workshop/seminar during their career, mostly run by an institution they worked/had worked for. However, only two participants saw attending such a workshop as having a significant influence on their scientific writing or writing practices (see Chapter 4), and this was directly related to the development of a writing group. Most participants who had attended writing workshops attributed their lack of value to leadership by

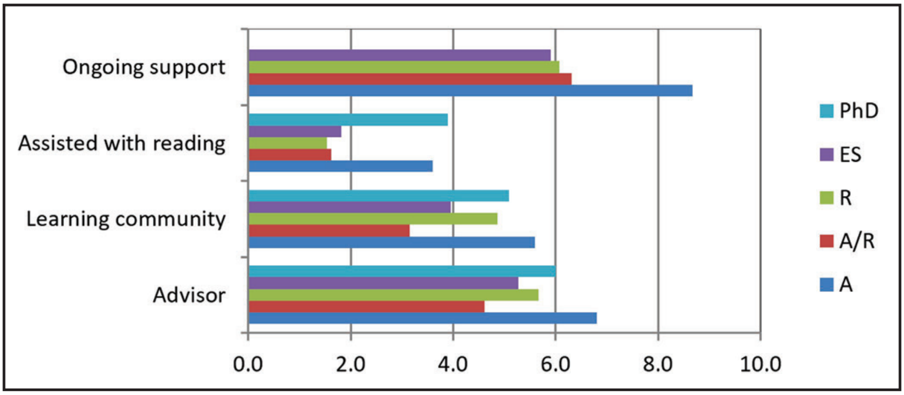

Figure 7.10: Support for writing

people who didn't know about writing in science (see, for example, Wendy's comment in Chapter 3 about the "writing for your doctorate" workshop) or writing in their specific discipline. Positive comments, by contrast, related to convincing empirical evidence that the strategies suggested would work, and opportunities to experience the process of writing science in an authentic setting (O'Gorman et al., 2014).

Mentorship was most commonly discussed as a critical, positive factor post-Ph.D. rather than during the Ph.D. For the emerging scientists, who were at the professional stage of learning to write papers without an advisor, this support was seen as the most significant in comparison to a range of factors during the doctorate.

Adaptive writers and doctoral scientists perceive that they had higher levels of support than the other groups (although the routine scientists do note significant levels of support from their community and a mentor during the doctorate).

Finally, the area where the least amount of support was encountered by all groups was in help with reading. Over a quarter of participants said either no-one had been an influence or a support in their development as writers or that the writings of another author (common influences were "great authors" such as Richard Feynman, Brian Cox, Richard Dawkins and Stephen Gould) were their central influence. A significant proportion of the sample, therefore, was primarily taught to write by reading and imitating the writing of others. I wanted to know what support the scientific writers in this study had experienced in terms of learning to engage with and understand the rhetorical features of writing in their discipline. The answer was: very little.

A few individuals had support in this area. Two emerging scientists, for example, talked about belonging to journal clubs where participants took it in turns to introduce and discuss a journal article. While the primary focus of these clubs was on content, both scientists suggested they had learnt about structure and style while engaged with these discussions. But, generally speaking, scientists in this study experienced a sink-or-swim approach to reading disciplinary texts. For some, this was a successful strategy, but many struggled:

> Because we were never given any instruction or anything or told how to write—it's just a matter of reading journal articles and then trying to [write]; I mean, it was never a conscious thing like I didn't specifically go to an article and think well, right this is how they write so I will go and try and do that; it was just a subconscious way of doing things . . . you get your structure in terms of abstract, introduction, results and so on—and that's basically all you have to go by. (Emerging Scientist, Animal Physiology)

One senior scientist explained this by way of a domestic metaphor:

> My wife is a designer and you know she visually designs things . . . and I look at them and say "I can see that's great because it's simple, it's elegant, it's beautiful, it's succinct visually and yet it conveys the message." But I couldn't create it, I could see it. And the same thing with writing; I can see it in writing but I can't easily create it. (Senior Scientist, Physics)

One of the difficulties with learning to write through unguided reading is that those who manage to this successfully often consequently lack the ability to articulate their understanding to their graduates (Alexander, 2005). The following senior scientist, who writes in three different disciplines, describes how he learnt the different styles:

> You start writing the paper and then you compare it with the other papers [in the new discipline] and there you see [something] that is odd; there is something written in a different way. And then by reading other papers [in the discipline] you absorb the style. The more you read then the more you absorb the style. And actually, for me now it's a kind of a switch in the brain. If I know that it's for a journal I already know, I have a layout of what I have to write in my mind and if I'm in physics the layout is different, you know; the way you order

> your thinking and ideas is different. But then it's something that would be very hard for me to teach to a student. (Senior Scientist, Biological Physics)

A further issue of note is that, while support for reading was low for all groups in this study, adaptive writers were more likely to have experienced such support than routine writers.

IMPLICATIONS OF THIS STUDY

In Chapter 1, I suggested three groups in particular needed to hear the voices of scientists talking about writing: undergraduates, graduate students, and the writing community. But before I turn to these groups, there are a number of implications of interest to the scientific community, and to educational communities in general.

The first is that learning to write science is a lengthy process which occurs from childhood to post-doctoral practice. Furthermore, we limit students' opportunities to develop the capacity, attitudes and beliefs needed to develop as effective writers of science if we focus primarily on the cognitive apprenticeship period. Given the difficulties of shifting beliefs and attitudes (Martinez et al., 2001; White et al., 2005), especially if these are reinforced through poor or damaging educational experiences related to writing in childhood (Brown et al., 2005; Sweeting, 2011; Tapia & Marsh, 2004), the K-12 years may be an important time to embed writing into the curriculum. While some of the participants in this study enjoyed creative writing in the English curriculum, for others it was a damaging experience which either initiated or consolidated beliefs that they were poor writers, that writing was not enjoyable, and that what they learned in English served little purpose and had little connection with their interests and strengths. The only writing any participants remembered within the science curriculum at school—if anything—was the lab report genre which was seen as highly formulaic and requiring no sustained argumentation skills (Lerner, 2007).

While many of the senior scientists in particular experienced their schooling many years ago, and much has changed in our education systems in this time, it is a matter of concern that only one doctoral student and none of the emerging scientists saw school as influential on their disciplinary writing development. Extensive research has been conducted on the impact of integrating writing into the science curriculum at school (see Chapter 1), but the extent to which these initiatives are reaching the students who need them and effecting change is unclear. More efforts are needed to embed writing in the school science curriculum or to broaden the K-12 English curriculum to engage students with scientific interests.

Second, for the majority of participants, the undergraduate years were equally devoid of authentic opportunities to engage as writers of science or to adjust the attitudes and beliefs about writing they had acquired as children. Again, given the impact of WID and WAC, this is somewhat surprising, especially in relation to the doctoral and emerging scientists, and we need to treat the results here with caution, since many of the senior scientists' undergraduate years occurred before the impact of these initiatives. But we might question the extent to which WAC and WID are reaching undergraduate programs and whether they are designed to meet the needs of our science students.

Nevertheless, the doctoral scientists' anomalous scores on almost all variables in our model are grounds for cautious optimism in relation to the impact of secondary and undergraduate education on developing scientists' preparedness for writing. Contrary to a hypothesised stages model of development, they appeared to have more positive attitudes and more sophisticated beliefs about writing and the role of science than any group apart from the adaptive senior scientists. And while their experience of support was low, it was still higher than that of the emerging, transitional or routine scientists on most variables.

As we have already noted, these anomalous findings may be a consequence of the size of the sample or the way the sample was chosen, and so any conclusions must of necessity be tentative. However, we might speculate, on the basis of comparatively high scores related to childhood experiences and attitudes, that changes in the school curriculum related to both science and writing (or English) are having a positive impact. These scientists did not *report* experiences of learning to write science in school or the undergraduate years, but their more positive attitudes and sophisticated beliefs suggest that they have somewhere experienced some effective teaching related to writing and/or scientific writing. Further research with a larger random sample of doctoral scientists is needed to examine whether these findings are generalizable.

What is even more encouraging in relation to undergraduate education is that, for the two participants who had experienced an integrated and authentic writing programme during the undergraduate years, the impact was profound. Both were of the view that, by the time they reached the doctorate, they knew how to read disciplinary texts and how to write. While I have suggested that this study throws little light on the impact of WAC and WID, it does nevertheless confirm the importance of these endeavours, and the difference they can make to those who choose to pursue a career in research science. Perhaps the greatest strengths of WID are its capacity to lay down a foundation of beliefs relating to the relevance of writing to science (the purpose of text and the role of the research scientist, the social context in which science is made, and the role of rhetoric) and to transform attitudes, provide motivation to write, reinforce the need for resilience, and restore self-confidence (Driscoll, 2011; Pittam et al., 2009; Rivard, 1994). These attitudes to, and beliefs about, writing are of vital importance in building the scientific writers of the future. Even if academic institutions are not prepared to fully adopt or resource WID programs in the sciences, one of the clear indicators of this research is that some way of engaging undergraduate science students in authentic writing activities would make a great difference to these students' ability to transition into research science.

The third major finding of interest to the scientific community is that the cognitive apprenticeship model, while laudable in theory, in practice is not always all it could be. Sometimes it works. Most of the senior scientists I interviewed saw themselves as teachers of writing, and some showed a sophisticated approach to supporting their students, including an emphasis on enabling the emerging scientist to develop their own style or voice:

> Your job is not to give them the ladder. Your job is to guide them to construct their own ladder. . . . One of the things I say to my students all the time is "my job is not to tell you what to think. It is to help you to understand how to think." In this context, I would say "my job isn't to tell you what to write. My job is to help you develop the mechanisms you will use to write in your own way." And there will be constraints. You may want to write in this way or you may want to write for that audience, and that way may not be appropriate. So you have to learn how to write for that audience. . . . the job of the supervisor and the other people—effectively scientists in this context—working with their colleagues as well as students is to quite consciously draw out the mechanisms that they use, and in this case to build their own ladder, and the more rungs you have on the ladder the more you can push forward. (Lemrol, Chapter 5)

One of the most difficult experiences of the doctoral students (or those remembering their doctoral experience) was uncertainty about asking for explanation from someone who is extremely busy and more senior—and who they experience as highly critical. Yet most of the senior scientists I interviewed felt a strong sense of care for their students, and sometimes the problem was really just part of the muddle of human relationships:

> One of my Ph.D. students told me two or three weeks ago . . . that I didn't care about the project anymore; I wasn't interested. And I said "of course I am—I'm just really busy."

> And then I got an email from that student on Thursday or Friday last week . . . and she said "I wish I'd not said that to you." And I just replied and said "I'm really glad you did because you need to make me aware of that, and you also need to remember—well for me at least—you're like my family. You're the most important part of my working life. You're the ones that keep me going; you're the ones that make the new compound." I mean, they've given me the buzz and the drive and I feed off their enthusiasm. And I also said "you've got to remember that, like my family, you see me when I'm most tired, most grumpy; you get the poorest quality time of everyone else. And that's wrong and I'm sorry, but that's how it is." (Senior Scientist, Chemistry)

But problems remain around the doctorate. Part of the problem lies simply in the uncertainty around the advisors' capability and willingness to engage with their doctoral students' writing. It seemed some students were lucky and others were not:

> I think our system of teaching graduate students to write is pretty bad because there is nothing that is really implemented and it's all left to the individual, so it's a bit of luck. If you come into a group where there is a supervisor that is caring, you get some support. If you go into another group you get absolutely nothing. (Senior Scientist, Chemistry)

For some there were ways around deficiencies in their advisor's capacity or willingness to engage: some called on support from their lab partners (e.g., a more experienced student, like Jane in Chapter 3), others found another mentor outside of the doctoral process, while others called on family members (e.g., parents or partners—see Grace in Chapter 5) or friends, some of whom were scientists and others "just good writers." But the fact that over a quarter of participants could identify no form of support, and that many others who did experience support had no help in interpreting revisions, remains a matter of concern.

And it was a matter of concern to the advisors too (Maher et al., 2013). Many of the participants in this study struggled in their role as a teacher of writing: "I'm not an English teacher!" was a common . . . no, not complaint, more like a heartfelt cry. While some, such as Richard and Lemrol, had a firm grasp on this role, others struggled with this turn in their careers, feeling ill-equipped and ill-prepared. And we could see this as a general problem of doctoral supervision—whatever our discipline, we may all struggle with learning the strategies of graduate advising—but I would argue that the problems are more acute and have greater impact in the sciences (Gardner, 2007, 2010; Golde, 2005, 2010; Rodriguez et al., 2012). It would be a rare humanities scholar who gave up writing their own research, and whose writing then primarily constituted forming co-authorship relationships in which their role is editing the work of others. Yet this is precisely the career turn that many university-based scientists seem to take (Maher et al., 2013), not many years past the submission of their own doctorate. The difficulties of engaging in this role (Lee, 2008; Paré, 2011) therefore have a career impact on both the advisor and the emerging scientists with whom they are working. Emerging scientists' difficulties with writing have implications for the advisor's career—a situation that is not replicated (or at least, not to the same extent) in other parts of the academy.

So, are standalone workshops on scientific writing the way forward? The problem is credibility, of writing being validated by someone who is perceived as credible (see Richard, Chapter 2), and socialisation (Brown et al., 2005; Ding, 2008). WAC and WID instructors are aware of the issues of authenticity and socialisation, but since WAC and WID course are perhaps most often focused at undergraduate level, we may be missing opportunities to grow our emerging scientists as writers in these final years of formal education. Instead, my suggestion is that we need equip scientists—and students—with an ability to articulate their rhetorical decisions (Beaufort, 2004). They need a language with which to *talk* about writing. And perhaps this is where the writing community can be of most use. Perhaps collaboration between science and writing faculty through WID is the best way to ease this pathway, as long as we are prepared to genuinely listen to one another and if we continue that collaboration further into doctoral advising. Whatever method is used, this study suggests that the scientific community would benefit from examining the way scientists are prepared to become teachers of writing. The current system is too unreliable for both the senior scientists, who often exhibit considerable anxiety around mentorship in relation to writing, and for the emerging scientists they are advising and with whom they are engaged in co-authorship.

The fourth significant finding of this study is the possibility that, beyond the predictable turn in most academic scientists' careers from writer to teacher of writing, scientists make choices about remaining on a narrowly focused disciplinary path or broadening their scope as both scientists and writers of science: the routine and adaptive pathways. Furthermore, writing (and differences in attitudes to and beliefs about writing, their role as a scientist, and the purpose of science) is central to the choices they make. It is clear that routine and adaptive scientific writers have equally valid career paths, and both are essential to the progression of science. But if we feel that scientists' engagement with public discourse around science is important, and that more scientists need to engage with non-scientific audiences (Brownell at al., 2013; Greenwood & Riordan, 2001; Leshner, 2003; Olson, 2009), then preparing emerging scientists for an adaptive role may mean working with their beliefs and attitudes, perhaps from an early age, and providing more support for them as writers.

What this study has not been able to achieve is an answer to the question of causation. While we have been able to show that routine writers are more likely to have negative experiences of and attitudes to writing as children, there is no clear causal link—indeed, some scientists with very negative childhood experiences of writing went on, with ongoing and positive support, to become high-profile adaptive writers. Similarly, it is not possible to ascertain whether different attitudes and beliefs caused or were a consequence of the choice to become an adaptive or routine writer (Chamberlin, 2010; Sweeting, 2011). Some participants in this study were able to identify the impetus to broaden their audience—some wished to kick start a new direction in their career, others were ambitious for research funding and saw reaching out to cross disciplinary teams as a way to achieve this; others were encouraged by senior mentors or advisors. Further research is needed if we are to understand these choices and develop pedagogy to address them. In the meantime, the challenge for the scientific community is to begin to model and articulate the attitudes and beliefs towards writing they wish to see in their graduate students.

Implications for the Writing Community

There are many possible implications from this study for the writing community, not least of which are the significance of the undergraduate years, the value of engaging with attitudes and beliefs, and the importance of seeing the scientific community as diverse in ways that go beyond disciplinary differences. However, I want to focus on just two issues here.

The first issue is a question of trust—and listening. A comment in an early WAC text has stayed with me throughout my career of working as a teacher and researcher in the sciences:

> [The engineering professor] fixed me with his eye and went on to say that we across the disciplines don't trust each other. I think he was right. My experience [of WAC] has, however, illustrated for me my own biases and lapses of trust. I am more aware that we college instructors . . . walk a common ground. Unfortunately, this common ground is often

> obscured by disciplinary boundaries and professional loyalty. (Yancey & Huot, 1997, p. 77)

Mya Poe, Neal Lerner, and Jennifer Craig (2010, p.199) end their book with a frank discussion of the relationships built through their WID program, commenting on the learning and frustration of engaging in a collaborative relationship with STEM faculty:

> Such reciprocity is rare in academia, where faculty often stay in their respective disciplinary territories and only occasionally venture to the other side of the campus for day-long teaching workshops. At times our collaborations have been frustrating, as our values and background knowledge seem so disparate. Yet with each iteration of our work we have come to better understand and appreciate the varied perspectives we both bring. . . .

The need for effective dialogue is generally seen as the cornerstone of collaboration—Brammer et al., 2008, for example, outline the history of conflict in cross-disciplinary pedagogical collaborations and pick up Pratt's (1991) concept of the "contact zone" as a way of finding common ground. "We must," they argue, "resist both colonizing and bring colonized," suggesting that "real" dialogue about learning to write will reveal, between writing teachers and faculty from other disciplines, more commonalities than differences.

But I would argue something quite different. While common ground is important, there is danger, in searching for those places where we meet, of failing to realize that the language we share (such as collaborative writing and peer review) may, in our different cultural contexts, means quite different things. I would also argue, since the research to date into scientists' perspectives of writing has primarily differentiated the scientific writer only by discipline or by a novice/expert divide and failed to see the immense complexity of the scientific community, that true dialogue has been hard to find.

Perhaps we need a new word that takes us beyond "dialogue." In Maori, the word *kōrero* (both a verb and a noun) means conversation, but a particular kind of conversation that prioritizes both respectful listening and authentic engagement (Soliday, 2011). I would suggest that it is by engaging in the *kōrero* that we become less fearful of the differences between us; that in the *kōrero*, instead of seeking out commonality, we will see differences more clearly and perceive those differences not as barriers but as energizing and creative opportunities. In this process, we will begin to see an altogether more differentiated story of scientists as writers—a story that has exciting possibilities for collaboration and pedagogy.

How do we engage in this way? There are some obvious starting points, such as taking time to ask questions of our STEM colleagues and listening for differences instead of commonalities, listening for the *taonga,* the unexpected story. But perhaps there is also a role for the writing community beyond its current limitations of collaborating with science faculty through WID and WAC during the period of formal education. Perhaps there is a place for writing teachers within WAC or WID programs to work alongside scientific research communities to help articulate, *within research teams*, the role of writing in research, and to provide greater access to language that would make writing more visible, more conscious, more manifest (Artemeva, 1998).

Three significant outcomes would emerge from this: first, emerging scientists may have more direct access to conversations about disciplinary writing, which would ease their transition to becoming writers within their discipline. Also if, as some of the participants in this study suggested, communicating across disciplines and to the broader public, is a moral, social, and economic imperative of science, then integrating writing teachers within research teams could provide a transitional non-scientific audience and a language and incentive to invite the "deep" conversations about the relationship between writing and science, and could thus enable existing learning communities in science to become expert writing communities (Bereiter & Scardamalia, 1993), extending their science beyond their disciplinary boundaries. But most importantly of all, writing teachers would gain from a more authentic engagement with, listening to, and understanding of scientists writing; much as we have to contribute, we have more to gain (Brammer et al., 2008; Mullin, 2008; Segal et al., 1998).

Implications for Students

There are multiple implications from this research for both undergraduate and graduate students in STEM. We might point to the broader findings related to the significance of writing, and attitudes and beliefs about writing, in relation to career direction. Or we might focus on the need to find an advisor or mentor who can talk about writing, the importance of learning to read not just for content but for the structural and stylistic attributes of a text, or the value of perceiving learning to write as a more intentional part of the cognitive apprenticeship process.

But, instead, in these last pages, I'd like to point to something else. My hope is that the students reading this book will focus on the particular experiences of the scientists who tell their story as writers of science. I hope they will be encouraged into resilience by reading of the struggles of the successful senior scientists, some of whom have overcome significant obstacles to become scientific writers:

> I was not born writing the way I write today, I had to struggle and learn exactly what you have to learn. (Lemrol, Chapter 5)

> I wouldn't say I'm a good writer now. I write terrible sentences and I have to correct them. I know how to do that. But, you ask me to write a paragraph and I write it down and then I read it back and I think "oh my God!" It seems OK as it's coming out of my head, but it's not OK when you read it . . . It's never gone away; I never find it easy. . . . But I do have a revision facility. (Timothy, Chapter 3)

> I remember taking an English class at university and I was lost. I was like, "I don't know what any of this stuff is." I just did not come from a really strong place and it's literally just been practice and good advice. And lots and lots of support. (Lizzie, Chapter 5)

I hope that, in reading these stories, they will see behind the confident exterior of their professors to the emerging scientist they once were, struggling with dyslexia, puzzling over the enigmatic scribblings of their advisor, staying home to write in their pajamas. They too found—and often continue to find—writing hard.

I hope the students reading this text will have learnt something about managing the gatekeepers, of knowing when to pull themselves together and learn from critique and when and how to resist (Lemrol, Chapter 5; Catalizador, Chapter 6). I hope they will have been empowered to articulate to their advisors what they need as writers: that they need not just corrections or revisions, but someone to talk through the revisions so that they can make more intentional and conscious decisions about writing; that they need a learning community that can engage with uncertainty about writing.

I hope they have learned something about writing process, particularly about writing from the inside of the paper outwards and the integral structure of a scientific paper:

> What I think young writers do is they write their intro first and it becomes this big blathering of everything they've learned on the topic and that's not what a journal wants to hear and it's not what a reader wants to hear. . . . you should write your results first, and then write the methods that explain your results. You don't write everything you did—you write only the methods that explain what you want to talk about. Then you write your discussion, which doesn't talk

> about anything except the results that you presented, and then you go back and write the intro that would lead you into that. That's very different from writing the intro by talking about the subject, especially when you're given the task of "do a literature review on everything that has to do with your topic." (Eugene, Chapter 4)

> [T]he whole structure of the paper is constructed around the hypothesis and the aims. So for example, let us say you have the hypothesis "if x then y." In writing the introduction you have to introduce x, you have to introduce y and you have to introduce the relationship between the two. Your hypothesis "if x then y," also determines your aims. The aims then automatically determine your materials and methods. And the aims then also automatically determine the laying out of the results. And the relationship between x and y automatically determines the structure of the discussion. (Elizabeth, Chapter 4)

I hope they've learned something about the centrality of the story and how that story can emerge from the "pictures" (as Richard discusses in Chapter 2) or from talking with others (Gao in Chapter 4).

And I hope they've learned something about agency, about how, in the absence of an effective mentor, they may seek out help from lab partners (Jane in Chapter 3), family members (Grace in Chapter 5), and friends; that they'll feel empowered to set up journal clubs and writing groups (Elizabeth and Sally, Chapter 4) and to build a supportive learning community around them. That they will understand that such groups do not need expert leadership, they simply need a group of peers who are willing to work with uncertainty together.

Perhaps most of all, I hope the students reading this book will pick up Richard's claim that "science is a youthful game," that they have a crucial role to play in both moving science forward and in engaging with the public understanding of science. I return to Randy Olson's comment (p.8) about the public's fear and rejection of science:

> It is a genuine threat to society. In the midst of this conflict, communication is not just one element in the struggle to make science relevant. It is *the* central element.

The hope of many of the scientists in this study lies with the young scientists who are emerging out of our classrooms and laboratories today:

> It is vital that these young people are able to think about these questions, think about context, think not just about the economic value but about the human consequences, the ethical issues that sometimes arise in science. Also to communicate the beauty and the passion around the subject and get people excited. So they see that science is . . . it's a wonderful thing. (Richard, Chapter 2)

LIMITATIONS OF THE STUDY

I was reminded, as I reread the interviews towards the end of this study, of the prevailing notion of "story" in this text, and Catalizador's observation that we are all engaged in writing stories:

> But when scientists give a talk, all of a sudden telling their audience about all those byways and the obstacles, the hill that prevented them, the hero of the monologue, from seeing the solution, becomes a natural process. With one proviso, that the hero always gets over the hill. So I listen closely to the narrative structure of the seminars; with a little work, I could tell them which Aarne-Thompson type of tale they were recounting. And of course this is so—because the speakers are human, and they're talking to other humans.

The primary aim of this research has been to offer a *taonga*, to tell a story, to invite the reader into the *kōrero,* into an engagement, at once empathetic and critical, with a series of voices that tell of scientists' experience of writing science—and to provide more insight into the diversity of how scientists see the relationship between writing and science.

There are, however, limitations to this study in terms of its secondary aim of providing a nuanced story through story analysis. While the sample size was larger than other studies that have engaged with scientists' perceptions of science, it still has limited scope, and the purposeful sampling technique means that the sample cannot be considered representative. It is highly likely, for example, that a more random sample would show a higher overall proportion of routine writers; this is reinforced by Yore and associates' work which clearly defines scientists' perceptions of writing from the point of view of the routine scientific writer. A larger sample of doctoral scientists is needed to give a clearer perspective on whether the changes indicated in this sample are more broadly applicable or how extensively changes in the curriculum and WID programs are impacting on science education. A larger sample of female scientists is needed to show whether women experience different levels of support as writers and whether they are supporting each other differently. A study which intentionally collected data from a limited number of defined disciplines would allow for a comparative analysis across disciplines.

The data collection methods used in this study present a retrospective picture of the scientist as writer. Apart from issues of reliability, which were discussed in Chapter 1, some of the experiences of the senior scientists—their experience of their education, for example—may be no longer applicable in a changing educational, social, and technological context. This study has addressed this issue by using a varied sample, so that the experiences of younger scientists (emerging and doctoral) can be compared with those of the senior scientists. A longitudinal study may provide richer and more reliable results, but this presents obvious challenges and will be someone else's work.

The data collected during this study is more extensive than could be discussed in one text. Numerous other themes could have been pursued, such as more in-depth discussions of scientists' struggle with the word "persuasion," their writing process, how the way they read a scientific paper often contradicted their explanation of why they wrote the way they did (Bazerman, 1985), how they perceived the relationship between words and figures, and perceptions of the scientific paper as primarily pedagogical. In this text, these themes were simply part of the context of a more focused analysis.

The *Taonga*: "We have to communicate the beauty and the passion"

Three unexpected words recur through the interviews in relation to writing science. The first two were "beauty," and its close cousin, "creative." While several participants deplored the quality and ugliness of scientific writing, many other participants talked about its capacity for beauty. Catalizador is somewhat disparaging of scientists' views of beauty as simplicity, while at the same time seeing the equation as fundamentally poetic. But simplicity was not what constituted beauty for most of the interviewees who discussed this. Instead they were likely to talk about clarity, accuracy, and effective story-telling, about shaping a narrative creatively so that it would engage rather than simply inform a reader.

The other unexpected word was "fun." "Why did you choose to write across disciplines/take up blogging/write poetry?" I would ask—and again and again, the response came back: because it's fun. I was left with the enduring sense that many scientists—in particular, the adaptive scientists—enjoy risk when it comes to writing. Often I asked the *why* question when someone had just finished outlining in detail the trauma of learning a new way of writing or of engaging with a new audience, or of feeling exposed in new ways. In fact, I can think of only one participant who actually suggested writing was easy; for many it was hard . . . but fun.

In thinking over this whole study, I keep coming back to Gao's comment about his choice of discipline: "I learned in my graduate programme that you're supposed to identify hard problems to work on and you're supposed to take your creativity and solve hard problems." It seemed to me that writing—and continually choosing to develop writing in new ways—was, for many of the scientists in this book, about taking their creativity to work on "a hard problem," but one that most of them actively chose to pursue, at least in part, because it was creative and fun. Many—perhaps most—are poorly prepared for this hard task, and their apprenticeship for writing science is intrinsically and intuitively intertwined with the disciplinary apprenticeship they encounter from graduate school onwards. Yet, as they engage with a changing social context for science, they are engaging as individuals and as communities, in the hard task of writing science.