

## CHAPTER 20.

# THE LIFE CYCLE OF THE SCIENTIFIC WRITER: AN INVESTIGATION OF THE SENIOR ACADEMIC SCIENTIST AS WRITER IN AUSTRALASIAN UNIVERSITIES

**Lisa Emerson**

Massey University

[T]here has been a great deal of research on writing; however, there has been less consideration of ... the transition from novice to expert science writer. (Yore, Hand, & Florence, 2004, p. 673).

Despite extensive interest in teaching writing in the sciences and the rhetoric of science in recent years, the beliefs, attitudes and practices of the senior scientific writer remain largely unexplored. While many resources on how to write scientific documents are available,<sup>1</sup> Morris and Murray (2001) and Bishop and Ostrum (1997), both commenting on the scarcity of research exploring the writing process of academics more generally, suggest that there is a gap between the writing processes described in such texts and “the real contexts and practices of [academic] writers” (Morris & Murray 2001, p. 3), and that empirical research on the writing practices of academic writers is needed. Recent empirical research on academic scientists as writers by Larry Yore and his associates between 2002 and 2008 explored the practices and beliefs of scientific writers post-PhD. The present study focuses on a smaller section of the academic scientific community, the senior scientific writer, hypothesising that this subset of the scientific community, in line with Dreyfus and Dreyfus’s model of expertise, will exhibit specific attitudes and beliefs and engage with a wider audience than that identified in the studies of Yore and his associates.

## EXPERTISE AND THE CHARACTERISTICS OF THE EXPERT SCIENCE WRITER

Traditionally, experts have been characterised, in contrast to the novice, by the extent of their knowledge and complexity of their skills (see, for example, Berliner, 1994; Carter et al., 1988; Livingston & Borko, 1989).

Advances in the field have challenged both a simple expert/novice dichotomy and the notion of expertise as skills and knowledge accumulation. Dreyfus' five stage model (Dreyfus, 2004; Dreyfus & Dreyfus, 1986, 2005), an influential model of expertise development, characterises expertise as developing through five stages (novice, advanced beginner, competent, proficient and expert) which outline a progression from explicit rule-following and detached, analytical engagement at novice level to advanced, intuitive "know-how" based on experience and engagement at the expert level.

Experts, according to Dreyfus' model, exhibit a number of characteristics. First, their expertise is *context-specific* and achieved by situational experience acquired over extensive periods (Dall'Alba & Sandberg, 2006). Second, they exhibit specific *attitudes* to their work: they are engaged and emotionally invested in working to a standard of excellence based on internal discipline rather than external supervision (Benner, 1984, 2004). Third, their *practice* is based on tacit understanding of context, practice and discipline which they have built up over an extensive period (Dreyfus, 2004); and finally, experts have a holistic view of complex situations within the context of practice, and are able to engage both analytical and intuitive understandings of a situation dependent on their understanding and experience of context (Dreyfus, 2004). Benner (2004, p.189), following Aristotle, characterises this as exhibiting skills of both *techné* (standardised routines in practice) and "*phronesis* (situated actions based on skill, judgment, character, and wisdom)."

Dall'Alba and Sandberg (2006), in their critique of this model, argue that "understanding of and in practice" is another vital component in the development of professional capability and that an individual's *beliefs* about the nature and purpose of their practice may define an individual's ability to attain expertise.

The literature on expert science writing has tended to focus primarily on the novice-expert distinction, and is largely informed by older models of expertise based on skills and knowledge. For example, Fahnestock and Secor (1986) focus on the expert writer's ability to engage with the needs of a scientific audience, Holyoak (1991) on expert writers' writing strategies, and Carter (1990) and Geisler (1994) on expert science writers' knowledge of both general writing and discipline-specific writing skills.

Florence and Yore (2004), however, suggest that expertise involves more than “stacking additional skills and knowledge on pre-existing competencies” (p. 640). They observe that expertise in science writing involves “a complex interplay of cognitive abilities, emotional dispositions, strategies, metacognitive awareness, executive control, domain knowledge, and discourse knowledge” (p. 640).

## **ATTITUDES OF EXPERT SCIENCE WRITERS**

Although Dreyfus (2004) sees attitudes as a critical factor of expertise, research into senior scientists’ attitudes to writing, ie the extent to which they enjoy or feel confident about writing, has been very limited. James Hartley and Alan Branthwaite (1989) in a study of academic psychologists, noted that the most productive writers in psychology had positive attitudes to academic writing, and felt that their writing was important to them (see also, Hartley & Knapper, 1984). They identify attitudinal distinctions amongst writing-active psychologists, that of “anxious” and “enthusiastic” writer, noting that those who enjoyed writing were less anxious and most productive: writing anxiety decreased with experience and productivity.

A more recent study, Florence and Yore (2004), following Daley (1999) identifies specific emotional characteristics of expert science writers, seeing them as driven individuals, continually dissatisfied with present understandings (Bereiter & Scardamalia, 1993), passionate about disciplinary investigation, and compelled to write by their passion to contribute to a continuing disciplinary debate.

A somewhat broader literature has gauged academics’ attitudes towards professional writing. Rodgers and Rodgers (1999), for example, show 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), and confidence (Morris & Murray, 2001; Shah, J., Shah, A., & Pietrobon, 2009) have also been identified as key characteristics of successful academic writers.

## **BELIEFS**

Dall’Alba and Sandberg (2006) suggest that a practitioner’s initial beliefs about the nature of a particular practice are an important determinant of the path to expertise. Florence and Yore (2004), Bereiter and Scardamalia (1987) and Keys (1999), by contrast, see beliefs as shifting over time, suggesting that while novices see scientific writing as knowledge reporting, ex-

perts see the purpose of writing as being the construction or transformation of knowledge.

However, the latter construction of expert beliefs about scientific writing was not supported by Yore et al. (2002), Yore, Hand, & Prain (2004), and only tentatively supported by Yore, Florence, Pearson, & Weaver (2006). Yore et al. (2004) conclude:

the [beliefs of the] prototypical science writer ... did not match the literature-based image [that expert writers see writing as knowledge building<sup>2</sup>]. These scientists perceived writing as knowledge telling not knowledge building (p. 346).

Not only did the beliefs of Yore et al.'s participants not conform to the literature on writing expertise, they also didn't conform with the scientists' stated understanding of the nature of science. Yore et al. observe (2004) that participants in their studies described writing in language associated with a traditional positivist view of science, even when they held a more modernist view of the nature of science. However, they do note that "the metacognition [of these scientists' views] of written discourse was tacit" (p. 346), observing that the scientists did recognise that drafting enabled them to construct a clearer story, but without conscious awareness of clarification as construction.

Related to this connection between beliefs concerning the nature of science and the purpose of writing is the question of whether scientific writing is persuasive. Yore et al. (2002, 2004) suggest that although scientists are unlikely to believe their writing is persuasive, nevertheless, they do use writing for persuasive purposes.

According to Dreyfus' model (2004), one of the difficulties of identifying the beliefs of expert practitioners is that their understanding of their purpose and practice is intuitive. As Benner (2004) observes of expert nurses: "situated practical innovations or sensible variations in practice may seem intuitively obvious to the [expert] practitioner and might not be easily captured in a narrative description of the situation" (p. 196). Such observations might equally be applied to academic science writers, most of whom learn scientific writing not by instruction but by observation and engagement with senior practitioners followed by extensive practice (Florence & Yore, 2004; Jacoby & Gozales, 1991), and whose beliefs about writing may indeed be tacit. Observation or close analysis of writers' descriptions of their writing process may yield a more useful understanding of scientists' beliefs about writing than direct questioning.

## WRITING TASKS AND AUDIENCE

Yore et al. (2004) comment that novice scientists most commonly begin their professional life by writing for the disciplinary community related to their doctoral research, “but some scientists belong to several discourse communities and cross borders among these communities, dealing with the public awareness of science, professional education of scientists, and multiple research interests” (p. 344). Similarly, Bazerman (1998) suggests that science communication begins with communication within a narrowly defined disciplinary community and then spreads into the public arena. Bazerman (1988) further suggests, more generally, that competent writers tend to cross disciplinary boundaries and conventions rather than writing focusing narrowly on the requirements of a single discourse community—which may lead to the expectation that senior scientific writers would engage with a range of audiences, both peers and public.

However, the findings of Yore et al. (2002, 2004, 2006) in relation to writing tasks suggest that expert science writers are not broadly but narrowly focused in terms of audience and task. Their conclusions are somewhat contradictory, but four clear findings emerge from the composite data: most scientists write primarily for teaching purposes; they write secondarily for the small number of journals that they read within their discipline; scientists are unlikely to write across disciplinary boundaries or for a general audience; and they do not see communicating with non-scientific audiences (other than students) as a necessary role of a scientist.

Within these narrow constraints, Yore et al.’s findings (2002, 2004, 2006) suggest science writers are highly cognisant of audience and skilled in writing in a way that suits their disciplinary discourse community (see Fahnestock & Secor, 1986; Ferrari, Bouffand, & Rainville, 1998). However, the extent to which expert scientists can articulate their rhetorical choices remains largely unexamined.

In relation to task and audience, there are some weaknesses in the studies of Yore and his colleagues. In particular, the range of tasks examined did not include some common activities that might be expected of senior academic scientists, e.g., rewriting or editing for co-authors, or reviewing for journals. Furthermore, only two non-scientific genres beyond lecture notes were investigated: letters to the editor and essays/short articles (conflating science and non-science publications). This study addresses this problem by investigating a greater range of publication types.

## METHOD

This study investigates a subset of the scientific community in Australasian universities, the senior academic science writer, using the Dreyfus and Dreyfus' (1986) model of practitioner expertise in the context of research into academic scientific writers. The participants for this study comprised 20 university scientists (thirteen male and seven female) who had achieved the status of associate professor or professor<sup>3</sup> from seven universities in Australia and New Zealand. The sample included theoretical (e.g., physicists) and applied scientists (e.g., researchers in human and animal nutrition, and environmental economics), with an aim of sampling as wide a range of scientific disciplines as possible. The sample was collected using a snowballing effect, asking participants to identify colleagues in related (but not identical) disciplines who were senior scientists, with a high publication rate, who might be interested in participating. The sample's median experience as research scientists was 25 years (dating from the completion of the PhD). All were prolific writers: several participants had published over 200 peer reviewed scientific papers as well as text books, book chapters and industry reports.

Data collection methods used were a questionnaire and a semi-structured individual interview. The questionnaire collected demographic and quantitative data for comparative purposes and identified common writing activities. Participants were asked to identify writing tasks they had engaged with in the last six months out of a list of 22 items including pre-writing activities (such as brainstorming and note-taking), writing tasks in a range of genres (such as writing a journal article, industry report, web-page, popular science article or piece of fiction), post-writing activities (e.g., reviewing the writing of a colleague or co-author), and quality assurance tasks (e.g., peer reviewing for a journal or editing a journal). Participants were then asked to identify up to five items which had taken up most of their professional time in the last six months. Nineteen out of 20 participants returned a useable questionnaire.

The interview was semi-structured, including questions covering writing process and environment, attitudes to science writing, issues of audience and persuasion, and how participants had gained skills as writers of science. These were followed by specific questions which arose from the questionnaire. Interviews ranged in duration from one to three hours. All 20 participants completed the interview. Interviews were transcribed and coded by hand.

## RESULTS

The results have been analysed by addressing the sample as a whole: because the sample size is not large, and there was very little disciplinary

overlap, analysing the senior scientists by discipline was not appropriate in this study.

## ATTITUDES

Benner's (2004) and Dreyfus' (2004) suggestion that experts tend to be emotionally engaged with their practice was strongly supported by this study. The overall attitude of the senior scientists to writing was strongly positive. Given that this group of participants were highly productive writers, this supports the findings of Hartley and Branthwaite (1989) that highly productive writers were likely to be more positive and less anxious about writing. Eighteen participants said they enjoyed writing, and most spoke with passion about, not just their science, but also their science 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.

When asked to rate themselves on a scale of one to ten, where 10 is an excellent writer, 17 rated themselves as seven or above, indicating a high level of confidence.

Most (16) participants were confident enough as writers and scientists to engage robustly with peers and reviewers rather than simply accepting critique:

So eventually, after about eight or nine papers where he had done this I wrote to him and said "I know you're trying to be helpful; I really appreciate the effort you're putting in; but to be perfectly honest, I think you're going over the top, because I believe you are now trying to convert my writing into your style. I'm very happy to accept the things that really do make it clearer, but I frankly want to retain my style" ... He got back and he said "yeah yeah fine. No problems. Take or leave what I say as you see fit."

Although most of the group classified themselves as confident writers, all, at some stage in the interview, discussed situations where they became anxious

about writing. Generally this related to writing to an unfamiliar audience or in an unaccustomed genre, or writing for a high stakes journal with a specific and tightly controlled style such as *Nature*. However, many participants discussed this anxiety in positive terms:

I do quite a lot of outreach type of activities and sometimes that involves writing things that are very non-specialist and I try to write them in ways that people who don't have scientific backgrounds can understand. It's challenging, but I enjoy doing it.

Only three participants could have been classified as anxious writers (Hartley & Branthwaite, 1989). However, these writers had developed strategies for overcoming their difficulties, mainly through collaboration with colleagues who were more confident or proficient writers.

Generally, participants wrote because they were compelled to do so by their passion for their discipline and not by external pressures. Without exception their attitudes to external systems designed to compel a certain level of productivity<sup>4</sup> were negative, with many of the participants suggesting such external controls were not conducive to high-quality science research, which was their primary concern.

Attitudes to popular scientific writing varied. All participants commented on the importance of communicating with the public about science, but they were divided on whether they enjoyed or felt confident writing in these genres. Several spoke of the pleasure of writing to groups who would be actively using their work (e.g., growers), or of enjoying the challenge of writing science for lay people (e.g., a newspaper column or a school text) while others saw writing for the public as their biggest and most fear-inducing challenge.

## **BELIEFS**

All participants believed writing is not simply reporting science but part of science, both in relation to writing for peers and writing for the public, and their beliefs about writing were consistent with their modernist beliefs about the nature of science, i.e., they saw writing as being about knowledge construction rather than simply knowledge reporting.

Writing is an incredibly important part of science. ... the next great advance in science is always based on ... half a dozen little tiny advances in science, and these are written

in journals. And it takes somebody clever to put those little threads together and do the next best thing. So it's an absolutely critical part of the process.

Writing was seen as being part of idea generation, both in relation to the immediate study participants were engaged with and the larger debate. Only one participant said he wrote an outline prior to writing; the rest generated ideas through the writing:

You don't really know what the main point's going to be until you start telling the story and analysing the data. And what you discover in that process definitely drives the next set of experiments. So I teach my students not to try to understand the whole problem they're working on first and then start writing because we could have missed something fundamental that we're not going to see until we start writing about it and thinking what the story is.

The concept of "telling a story" or "creating a picture" in the reader's mind were recurring themes for all participants, again supporting the notion of scientific writing as knowledge construction. Several participants reflected on the complexity of results and evidence, and the role of the scientific writer in sifting through the evidence to construct the story:

You are telling a story and in truth you've done all these experiments and this didn't work and this didn't work, but this did and ... we've got to somehow sift out of all this complexity, what we've learned, and throw the extraneous stuff away, and tell a story.

The more experienced participants suggested that their mastery of their field meant that, when they designed a project, they simultaneously anticipated the outcome, and for this reason, generated ideas at a higher level than simply interpreting the data when writing:

you get to the stage where you've worked it out what it means , , , you've got an idea of where you you're heading before you start... . That isn't to say that in the process of writing, and then pulling in the references to give the embellishments and the support or the caveats, that you don't suddenly have

a fresher idea than you've had. It might take a different direction. But it's not from the very beginning working out your ideas.

Several participants believed the purpose of producing writing, evidence, results, and communicating about science to the public was an ethical dimension of science:

This is how much money I've had in research grants over the years. That's 600 hip replacements or 120 septum treatments for one year of breast cancer. That's what my scientific research has cost the tax payer. How do I justify that? Who pays for what we do? It's people who clean the buildings at three o'clock in the morning ... how do we say to these people that that was money well spent? ... We have to communicate the beauty and the passion around the subject and get people excited. So they see that science is ... a wonderful thing.

However, the question of whether scientific writing (beyond grant applications) was persuasive caused most of the participants in this study some difficulty. Most participants (18), after considerable discussion, decided that scientific writing was persuasive, but with over half expressing reluctance or reservation, particularly in relation to speculation or "rhetorical language." These anxieties seemed to relate mainly to the importance of not biasing results, and of, in the language of creative writing, "showing not telling," i.e., letting the evidence speak to the reader. Generally the key to persuasion was seen as shaping and presenting enough evidence to convince the reader of its significance or relevance. While they acknowledged that authorial construction of the evidence was part of writing, they felt that the implications of the evidence should, to some extent, be shaped by the reader. This sits somewhat uneasily with beliefs of scientific writing as "story," which implies theme as well as plot, and would bear further investigation.

## TASKS

Contrary to Yore et al.'s (2002) findings, the participants in this study were not narrowly focused in terms of audience and task, and saw the role of science as being to communicate on a wider stage.

Classroom-based students were not a primary audience for the participants in this study: only three participants identified writing teaching materials for a

class as a key recent activity. Instead, participants engaged primarily with scientific peers, both within their discipline and more widely within the scientific community. The most common recent activities were brainstorming or making notes for a new project and drafting a scientific paper (19 participants), editing a research proposal, redrafting or editing a co-authored paper (18 participants), drafting a research proposal and peer reviewing for a journal (17 participants). Interviews showed that participants had not only engaged with these tasks in the last six months, but saw these activities as amongst their most regular writing tasks. With the exception of brainstorming or taking notes, these activities were also identified as the writing tasks that had taken up most of the participants' time in the last six months. All participants wrote not only in their own discipline but also for cross-disciplinary or broad-based journals.

A majority (14), while primarily writing for peers, also wrote for a broader public. In the previous six months, five participants had written for a popular journal, five for a science-related website and three had engaged in some form of creative writing. During their professional lives, participants had published creative writing (four), popular science (12), and documents for specific non-scientific audience (eight). Furthermore, rather than showing scepticism about popular forms of scientific writing, over half of the participants (12) expressed strong interest in having more opportunity to write popular science or creative non-fiction.

In terms of audience, all but one participant said they were continually making rhetorical decisions based on audience. Several participants commented that there were very few people in their field, most of whom they knew personally, and so when they wrote for this small disciplinary group they could target their writing to the knowledge and interests of this group. But generally participants were engaged in writing for larger cross-disciplinary scientific (and sometimes non-scientific) audiences, and so were conscious of the need to consider to engage their audience:

the ... common thread from an 8 year old to an 80 year old professor is to try and think well what would be their experience and perspective? ... To help people assimilate information you've got to think, well what hanging hook have they already got in their brain? Most hanging hooks are shaped by experience and knowledge at that time. So [for]an 8 year old ... their world is small, ... this is me and there's my mum and dad and there's my dog and there's my school and that's about it. ... So I'm trying to link in to their level of experience. ... Whereas when I'm writing for a scientific audi-

ence—and undergraduates is different from postgraduates is different to a research colleague—I'm going to assume a level of knowledge.

All participants articulated ways in which they managed some aspects of style, particularly in relation to various audience:

[with scientists in the discipline] I'm going to assume that they're busy people, and I'm going to assume that they will want clarity, and they will want to be able to skim it. So I will tend to use a style of writing, which is: I'm going to tell you in my first sentence or my first couple of words what this paragraph is going to be about. If I'm writing for somewhere in-between. like an undergraduate who's got a degree of knowledge—I'm going to keep the terminology from overwhelming the concept and I'm going to be trying to pull out the concept ... that's number one I want them to get, the terminology is number two. So I have a priority of how I want you to pick up this information.

As well as considering audience, all participants engaged analytically with issues of sentence length, active and passive voice, and use of personal pronouns. Beyond this, however, they were likely to work more intuitively, using broad terms such as conciseness, clarity, story, creativity and beauty, without explaining what constituted these essential qualities of scientific writing in relation to audience. This more intuitive approach to writing style they saw as based on immersion in the discourse:

fundamentally the ability to write comes from the fact we've read. There's a resonance to the language ... we write almost instinctively because there's a register of voice that we're used to and we've picked it up, you know, from our reading. Things unconsciously become part of the means in our brain and they end up on the page.

Even when working with PhD students, all but one participant worked intuitively, rewriting sections of student writing rather than using the language of writing instruction. Direct questions about style, such as questions about the use of metaphor or paragraph structure, usually elicited long discussion where the participant worked their way towards a tentative answer.

## DISCUSSION

The findings of this study provide support for the hypothesis that senior academic scientists would conform with Dreyfus and Dreyfus' model of expertise as demonstrating particular attitudes, beliefs and practices concerning writing which differ from those of academic scientists more generally.

Yore and his colleagues, investigating scientists post-PhD, develop a portrait of the scientist as narrowly focused in practice and demonstrating an understanding of the purpose of scientific writing which is both limited and inconsistent with their beliefs about the nature of science. Such observations contrast with Bazerman (1988), who perceives expert writers more generally as working across boundaries, and science itself as moving from a narrow to a broader focus (Bazerman, 1998) and with the literature on expert writers (Yore et al., 2002, 2004).

The findings of this study support Bazerman's observations and contrast with those of Yore and associates. The participants in this study were broadly focused in practice and showed a sophisticated understanding of the purpose of scientific writing which was consistent with both research into the writing of experts and their understanding of the nature of science. While they were all engaged in narrowly-focused writing in their discipline (though often by reviewing/revising the work of others), participants were also engaged with broader cross-disciplinary audiences and saw writing for non-scientists as an important aspect of science.

Senior academic scientists in this study perceived writing to be an intrinsic aspect of the science itself, and implicitly perceived the function of writing as being knowledge construction. Their focus on developing and shaping new knowledge through writing, creating a story or picture for the reader, and through consciously excluding information in the interests of crafting a story, suggests they have a sophisticated understanding of the integration of writing, science and meaning, which is developed largely through immersion in practice. While the issue of persuasion was contentious, these senior academic scientists were aware of the importance of crafting their work for an audience, and writing in a way that would enable the reader to make meaning from the evidence presented.

Furthermore, in line with Hartley and Branthwaite (1989), Boice (1994), Morris and Murray (2001), and Shah et al. (2009), most participants in this group were strongly engaged by writing: most relished the challenges of writing in new genres to new audiences, showed an ability to engage both analytical and intuitive understandings of scientific writing, and exhibited both confidence and resilience.

Some of the differences between this study and those of Yore and associates may, in part, be attributed to methodology: for example, this study investigated a wider range of writing tasks, and extrapolated beliefs from detailed analysis of scientists' description of their writing processes in relation to a particular project.

However, another explanation lies in the group investigated in this study and the model of expertise employed. Yore et al. construct the expert science writer as a scientist who is post-PhD. This study, following Dreyfus and Dreyfus (1986), Benner (1984, 2004) and Dall'Alba and Sandberg (2006), started from the premise that expertise is developed more slowly, and that the expert science writer is not simply a research scientist who has completed a PhD, but one who is acknowledged as a disciplinary leader through extensive publication and situational experience acquired over extensive periods. Such an individual is likely, according to Dreyfus and Dreyfus, to have developed an emotionally engaged, intuitive, broad view of both practice and context, and this is supported in this study.

One of the participants in this study, in a discussion of the wide range of genres and audiences he engaged with, proposed the idea of the "lifecycle" of scientific writers, postulating that scientific writers go through several stages in the types of writing they engage with post-PhD and that the final stage involves a more expansive view of science which leads to a perceived need to bring science into a broader arena for various publics. Subsequent discussion of this cycle with other participants led to acknowledgement that this was a general model that applied in the scientific community and lively debate about whether such a model was ideal. Such a model supports Dreyfus and Dreyfus' model and would bear further investigation.

One of the questions that might be asked of this study is whether the findings are generalisable beyond the Australasian context. This is not easy to answer without conducting empirical investigation beyond the Australasian context, but several factors suggest the findings may apply more broadly across Western nations. First, a little over a third of participants were born and educated (schooling and/or undergraduate studies) outside of Australasia. Two-thirds had conducted their PhD or post-doctoral education in a university in another (most commonly Western) country. And finally, all participants saw themselves as part of an international community of scholars, within their own discipline and, often, more broadly; all had co-authored work with international colleagues, and most travelled regularly to international conferences. Nevertheless, it would be useful to test the generalisability of the findings by investigating the beliefs, attitudes and experiences of senior scientists as writers in other countries. It would be particularly interesting to investigate these issues in countries

where English was not a first language and where scientists, in order to join their disciplinary communities, were compelled to work in a second language.

This study suggests further directions for future research. Given the limited empirical research into the beliefs and practices of the expert science writer, and the conflicting findings of this study and those of Yore et al., it is clear that more research is needed on both the writing and development of academic scientists. In particular, it would be useful to investigate the concept of the “lifecycle” of the scientific writer, perhaps in the context of Dreyfus and Dreyfus’s five-stage model of expertise, by researching the attitudes, beliefs and writing practices of academic scientists at various stages in their academic careers. An investigation of whether academic scientists’ beliefs about science and writing change over time on the basis of situational experience would be particularly useful given the conflicting observations of Dall’Alba and Sandberg (2006), and Florence and Yore (2004). Academic scientists, it seems, are an almost “forgotten tribe” of writers, and yet they have much to tell us about writing in practice, especially in the context of the teaching of science writing; it is surely timely that their voices are heard.

## NOTES

1. See, for example Penrose and Katz (2004), Blum, Knudson and Henig (2006), and Day & Gastel (2006).
2. See Bereiter and Scardamalia, 1987.
3. Australia and New Zealand follow the British system of academic ranking: associate professor and professor status is reserved for faculty who have achieved academic leadership in their field.
4. E.g., New Zealand’s Performance based research fund.

## REFERENCES

- Bazerman, C. (1988). *Shaping written knowledge*. Madison, WI: University of Wisconsin Press.
- Bazerman, C. (1998). The production of technology and the production of human meaning, *Journal of Business and Technical communication*, 12, 381-187.
- Benner, P. (1984). *From novice to expert: Excellence and power in clinical nursing practice*. Reading, MA: Addison-Wesley.

- Benner, P. (2004). Using the Dreyfus model of skill acquisition to describe and interpret skill acquisition and clinical judgement in nursing practice and education. *Bulletin of Science, Technology and Society*, 24(3), 189-199.
- Bereiter, C., & Scardamalia, M. (1987). *The psychology of written composition*. Hillsdale, NJ: Erlbaum.
- Bereiter, C., & Scardamalia, M. (1993). *Surpassing ourselves*. Peru, IL: Open Court.
- Berliner, D. (1994). Expertise: The wonder of exemplary performances. In J. Mangieri & C. Block (Eds.), *Creating powerful thinking in teachers and students: Diverse perspectives* (pp.161-186). Fort Worth, TX: Harcourt Brace College.
- Bishop, W., & Ostrom, H. (1997), *Genre and writing: Issues, arguments and alternatives*. Portsmouth, NH: Boynton/Cook.
- Blum, D., Knudson, M., & Henig, R. M. (2006). *A field guide for scientific writers* (2<sup>nd</sup> ed.). New York: OUP.
- Boice, R. (1994). *How writers journey to comfort and fluency: A psychological adventure*. Westport, CT: Praeger, Greenwood.
- Carter, M. (1990). The idea of expertise: An exploration of cognitive and social dimensions of writing, *College Composition and Communication*, 41, 265-286.
- Carter, K., Cushing, K., Sabers, D., Stein, P., & Berliner, D. (1988). Expert-novice differences in perceiving and processing visual classroom information. *Journal of Teacher Education*, 39, 25-31.
- Dall'Alba, G., & Sandberg, J. (2006). Unveiling professional development: A critical review of the stages models, *Review of Educational Research*, 76, 383-412.
- Daley, B. J. (1999). Novice to expert: An exploration of how experts learn, *Adult Education Quarterly*, 49, 133-148.
- Day, R. A., & Gastel, B. (2006). *How to write and publish a scientific paper*. Westport, CT: Greenwood.
- Dreyfus, H. L., & Dreyfus, S. E. (1986). *Mind over machine: The power of human intuition and expertise in the era of the computer*. New York: Free Press.
- Dreyfus, H. L. (2004). The five-stage model of adult skill acquisition, *Bulletin of Science, Technology and Society*, 24(3), 177-181.
- Dreyfus, H. L., & Dreyfus, S. E. (2005). Peripheral vision: Expertise in real world contexts. *Organisation Studies*, 26(5), 779-792.
- Fahnestock, J., & Secor, M. (1986). Accommodating science: The rhetorical life of science facts. *Written Communication*, 3, 275-296.
- Ferrari, M., Bouffard, T., & Rainville, L. (1998). What makes a good writer ? Differences in good and poor writers' self-regulation of writing. *Instructional Science*, 26, 473-488.

- Florence, M. K., & Yore, L. D. (2004). Learning to write like a scientist, *Journal of Research in Science Teaching*, 41, 637-668.
- Fox, M. F., & Faver, C. A. (1985). Men, women, and publication productivity: Patterns among social work academics, *The Sociological Quarterly*, 26, 537-49.
- Geisler, C. (1994). *Academic literacy and the nature of expertise: Reading, writing, and knowing in academic philosophy*. Hillsdale, NJ: Erlbaum.
- Hartley, J., & Branthwaite, A. (1989). The psychologist as wordsmith: A questionnaire study of the writing strategies of productive British psychologists, *Higher Education*, 18, 423-452.
- Hartley, J., & Knapper, C. K. (1984). Academics and their writing, *Studies in Higher Education*, 9, 151-167.
- Holyoak, K. (1991). Symbolic connectionism: Towards third-generation theories of expertise. In K. A. Ericsson, & J. Smith (Eds.), *Toward a general theory of expertise: Prospects and limits* (pp. 301-336). Cambridge, UK: Cambridge University Press.
- Jacoby, S., & Gonzales, P. (1991). The constitution of expert-novice in scientific discourse. *Issues in Applied Linguistics*, 2, 149-181.
- Jones, J. E., & Preusz, G. C. (1993). Attitudinal factors associated with individual factor research productivity, *Perceptual and Motor Skills*, 76, 1191-1198.
- Keys, C. W. (1999). Revitalizing instruction in scientific genres: Connecting knowledge production in the writing to learn in science, *Science Education*, 83, 115-130.
- Livingstone, C., & Borko, H. (1989). Expert-novice differences in teaching: A cognitive analysis and implications for teacher education. *Journal of Teacher Education*, 40, 36-42.
- Morss, K., & Murray, R. (2001). Researching academic writing within a structured programme: Insights and outcomes, *Studies in Higher Education*, 26(1), 35- 52.
- Penrose, A. M., & Katz, S. B. (2004). *Writing in the sciences: Exploring conventions of scientific discourse*. New York: Pearson Longman.
- Rodgers, R., & Rodgers, N. (1999). The sacred spark of academic research, *Journal of Public Administration Research & Theory*, 9(3), 473-492.
- Shah, J., Shah, A., & Pietrobon, R. (2009). Scientific writing of novice researchers: What difficulties and encouragements do they encounter?, *Academic Medicine*, 84, 511-516.
- Yore, L. D., Hand, B. M., & Prain, V. (2002). Scientists as writers, *Science Education*, 86, 672-692.
- Yore, L. D., Hand, B. M., & Florence, M. K. (2004). Scientists' views of science, models of writing, and science writing practices, *Journal of Research in Science Teaching*, 41, 338-369.

Yore, L. D., Florence, M. K., Pearson, T. W., & Weaver, A. J. (2006). Written discourse in scientific communities: A conversation with two scientists about their views of science, use of language, role of writing in doing science, and compatibility between their epistemic views and language, *International Journal of Science Education*, 28(2-3), 109-141.