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Writing Science: Implications for the Classroom

Lisa EMERSON¹

¹ College of Humanities & Social Sciences, Massey University, New Zealand

Address for Correspondence:

Assoc Prof Lisa EMERSON. College of Humanities & Social Sciences, Room 316, SGP Building, Turitea, Massey University, Taranaki, Wanganui & Manawatu, New Zealand

Phone: (64) 06 356 9099 ext. 84547

Email: L.Emerson@massey.ac.nz

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Writing Science: Implications for the Classroom

“...communication is not just one element in the struggle to make science relevant. It is the central element”—Randy Olson, 2009

ALL SCIENTISTS ARE WRITERS

Writing is a pervasive aspect of a career in science: research scientists' careers are determined by their capacity to write papers, reviews and grants, and to engage with both their disciplinary community and the broader scientific community (Bazerman, 1992). For science graduates who choose a career outside of research, writing and communication remain critical professional skills: extension scientists and consultants must communicate with farmers, growers and industry; food scientists must communicate with the health industry and with the public; engineers must write reports and compliance documents (Bernhardt, 2004). Indeed, Bernhardt, like Olson (2009 cited above) argues that, in the face of global crises, the capacity of scientists to communicate, within their own discipline and with the wider public, has never been more important.

Yet writing remains a strangely neglected aspect of the science curriculum at both undergraduate and graduate level in many universities. In New Zealand, for example, only one university has made a communication course compulsory in the BSc. Individual initiatives to integrate writing into the science curriculum have been implemented and researched (see, for example, Brieger & Bromley, 2014; O’Gorman et al., 2014)—but these initiatives remain the work of individual teachers, without significant impact on the broader curriculum. While some universities in North America have taken a broader institutional approach, using a writing across the curriculum (WAC) or writing in the disciplines (WID) method (McLeod & Soven, 1992), they are far from the norm.

My aims in this paper are to examine how scientists currently learn to write science and to explore potential models to improve this process. Drawing on current literature and the data from an extensive study I conducted into the development of research scientists as writers of science (Emerson, 2012; Emerson, 2016), I also aim to point a way forward for universities to develop emerging scientists as writers and communicators¹.

MISSED OPPORTUNITIES

One of the key issues to emerge from current literature is that science students are unlikely to develop positive attitudes towards writing during their schooling or undergraduate years, and that the writing they do encounter may provide misinformation about the relationship between writing and science.

While multiple studies have demonstrated the pedagogical value of integrating writing for learning in science in schools (see, for example, Choi et al., 2010; Chinn & Helgers, 2000; Prain & Hand, 1999; Shanahan, 2004), and some national curricula, such as that of New Zealand schools, aim to embed writing and communication into the science curriculum at both elementary and secondary school, research suggests (Martin, 2012; Poe et al, 2010) that science students do not engage positively with writing or learn science-related writing at school. This latter perspective was confirmed by my 2016 study: fewer than 10% of participants said they had learned something about scientific writing in secondary school. Furthermore, those participants who did suggest that school experiences included the teaching of scientific writing tended to focus on generic aspects of ‘good writing’, essay writing (taught in traditionally writing-rich classes, such as history or English rather than science-related subjects) or the lab report, a genre that was seen by other participants as actively unhelpful for learning to write science:

You were taught what a lab report structure was and aims and methods and stuff [at school] but when I got to doing my PhD I quickly realised that this was just fantasy – like, 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’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—Emerging Scientist, Chemistry.

We had this awful thing at school, you know, ‘Observation, Results, Experiment’... I mean, whoa! ...You know, the things we do to kids, we teach them this garbage! No, no, you are telling a story—Senior Scientist, Physics.

Similarly, Lerner, (2007, p. 214), commenting on informal writing, another genre of writing found in the school 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.100).

Furthermore, despite initiatives such as WAC and WID (McLeod & Soven, 1992), most of the participants in my research found the undergraduate years to be equally devoid of authentic opportunities to engage with scientific writing. 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 rare few discussed a specific teacher who required them to write and to think about writing, and only two (out of 106 participants) experienced in-depth, authentic opportunities to understand the relationship between writing and knowledge creation in science.

SO HOW DO SCIENTISTS LEARN TO WRITE SCIENCE?

Research suggests that scientific writing is most commonly learnt at post-graduate or doctoral level, through the cognitive apprenticeship model, i.e., through co-authorship, doctoral supervision, and reading and imitation. Within this model, faculty-student co-authorship (Maher et al., 2013), imitation of disciplinary texts (Burton & Morgan, 2000), and feedback from lab associates, doctoral advisors (Florence & Yore, 2004; Kamler, 2008), and peer review (Austin 2002; Burton & Morgan, 2000; Gardner, 2009) are the primary ways in which students learn to write. The model can be seen as the interaction of four factors as outlined in Figure 1.

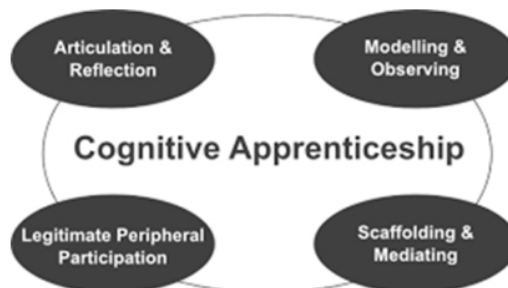


Figure 1. The cognitive apprenticeship model (Bury, 2015).

While such an approach to learning disciplinary writing clearly can be successful (see Florence & Yore's 2004 discussion of co-authoring), its reliability as a strategy is open to question (Lee & Aitchison, 2009; Paré, 2011; Starke-Meyerring & Paré, 2011). Writing collaboratively with a mentor, for example, is a socially complex process, incorporating hierarchical structures which may present problems for the student (Florence and Yore, 2003; Jacoby & Gonzales, 1991). Co-authors may bring expectations (Maher et al., 2013) that students cannot meet. Learning by reading and imitating disciplinary texts as models is problematic since the rhetorical strategies and processes that go into the construction of those texts are not easily apparent (Collins et al, 1987). Furthermore, resources designed to support the writing of emerging scientists (e.g., style guides and journal guidelines) may not provide accurate direction (Burton & Morgan, 2000). Without access to the metacognitive strategies needed to unlock a text, students must learn by intuition, and thus lack a capacity to articulate their rhetorical choices. This leads to a cyclical problem: as these emerging scientists learn to write without access to a language with which to talk about writing and move into senior academic positions, they may then struggle as advisors and mentors to teach writing to their own students.

And indeed while, for some participants in my research, the advisor or mentor was a life-line in relation to learning the conventions and processes of scientific writing, more participants had negative or limited experiences of learning to write with an advisor than had experiences which they perceived as positive and constructive. Few participants had advisors who talked through rhetorical decisions or scaffolded authentic writing tasks (such as actively drafting an academic paper together). The following is an extreme example:

[My advisor] was not very interactive; he didn't really speak, and I never really had a conversation with him ... So the process of writing my PhD was very solitary; I mean I did it absolutely by myself. I would give him drafts of my chapters and he would hand it back and there would be nothing on it. On the page, out in the margin, there would be like a cross or a question mark, and I would have to go back to him and say 'why is this here?' I would have to go and ask him about every point. So in the end when I needed to submit, I would actually print off a sheet of paper with specific questions for him like, 'do you think I should include this in Chapter 1 or Chapter 3?' because I was really struggling and looking for advice—Emerging Scientist, Community Ecology

While few participants experienced an advisor who was quite as unengaged as this, many participants were left alone to decipher their advisor's revisions and apply them to their own text, to call on help from family, friends, and

lab partners, or to endeavour to glean rhetorical processes through reading. Almost a third of participants said that no-one helped them develop as writers of science. The outcome of such isolation was often a crisis of confidence:

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. For me I think it was the crisis that I thought I was writing better and then I suddenly went back again and 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' and it was so depressing at the time... They told me that you are supposed to become independent at the writing, and it's like you are a little child again—
Emerging Scientist, Food Technology.

At the heart of the problem with the cognitive apprenticeship model is the issue of chance: whether the student is actively taught to write in their discipline is something over which they have little control. Some advisors are willing and able to engage in this process: others don't want to or are unable to do so because they lack a language with which to talk about writing. One scientist I interviewed expressed the problem thus:

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

While most of the senior scientists in my research perceived they had a role as a teacher of writing, the majority felt ill-equipped to engage with this role.

It seems the limited strategies currently used to address the teaching of scientific writing may be insufficient to develop in emerging scientists the complex writing and communication skills they will need in today's world. The majority of students are unlikely to acquire the positive attitudes and beliefs about writing and its relationship to science that they need to develop as scientists, either during their schooling or in their undergraduate years, and the pedagogical approaches and process they do encounter may be counter-productive. Meanwhile, the cognitive apprenticeship model – while robust in principle—may be unreliable in practice. Given the centrality of writing to the process of constructing science in scientific disciplines (Bazerman, 1992),

and the importance of communication in most science-related career options, we need a more reliable, robust approach to this gap in the curriculum. In the following section, I outline the possible approaches tertiary institutions might consider, and the strengths and weakness of the different models.

INTEGRATING WRITING INTO THE UNDERGRADUATE SCIENCE CURRICULUM

Strengthening the undergraduate curriculum by integrating writing into the programme is an important first step in developing science students as scientific writers. Actively teaching science writing and communication strategies and processes at undergraduate level can make a critical difference to student attitudes and beliefs about writing (Poe et al., 2010), strengthen their skills and processes, and prepare them for science-related careers. A number of options are available.

The first option is the first year science writing course. The key advantage of offering science students such a course is that it provides an early message about the importance of writing as an integral aspect of science, and the value of writing and communication for careers in science. Furthermore, key skills and concepts—such as information literacy, knowledge construction in the sciences, science writing process, and argumentation skills—can be introduced at an elementary level, and any remedial issues (relating to the mechanics of writing) identified.

Such a course, however, has its limitations. Establishing a foundation without building on it throughout the curriculum may undermine the credibility of the course in the eyes of students who may present as resistant to writing (Poe et al., 2010). There is also a danger of unrealistic faculty expectations and raising expectations of a “quick-fix” solution to concerns about student writing: with writing and communications siloed into “the writing course,” science faculty may feel absolved of any responsibility to integrate writing or communication into disciplinary courses. Finally, such a course can only deliver broadly based science writing—it cannot provide the in-depth disciplinary knowledge required of research writers. Nevertheless, the first year science writing or science communication course can offer a strong base for a broader programme of integrating writing into the curriculum.

A more comprehensive approach, which overcomes many of the shortcomings of the first year course, is the integrated model based on WAC or WID. This model, which involves subject specialists building intentional writing pedagogy into disciplinary courses across a major, offers multiple advantages (Holyoak, 1998): because the teaching staff are disciplinary specialists, students are

likely to accept the centrality of writing in science; an integrated model allows for writing instruction to be stepped towards more complex understandings, skills, and processes throughout a major; and opportunities for engagement with authentic disciplinary genres mean that students will learn skills that are immediately relevant and discipline-specific. Models of such an approach are already available: for example, MIT offers a comprehensive example of integrating writing in the sciences (Poe et al., 2010).

The disadvantages of this model relate to resourcing, leadership, and sustainability: an integrated approach requires considerable faculty buy-in and willingness to engage with pedagogy and curricula outside their comfort zone, strategic leadership, financial resourcing, and a strategic approach to faculty turnover. For many institutions, the strategic and resourcing issues remain barriers to implementation.

An approach which combines a first year course with a senior science writing course or seminar may be a feasible alternative to the resource-hungry integrated programme. Student buy-in to such a seminar is likely to be high: at this pre-launch point in their careers, students are likely to have a deeper understanding of the importance of writing and communication to their choice of profession. Students planning a future in research may already be involved in a research lab, allowing opportunities for authentic research-related writing; and in an applied discipline such a health or engineering, the teaching of industry-relevant genres and processes can be the focus of course content and assessment. There are therefore opportunities to develop highly relevant curricula focused on student or industry needs. While the senior science-writing seminar does not offer the same graduated, embedded possibilities of the integrated model, nevertheless, it is less resource intensive and offers real opportunities for students to engage with relevant curricula.

ENGAGING THE GRADUATE STUDENT

Integrating the teaching of writing into the undergraduate programme offers the potential to make a significant difference to graduates' capacity to write science. However, for students who wish to make a career in research science, more focused disciplinary-writing training is needed to develop advanced skills and processes.

The graduate science-writing course allows for the teaching of discipline-specific writing and, since students may already be engaged with a disciplinary community, the immediate applicability of their learning will be apparent. Key concepts, skills, and processes can be taught at exactly the time students need them, ensuring student buy-in, and there is the potential for authentic,

discipline-specific assessment. Perhaps most importantly, advisors have the opportunity to build on the learning in such a course, beginning the cognitive apprenticeship process from a position of shared understanding.

A potential difficulty, however, concerns who teaches such a course. While science faculty may lack the language and pedagogical know-how to teach science writing, writing teachers may lack the deep knowledge of writing in a specific genre that is needed. Collaborative teaching may not easily fit into institutional frameworks, but may provide a solution to this dilemma.

The cognitive apprenticeship model, however, remains an ideal in terms of teaching writing. Strengthening this model by offering professional development opportunities to doctoral advisors to further develop their understanding and capacity to implement both the cognitive apprenticeship model and writing pedagogy may be the most significant change we can make for our graduate students. In particular, strengthening doctoral advisors' capacity to engage with two aspects of the cognitive apprenticeship model - articulation and reflection, and scaffolding and mediation - may lead to improvements in the experiences of graduate students at a critical stage in their development as scientific writers.

Finally, there is evidence that a relatively new model of writing support (Grant & Knowles, 2000; Grant, 2006) is emerging in some institutions to address the deficits of current models of writing development: the writing group or journal club. These groups comprise scientists at varying career stages, often including doctoral students, who meet together to discuss and support one another's writing, increase publication rates, and analyse and discuss disciplinary texts. While these groups are informal, and still not commonplace, they demonstrate ways of supporting writing outside of prescribed curricula. Writing or journal groups are distinctively different to other models of writing development in that they are initiated by practitioners and demonstrate the characteristics of a learning community which Bereiter and Scardamalia (1993) describe as the ideal learning environment. The strengths of this model are that groups are disciplinary focused, peer support is valued, participants are generally highly motivated, and the group can be tailored to the needs of participants. The weaknesses of the model are that, because of the informality of the group and its dependence on participant motivation, sustainability, leadership, and the potentially limited knowledge base of the group may prove problematic. Nevertheless, this is a new opportunity that invites further exploration.

PUTTING IT TOGETHER

At a time when preparing students for careers in the STEM disciplines has become increasingly important, and ensuring that scientists are able to engage with public discourses around science has become a matter of global welfare (Olson, 2009), there is a clear imperative to teach science students to write. Current approaches, while often robust in theory, may be failing to meet the needs of our students and scientific communities, as well as society more broadly. In this paper, I have outlined opportunities for us to improve the way we teach writing to our emerging scientists, at both undergraduate and graduate level. While multiple models are available to address this issue, assessing the appropriate model for a specific institution remains a challenge. However, we might draw some broad guidelines:

First, the undergraduate years are a critical time for science students' development as writers. Given the centrality of writing to careers in science, any institutional model should include writing initiatives in the undergraduate curriculum. While an integrated model within a major may represent an ideal, where resourcing or staffing constraints make this unfeasible, a model that combines a first year and senior year writing or communication course may be an effective alternative.

Second, the current hit-or-miss approach to the cognitive apprenticeship model at graduate level is insufficiently reliable. Strengthening the cognitive apprenticeship model through training and ongoing support in writing pedagogy for doctoral advisors is an essential first step, ideally combined with a graduate science-writing course and support for disciplinary writing groups.

Third, any model for teaching science writing is more effective when it is discipline-specific. Given the distinctive genres and styles of disciplines in the sciences, a generic strategy is unlikely to be sufficiently focused to meet the needs of, or be seen as credible by, students.

Finally, one shape does not fit all when it comes to teaching science writing. Adopting just one of the options listed here is unlikely to be sufficient to meet the needs of all science students. Instead, a comprehensive approach, specifically designed for the needs of the specific institution, spanning undergraduate and graduate curricula, is recommended.

ENDNOTE

1. Emerson (2016) is based on a sample of 106 academic research scientists selected using a purposeful sampling technique (Leydens, 2008) to represent the diversity of the scientific community. Two forms of data were collected: a survey and a semi-structured interview. For more detail on method, see Emerson (2016).

ABOUT THE AUTHOR

Lisa EMERSON is Associate Professor and Director, Teaching and Learning, at the College of Humanities and Social Sciences at Massey University. Her scholarly interests include science writing, scientists as writers, academic writing, plagiarism, and transitions to academic literacy. Her work has appeared in *Double Helix*, *Curriculum Matters*, and *Higher Education Research and Development* as well as other publications.

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