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LANGUAGE AND SCIENCE*

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INTRODUCTION

In looking back at the last review of research on the language-science connection to appear in *ARAL* (van Naerssen and Kaplan 1987), one is struck by the great changes in this relationship that have taken place over the past dozen or so years. On a general level, such changes are perhaps inevitable given the youthfulness of this area as a research domain, but more specifically, they can be traced in large part to two related trends: 1) a shift away from research with direct pedagogical aims and motivations, and 2) the powerful influence of the interdisciplinary field known as social studies of science. Both trends will be recurrent themes of this review.

To frame this discussion, some terms must first be defined, and a statement of overall purpose must be given. "Science" in this review includes the natural sciences, but does not include clinical medicine, engineering, the social sciences, or the human sciences. While the latter four areas have all been the subject of language-connected research, taken together they are too diverse to consider here. "Scientific language," as used here, will include all types of language-in-use associated with the natural sciences, including those intended to teach as well as to popularize science. Textbooks and other pedagogical materials, however, are not covered in this review. As will be seen, most research on scientific language thus defined has, in fact, centered on scientific research writing, but there are important exceptions.

"Applied linguistics" is defined for the purposes of this review in two senses. First, it is defined broadly as a cross-disciplinary endeavor which attempts to study how language is used by humans—that is, how language is actually applied across the range of human life. In this sense, "applied linguistics" encompasses a significant part of the language-focused research undertaken in such diverse fields as rhetoric/composition, speech communication, technical

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communication, sociology, anthropology, history, philosophy, education, and of course linguistics and (traditionally defined) applied linguistics. Second, I employ the term "applied linguistics" more narrowly and traditionally, as referring to that area of study in which people identifying themselves professionally as applied linguists work. This field has of course been substantially concerned with reforming and improving actual language use, including the teaching and learning of languages, although in recent years it has developed areas of overlap and fuzziness vis-à-vis the broader definition of applied linguistics I have already given.[1]

Given these general definitions, the overall purpose of this article is, primarily, to review recent applied linguistic research—in the broad sense—on science and language, especially for the period 1990–1998. Secondarily, it attempts to outline major changes that have taken place in research in this area since the van Naerssen and Kaplan (1987) review was written.

BACKGROUND: ACTIVITY ACROSS DISCIPLINES

It will be useful to begin with the second purpose mentioned above—an outline of major changes in the area of language and science—in order to provide some historical and intellectual context for the review of more recent research. The study of scientific language has commonly been conceived of within traditionally defined applied linguistics as part of English for Specific Purposes (ESP) in the English-dominant world, and Language for Specific Purposes (LSP) in continental Europe.[2] The specific area of ESP which concerns science has been denominated English for Science and Technology (EST). Pioneering work in EST was done both in the US, where one active research group centered around Louis Trimble at the University of Washington (e.g., Selinker, *et al.* 1981, Trimble 1985), and by British applied linguists (e.g., Robinson 1980, Swales 1971, Widdowson 1979). In nearly all cases where empirical research was undertaken, the emphasis was on small-scale case-type studies which either came directly out of questions generated in the classroom, or which were subsequently applied directly at the level of classroom practice. Two studies, however, represent noteworthy exceptions: Swales' (1981) *Aspects of article introductions* and Tarone, *et al.*'s (1981) "On the use of the passive in two astrophysics journal papers." It is with these papers that the current approach to ESP-related research on scientific language—an approach in which descriptive depth takes precedence over direct applicability—can perhaps be said to begin.

At the same time as ESP was reaching its early maturity as a research endeavor, scholars from a cluster of other fields were busy looking at scientific language from a different perspective, that of social constructivism. What has since grown into a wide-ranging interdiscipline (parts of which are known by the overlapping and sometimes synonymous names of science studies, social studies of science, sociology of scientific knowledge, and science and technology studies) had its roots in the work of Thomas Kuhn, Ludwick Fleck, and certain European social

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philosophers (e.g., Bachelard, Foucault, Wittgenstein, and Simmel) and was actively developing in Britain and France in the 1970s largely under the rubric, sociology of scientific knowledge (SSK). An early landmark study that gave language pride of place was Latour and Woolgar's (1979/1986) ethnography of a Salk Institute neuro-endocrinology laboratory. Based on their observations, the authors came to the radical conclusion that virtually *all* laboratory activity was organized around the acts and artifacts of writing—that the ultimate product of the laboratory, in material terms, was research papers. They further endeavored to show how language was used to construct scientific "facts" by abstracting away from and systematically erasing, or "blackboxing," their complex conditions of production. Other pioneering SSK research giving language an important role in the construction of scientific knowledge includes Dear (1985), Gilbert and Mulkay (1984), Knorr-Cetina (1981, especially chap. 5), Latour (1987, especially chap. 1), Lynch (1985), and Shapin (1984). Overall, however, language was but a minor interest in early social studies of science. This shortcoming was remedied especially by two writing researchers who, although professionally associated with the field of rhetoric/composition, had at least one foot in SSK: Charles Bazerman and Greg Myers.

Bazerman was an English professor who, by his own account (1988; 1994), became interested in how writing functioned in different disciplinary fields in order to better teach his students how to write. An early representative effort (reprinted as Bazerman 1988, chap. 2) compared Watson and Crick's paper identifying the structure of DNA with essays from the sociology of science and literary studies, examining the authors' disparate approaches to making knowledge in their respective fields. Over the course of the 1980s, as he became more interested in and influenced by the sociology and history of science, Bazerman's work became increasingly sophisticated; his *Shaping written knowledge* (1988) collects much of his best work from the period, although a seminal review of early SSK research related to language (Bazerman 1983) is not included there.

Greg Myers is the scientific writing research pioneer who has perhaps been most directly involved with SSK, as seen for instance in some of his recent writings (e.g., Ashmore, *et al.* 1994, Myers 1996). Starting out as a composition researcher, Myers has also moved professionally in the direction of more-or-less traditional applied linguistics in recent years, taking a progressively more "linguistic" approach to scientific language (e.g., Myers 1989; 1993), though without losing his rhetorical focus. Like Bazerman's 1988 volume, Myer's *Writing biology* (1990) collects his earlier and more mainstream rhetorical work, including two well-known semi-ethnographic studies of biologists preparing, respectively, grant proposals and articles for publication.

Other researchers from the fields of rhetoric/composition, speech communications, and technical communication also broke new ground in the study of scientific language in the 1980s, although they were not in most cases influenced directly by SSK/social studies of science. These researchers include Campbell (e.g.,

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1986), Fahnestock (e.g., 1986), Gross (collected in Gross 1990), Prelli (1989), and Rymer (1988), as well as several of the writers represented in Anderson, *et al.* (1983).

Largely following the lead of Tarone, *et al.* (1981) and Swales (1981), more-or-less traditional applied linguists were also active in the study of scientific language throughout the 1980s. Dubois (e.g., 1980; 1987), Halliday (reprinted as Halliday and Martin 1993, chap. 3), Huckin (reprinted as Berkenkotter and Huckin 1995, chap. 2), Salager (1984), and Swales (1988; Swales and Najjar 1987) all made signal contributions, with Halliday and Huckin providing early diachronic studies of scientific discourse development. Two valuable reviews appearing at the turn of the decade (Kaplan and Grabe 1991, Swales 1990, chap. 7) tied research in rhetoric/composition and SSK more closely to traditional applied linguistic concerns, while also expanding the scope of traditional applied linguistics to include questions of epistemology and social constructivism.

The publication of John Swales' *Genre analysis* in 1990, a landmark in the area of discourse-oriented applied linguistics, brought two concepts of major importance to the fore in studies of scientific language: "genre" and "discourse community." As defined by Swales:

> A genre comprises a class of communicative events, the members of which share some set of communicative purposes. These purposes are recognized by the expert members of the parent discourse community, and thereby constitute the rationale for the genre. This rationale shapes the schematic structure of the discourse and influences and constrains choice of content and style. Communicative purpose is both a privileged criterion and one that operates to keep the scope of a genre...narrowly focused on comparable rhetorical action (1990:58).

Swales' (1990, chap. 2) definition of discourse community is more involved, but the sharing of one or more common genres is one important criterion—the two concepts are thus mutually defining. One effect of the integration of these notions into traditional applied linguistics is a much expanded coincidence of interests with the field of rhetoric/composition, which has long seen overall rhetorical/communicative purpose as perhaps the single most powerful defining characteristic of texts.

SCIENTIFIC LANGUAGE RESEARCH IN THE 1990s

This section reviews research produced in the 1990s in most of the fields mentioned to this point. Here, studies are organized according to the subjects they primarily treat rather than by their source disciplines. This approach yields a truer version of the many interconnections and indeterminacies that currently exist among fields studying the science-language relationship.[3]

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1. Specialized/functional grammar and lexis

Hedging and the expression of evaluation in scientific research articles (hereafter RAs) have been treated by a number of researchers in this decade. Hyland (1994; 1996a; 1996b; 1998) has been especially productive; his 1998 publication is a book-length treatment of hedging in scientific writing. Myers (1993) looks at the language used to criticize others' work by examining a single influential scientific article by Stephen Jay Gould and Richard Lewontin. Other recent studies in this area include Butler (1990), Farnsworth and Crismore (1991, described in more detail below), Grabe and Kaplan (1997), and Hunston (1993), the latter two being corpus-based.

The role and structure of grammatical subjects and information-structure themes in scientific writing have also been the focus of substantial research. Master (1991) looks at the important collocational phenomenon in science writing of inanimate subjects with active-voice verbs, although he does so in a popular scientific newsletter rather than in specialist journal articles, where even greater frequency and discourse-functionality might be expected. In a pair of studies, Gosden (1992; 1993) investigates how marked theme/grammatical subject is used to structure scientific text at the level of discourse in a corpus of 36 physics, chemistry, and biology RAs. Vande Kopple (1994) studies the presence and functionality of "markedly long" subject noun phrases in three articles from different scientific fields (and a fourth from the *New England Journal of Medicine*). Continuing earlier work (reprinted as Halliday and Martin, 1993, chap. 3), Halliday (1998) focuses especially on the power of nominalization processes to fix scientific concepts as "objects" through the production of "grammatical metaphor." For Halliday, this is the single most important feature of modern scientific writing—and one to which all others relate (see also Martin's work in Halliday and Martin 1993, chap. 11).

The "scientific passive" has received substantial attention from researchers in the last eight years. Ding (1998) examines the historical roots of the scientific passive, tracing its development out of a much more personal/involved tradition of scientific reportage. Espinoza (1997) compares uses of the passive in English versus Spanish scientific prose from the perspective of contrastive analysis, predicting that there will be various levels of acquisitional difficulty across the two languages depending on the tense and aspect of various passive forms. Wilkinson (1992) argues that calls for the avoidance of passive forms and "scientific jargon" in scientific research writing are misguided, given that scientists are writing in this case for a specialist audience rather than the general reader. Tarone, *et al.* (1998) update their earlier classic paper already mentioned—both concern the functional alternation of passive verbs versus "*we* + active verb" statements in two theoretical astrophysics RAs written in English, while the newer version also discusses the possible extension of the patterns found into other theory-oriented fields and other languages.

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Following up an earlier study that dealt explicitly with the scientific passive (Rodman 1981), Rodman (1994) examines the occurrence and functionality of *active voice* verbs in the different conventionalized sections (i.e., Introduction-Methods-Results-Discussion, hereafter IMRD) of the experimental scientific RA. A second recent study by Rodman (1991) investigates the functions of "anticipatory *it*" (e.g., "It has been claimed that...") in scientific and engineering RAs. Myers (1992a) studies differences in lexical cohesion strategies in scientific RAs versus popular science writing. He finds that the former depend on specialist knowledge to supply cohesive links, while the latter depend on explicitly marked cohesive relations. Vande Kopple (1998) builds on earlier work by Bazerman (reprinted as Bazerman 1988, chap. 6) in an analysis of the changing functions of relative clauses over 100 years in spectroscopy articles in the *Physical Review*. Finally, Swales, *et al.* (1998) investigate the differing uses of imperative forms in academic journals across fields, including experimental geology, in which "individual styles and personal preferences held sway" (p. 114) regarding the field-specific functionality of this feature.

2. Register

Halliday (reprinted as Halliday and Martin 1993, chap. 3) defines a register as "a cluster of associated features having a greater-than-random (or rather, greater than predicted by their unconditioned probabilities) tendency to co-occur" (p. 162). Register studies therefore examine "syndromes of features" (Halliday 1998) in particular kinds of discourse rather than single features. Halliday is himself the most active participant in this line of research as regards scientific language. His main concern has been with the profound scientific text-building—and in fact scientific *concept-building*—potential of nominalizations and complex nominal groups, but he has typically discussed these features in relation to other linguistic features. Halliday (reprinted as Halliday and Martin 1993, chap. 3), for example, also discusses semantically weak verbs, agentless passive verb forms, and specialized lexis in addition to his main focus on nominalizations and nominal groups, exemplifying how this feature syndrome has changed over the past approximately 600 years. A second study within the Hallidayan systemic-functional framework by Martin (Halliday and Martin 1993, chap. 10) examines the lexicogrammatical means by which abstraction and technicality are constructed in science textbooks.

Other register research on scientific writing in the 1990s includes Biber's (1995, chap. 6) comparative study of English registers across time employing the multidimensional approach to register analysis he earlier innovated (Biber 1988). Using this same methodology, Conrad (1996) compares writing from composition textbooks, ecology textbooks, and ecology RAs to show the scope of register variation among different varieties of "academic texts." Atkinson (1996; 1999) combines multidimensional analysis and qualitative rhetorical analysis to arrive at a description of the changing norms of discourse in the *Philosophical Transactions of the Royal Society of London* across the period 1675–1975.

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3. Higher-level discourse structure of scientific RAs

The study of the rhetorical and linguistic strategies (or "moves") adopted in the conventionalized IMRD sections of the scientific RA was introduced by Swales (1981; 1990). His 1990 book (chap. 7) comprehensively reviews research done on these sections up to the late 1980s.

In more recent work, Paul and Charney (1995) describe the rhetorical strategies taken by pioneering chaos theory researchers in their original RA introductions on the topic and compare these to later article introductions by the same authors. Myers (1992a) investigates the conventionalized "In this paper we report..." statement (Swales 1990's "Move 3") of introductions in a corpus of molecular genetics RAs, treating it in terms of speech act theory. Bhatia (1993, chap. 4) compares RA introduction sections and abstracts from a number of different fields, both scientific and nonscientific—as well as describing introductions in specifically scientific RAs, lab reports, and dissertations—to show their varying functions. Taylor and Chen (1991) analyze RA introductions from papers written by native English speakers writing in English, native Chinese speakers writing in English, and native Chinese speakers writing in Chinese. They conclude that, while the Chinese writers were more likely to stick to Swales (1981) basic four-part "move" sequence, they also more often omitted the literature review move (i.e., Swales' 1981's "Move 2").

Barton (1996) discusses the contrasting requirements for precision and vagueness that affect the language of methods sections. Although her examples come from medical and linguistics articles, the larger issues she treats are directly related to scientific writing, as Barton herself makes clear. Berkenkotter and Huckin (1995, chap. 2) devote part of their investigation of the growing value of the "newness" or "news value" of the information being reported in scientific RAs to describing the gradual "backgrounding" of methods descriptions and therefore methods sections. Thompson (1993) identifies six rhetorical moves commonly made in results sections of scientific RAs in biochemistry. She finds that results sections do far more rhetorically than their title would imply, not only reporting results but also framing them in ways that justify the methods and interpret the data. Dubois (1997) provides a monograph-length genre analysis of discussion sections in biomedical research articles, examining paragraph structure, rhetorical moves, and top-level discourse structure of discussion sections in 20 articles from a range of biomedical journals.

4. The scientific RA in general

Harmon (1992a) provides a formal/stylistic analysis of 50 of the most-cited papers (as identified in the *Science Citation Index)* appearing in the specialist scientific literature over the last 50 years. A second paper (Harmon 1992b) describes a form-and-content analysis of 40 of the most-cited theoretical papers in the last 50

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years, about half in the field of chemical physics, and compares the results of this analysis with what is known about experimental RAs. Harvey (1992) deals with the phenomenon of "referential fuzziness" regarding discourse participants in a mixed corpus of popular and specialist scientific writings. Gragson and Selzer (1990) examine differing textual strategies by which biologist authors "construct" or position their RA audiences. Markel (1993) discusses the epistemological and rhetorical basis of the scientific RA, arguing against earlier claims that it presents a sanitized and systematically misleading account of scientific activity (e.g., Medawar 1964).

5. Other scientific genres and modes of discourse

Although the scientific RA has received the lion's share of attention across disciplines, other scientific genres have also been studied in the 1990s. Within the framework of Australian genre theory, Martin (Halliday and Martin 1993, chap. 9) examines a number of the text-building strategies in high school science textbooks, including classification devices, the labeling of diagrams, and "how-to" descriptions of experiments. Also focusing on textbooks, Myers (1992b) investigates the specialized rhetorical situations which science textbooks address, contrasting them with other scientific genres in this regard. Aside from textbook analyses, a number of other genres and modes of discourse have been explored. Flowerdew (1992) describes the role of 'definition' speech acts in undergraduate lectures given in English to biology and chemistry students in Hong Kong. Rauch (1997) looks at the role of scientific journal commentary pieces in disagreements in evolutionary biology. Myers (1991b; see also Myers 1990, chap. 3) shows how review papers actively shape the field purportedly under review into a coherent and self-interested narrative. Reeves (1992) discusses the role of review-article "discovery accounts" in asserting priority claims in the discovery of the AIDS virus. Sinding (1996) argues that the review paper has at least sometimes given biologists more freedom to introduce new knowledge claims than the RA. Ochs, *et al.* (1996) examine the semiotic means by which solid-state physicists create a shared identity with the objects they describe in "blackboard talks" to other members of their laboratory. Several studies have also analyzed "blurred" and "new" genres (Geertz 1983, chap. 1), such as the essays of the British evolutionary biologist and Marxist J. B. S. Haldane (Journet 1993), and Erwin Schrödinger's "What is Life?" (Ceccarelli 1994).

The role of narrative in scientific writing—both specialist and popular—has also been substantially researched. Harré (1990) lays out some of the main issues in the study of scientific rhetoric and narrative (whether surface narrative or the underlying narrative structuring of events portrayed in markedly non-narrative forms), including the construction of trust and factuality. He differs from many in science studies, however, in unequivocally supporting scientific approaches as "the most perfect and generally sustained moral order ever created by mankind" (p. 99). Holmes (1991) also deals with major issues in the study of scientific narrative, but from a historical point of view.

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Curtis (1994) argues that narratives in science journalism support an ideology of science as an inductive, cooperative—in short, classically Baconian—endeavor. He calls for the development of alternative literate forms for the reporting of popular science. Battalio (1996; 1998a) describes how the decreasing use of personal narrative in one historical journal marks the development of American ornithology from amateur natural history into professionalized, academic science. Journet (1991) examines competing ecological theories in the first half of the 20th century as scientific and cultural narratives. Finally, in a series of studies, Myers (1990, chaps. 4, 5, and 6) looks at the role of narrative in the construction of both specialist and popular scientific knowledge.

6. Process accounts of scientific composing and reading

Research on the composing and reading processes of scientists was first undertaken in the 1980s by Bazerman (reprinted as Bazerman 1988, chaps. 7 and 8), Myers (reprinted as Myers 1990, chaps. 2 and 3), and Rymer (1988). More recent work in this area includes Berkenkotter and Huckin's (1995, chaps. 3 and 4) investigations of the revision strategies of, and peer reviewers' responses to, editor-mediated interactions with a microbiologist during her writing of a single RA. Graves (1995) describes conversations, "think-aloud" reports, and other activities of physicists surrounding the interpretation of observational results in the writing of RAs, using them to support her claim that the "rhetoric-as-epistemic" argument vis-à-vis scientific writing (i.e., that scientific results are substantially socio-rhetorical constructions) is simplistic. Charney (1993) also uses the "think aloud" procedure to examine the reading of an important if unusual RA (the paper by Stephen Jay Gould and Richard Lewontin mentioned earlier) by seven evolutionists—four faculty members and three graduate students—across fields.

Several studies of scientific composing processes have focused on the writing strategies of graduate students and other less experienced scientific writers. Gosden (1995) looked at the type and frequency of revisions undertaken by Japanese science graduate students writing RAs in English. In a follow-up study, Gosden (1996) interviewed Japanese doctoral students in the sciences regarding their experiences and strategies writing their first RAs in English. Dong (1996) studied how three Chinese graduate students in different scientific fields worked with their native-English speaking doctoral advisors to acquire the field-specific citation skills necessary to complete the introductory chapters of their dissertations. Walvoord and McCarthy's (1990) investigation of approaches to writing taken in undergraduate classes in different disciplines included a biology class (chap. 6).

There are also studies that examine the writing behaviors of experienced scientists for more directly pedagogical purposes. Lott and Barrett-O'Leary (1996) interviewed five veterinary scientists about their writing experiences and practices in their field, finding (among other things) that they had received little educational support in this endeavor. Sionis (1995) interviewed two generations of French

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scientists writing in English to see if the differing approaches to EFL pedagogy obtaining during their schooling had affected their attitudes toward English writing and subsequent language learning in their fields.

7. Scientific rhetoric

A number of recent publications treat scientific language from the point of view of rhetorical theory and practice. Harris (1990; 1991) presents useful overviews of major issues in scientific rhetoric; his 1997 edited volume, *Landmark essays on the rhetoric of science,* also collects earlier classics in this field. Gross (1990, especially chap. 1), Pera (1994), and Taylor (1994; 1996) describe more specific and differing approaches to the rhetorical study of science, and Gross and Keith (1997) provide a lively debate over the rhetoric-as-epistemic question vis-à-vis science. Gross (1993) distinguishes between rhetorical and literary analysis of experimental scientific texts, arguing for the greater effectiveness of the former. Ashmore, *et al.* (1994) and Myers (1996) connect recent theory and practice in social studies of science to more mainstream rhetorical concerns. Miller (1992) examines the role of the rhetorical concept "kairos," or timing, in scientific discovery and discourse. Horsella and Sinderman (1992) apply Toulmin's model of argumentation to the analysis of conditional arguments in science textbooks.

8. Historical studies of scientific discourse and rhetoric

Several of the studies cited so far (e.g., Campbell 1986, Halliday in Halliday and Martin 1993, chap. 3) have attempted to trace changes in scientific writing over time and historical circumstances, or to describe influential historical scientific writings in terms of their responses to, and construction of, specific contexts or rhetorical situations. Bazerman (1988, chaps. 3, 4, 6, and 7) has once again been a trailblazer in these endeavors, as has Campbell (e.g., 1986).

Bazerman (1991) studied the communal methodology of scientific endeavor exemplified by Joseph Priestley in his *History and present state of electricity* (1767). In a later methodological account, Bazerman (1994, chap. 9) takes a reflexive and revealing look at how he carried out his 1991 study. Halliday (Halliday and Martin 1993, chap. 3) analyzes writing in what is now known as physics across a span of about six hundred years in English; an earlier chapter in this same volume (chap. 1) lays out a rationale for studying the changing language of science.

Following Bazerman's seminal studies of the *Physical Review* (reprinted as Bazerman 1988, chap. 6), and the *Philosophical Transactions of the Royal Society of London* (hereafter *Philosophical Transactions*) (1988, chap. 3), a number of studies have examined the changing discourse across time in well-known and highly influential scientific journals. Atkinson (1996; 1999) combines rhetorical and register analysis in a broad description of discourse change in the *Philosophical Transactions* across 300 years of its existence. In an ongoing series of studies, Valle

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(1993; 1997; in press) has looked at life science discourse in the *Philosophical Transactions* from a number of different perspectives, most recently analyzing the changing semiotic means by which discourse communities are constructed, including the use of citation practices, intertextuality, and reporting verbs (Valle in press). Allen, *et al.* (1994) offers a careful quantitative study of citation practices as strategies of persuasion across substantially the whole history of the *Philosophical Transactions.* Broman (1991) examines the influence of discourse in the German *Archiv für die Physiologie* [*Archive of Physiology*] on the shape of physiology from 1795 to 1820.

The scientific program of the early Royal Society and some of its leading members have been viewed from a rhetorical point of view in a number of studies. Shapin (1984) and Dear (1985) were early innovators in the area, and Shapin, in particular, has continued to mine this rich vein in the 1990s. His landmark volume, *A social history of truth* (1994), seeks to portray the system of truth-telling that operated in 17th–century genteel English society in general, and in English science more specifically. His portrait of Robert Boyle as the self-fashioned paragon and living symbol of truth-saying genteel English science (1994, chap. 4) is an enlightening sequel to his widely-cited 1984 paper. Harwood (1994) also investigates Boyle's career as author and rhetorician of science; Gross (1990, chap. 8) analyzes Newton's changing rhetorical strategies for presenting his work on optics; and Westfall (1991) examines the differing rhetorical strategies of Newton and Galileo in their written works.

Walters (1993) examines conflicts in the early Royal Society over how to experiment and how to communicate the knowledge derived from such activity. Johns (to appear) looks at the literate technologies that printers were innovating in this period in the form of the scientific journal. An earlier study (Johns 1991) gives a more general account of the role of new literate forms and technologies in the making of early modern English science; like Golinski (1990), this article introduces major issues and trends in scholarship on the written rhetoric and language of early modern science (and, in the case of Golinski 1990, also more recent science). Machamer (1991), taking a somewhat different view, examines the "person-centered rhetoric" of seventeenth-century scientific writing.

Another influential era of British science that has attracted the attention of language-focused scholars is the Victorian period. Not surprisingly, Darwin and his work have been the most frequently treated subjects here. In the 1990s, Campbell has continued his pathbreaking series of studies on Darwin's rhetoric: A 1990 study analyzes Darwin's invention strategies in various notebooks that provided the raw material for his *Origin of species,* while Campbell (1994) describes the use of *vera causa* logic in *Origin.* Gross (1990, chap. 10) has also analyzed the rhetorical characteristics of Darwin's earlier "Red notebook." Fahnestock (1996) examines Darwin's use of "series reasoning" in *Origin* in relation to the classical rhetorical figures of *gradatio* and *incrementum.* Halliday (Halliday and Martin 1993, chap. 5)

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provides a detailed functional linguistic analysis of the final two paragraphs of *Origin,* showing how the lexicogrammatical patterning masterfully reinforces the overall argument of the book. Farnsworth and Crismore (1991) examine some of Darwin's rhetorical tools, including the use of hedges in his "other big theory"—that of coral reefs, as described in *The structure and distribution of coral reefs.* Other work on the rhetoric of Victorian science includes Jensen's (1991) self-described "rhetorical biography" of Thomas Henry Huxley—among many other things, Darwin's main public defender.

The power and use of metaphor and analogy at different historical moments in science has been a topic of scholarly interest especially among rhetoricians in the 1990s. Gross (1990, chap. 2), for example, examines the differing uses of analogy in political and scientific argumentation, drawing examples of the latter from two different periods of scientific history. Johnson-Sheehan (1995) investigates the use of metaphor in Einstein's revolutionary 1905 paper on special relativity, and in a later paper (Johnson-Sheehan 1997) uses metaphor analysis to assess the accuracy of the claim that Max Planck discovered quantum theory. In both papers, Johnson-Sheehan is equally concerned with demonstrating the efficacy of metaphor analysis in historical studies of scientific language and rhetoric.

9. Other studies of science and language

A small number of recent works on the topic of science and language do not fall handily into any of the categories provided so far. In this section, I will describe several recent book-length works fitting this description. Locke (1992) represents a major attempt to view different kinds and periods of scientific writing from the perspective of literary studies, although many of the issues dealt with resemble those treated by other students of scientific writing, such as Bazerman, Gross, and Myers. Locke's study nonetheless also offers fresh perspectives, in several cases made possible by the insider knowledge the author brings with him as a former professional chemist. Another scientist—this time a geologist—has written a book on scientific language (Montgomery 1996) which is remarkable at least for its pristine lack of knowledge of other recent work on the subject, although this in itself should not be cause to dismiss the work out of hand. As points of interest, for example, it has an extensive chapter on historical scientific discourse, and it intermittently takes an interesting if quirky "post-modern" stand on scientific prose. Finally, Swales (1998) provides a fascinating look at the comparative "genre systems" operating in a computing center and two academic units in a single building on the University of Michigan campus. The longest and most detailed of these "textographies" is devoted to the Herbarium, specializing in the collection and cataloging of botanical specimens.

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CONCLUSION

In this review, I have tried to provide a fairly comprehensive listing and description of work done on science and language in the 1990s. However, it is now clear to me that I have had only middling success in this endeavor. This is true especially in regard to less traditional topics and areas in which connections are only starting to be made. I would therefore like to conclude by specifying several areas that I have not covered, but that seem to hold promise for future language-and-science research.

Much ink has been spilled in the last four or so years in "the science wars"—the lively if vitriolic debate between realists and constructionists (and those occupying positions in between) on the epistemological status of scientific endeavors. Gross and Leavitt (1994) opened the debate and gave it much of its subsequent character. Since one of the main points they argue against is that scientific facts are (in part or in whole) a social and linguistic construction, there would seem to be implications and possible openings for future research involving language in this area.

A second area which I have not treated concerns science-gender issues. Although a substantial amount has been written about the (often marginal) position of women in science in the last 20 years, researchers do not seem to have been especially interested in the science-and-language connection vis-à-vis women's roles in science, although a recent book by Haraway (1997) at least moves in that direction.

A third area I have not covered—but one in which there is in fact a growing literature—involves the various extensions of scientific activity outside of the realm of "pure science," for example, into the realms of corporate culture and public policy. Only in terms of some ideal version of science is it an autonomous activity. And in a world where academic linkages with non-academic (and especially corporate) institutions are being relentlessly promoted, this ideal carries even less truth than formerly. A number of recent and forthcoming publications (e.g., Bazerman forthcoming) investigate the linkages and embeddings of science in the non-scientific world, and this area holds much promise for future science-and-language research.

Finally, I am convinced that there must be much more work with implications for language use in recent social studies of science/SSK. Myers (1996) sketches such possibilities in one area of recent SSK interest—actor network theory—but a good many more must exist, even if interest in discourse and rhetoric is not what it once was in this field.

To conclude, the study of language and science has been a broad and variegated field of endeavor in the 1990s that in several ways crosses and blurs

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disciplinary boundaries. Born out of some fairly discrete traditions of research and analysis, it has now progressed substantially beyond them. With centripedal rather than centrifugal forces in the ascendancy at the moment, we will probably have to wait for the coming century for new and fruitful syntheses, organizing dynamics, and interdisciplinary formations to emerge.

NOTES

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1. Needless to say, I realize that by attempting to define "applied linguistics" at all I am stepping into the midst of a debate.

2. Due largely to the present reviewer's own linguistic limitations, this review focuses substantially on language-and-science research in English. Reviews, however, of European LSP research have been undertaken by Schröder (1991) and Gunnarsson (1995), although these reviewers do not limit themselves to studies of scientific language. It should also be noted that an increasingly large number of European LSP researchers are writing in English as well (e.g., Gunnarsson, Linell and Nordberg 1997).

3. I have not been able to provide full coverage of various edited volumes, reviews, and special journal issues devoted to science and language in this paper. These resources include: Golinski (1990), Pera and Shea (1991), Simons (1990), and *Rhetoric Society Quarterly's* special issues on the rhetoric of science (Ceccarelli, *et al.* 1996). Additionally, two very recent edited volumes—Battalio (1998b) and Martin and Veel (1998)—reached me only as I was completing this review, although I was able to cite selected papers from these two publications.

UNANNOTATED BIBIOGRAPHY

Allen, B., J. Qin and F. W. Lancaster. 1994. Persuasive communities: A longitudinal analysis of references in the *Philosophical Transactions of the Royal Society*, 1665–1990. *Social Studies of Science.* 24.279–310.

Anderson, P. V., R. J. Brockmann and C. R. Miller (eds.) 1983. *New essays in technical and scientific communication: Research, theory, practice.* Farmingdale, NY: Baywood.

https://doi.org/10.1017/S026719059919010X Published online by Cambridge University Press

Ashmore, M., G. Myers and J. Potter. 1994. Discourse, rhetoric, reflexivity. In S. Jasanoff, G. E. Markle, J.C. Petersen and T. Pinch (eds.) *Handbook of science and technology studies.* Thousand Oaks, CA: Sage. 321–342.

Atkinson, D. 1996. *The Philosophical Transactions of the Royal Society of London,* 1675–1975: A sociohistorical discourse analysis. *Language in Society.* 25.333–371.

_____ 1999. *Scientific discourse in sociohistorical context: The Philosophical Transactions of the Royal Society of London, 1675–1975.* Mahwah, NJ: L. Erlbaum.

Barton, E. 1996. Conventions of methods sections. Paper presented at AILA Conference. Jyväskylä, Finland, August 1996.

Battalio, J. T. 1996. The interplay between narrative, education, and exposition in an emerging science. *Journal of Technical Writing and Communication.* 26.177–191.

_____ 1998a. *The rhetoric of science in the evolution of American ornithological discourse.* Greenwich, CT: Ablex.

_____ (ed.) 1998b. *Essays in the study of scientific discourse: Methods, practice, and pedagogy.* Greenwich, CT: Ablex.

Bazerman, C. 1983. Scientific writing as a social act: A review of the literature of the sociology of science. In P. V. Anderson, R. J. Brockman and C. R. Miller (eds.) *New essays in technical and scientific communication: Research, theory, practice.* Farmingdale, NY: Baywood. 156–186.

_____ 1988. *Shaping written knowledge: The genre and activity of the experimental article in science.* Madison: University of Wisconsin Press.

_____ 1991. How natural philosophers can cooperate: The literary technology of coordinated investigation in Joseph Priestley's *History and present state of electricity* (1767). In C. Bazerman and J. Paradis (eds.) *Textual dynamics of the professions.* Madison: University of Wisconsin Press. 13–44.

_____ 1994. *Constructing experience.* Carbondale: University of Southern Illinois Press.

_____ Forthcoming. *The languages of Edison's light: Rhetorical agency in the material production of technology.* Mahwah, NJ: L. Erlbaum.

Berkenkotter, C. and T. N. Huckin. 1995. *Genre knowledge in disciplinary communication: Cognition/culture/power.* Hillsdale, NJ: L. Erlbaum.

Bhatia, V. K. 1993. *Analysing genre: Language in professional settings.* London: Longman.

Biber, D. 1988. *Variation across speech and writing.* Cambridge: Cambridge University Press.

_____ 1995. *Dimensions of register variation: A cross-linguistic comparison.* Cambridge: Cambridge University Press.

Broman, T. H. 1991. J. C. Reil and the "journalization" of physiology. In P. Dear (ed.) *The literary structure of scientific argument: Historical studies.* Philadelphia: University of Pennsylvania Press. 13–42.

https://doi.org/10.1017/S026719059919010X Published online by Cambridge University Press

Butler, C. 1990. Qualifications in science: Modal meanings in scientific texts. In W. Nash (ed.) *The writing scholar: Studies in academic discourse.* Newbury Park, CA: Sage. 137–170.

Campbell, J. A. 1986. Scientific revolution and the grammar of culture: The case of Darwin's *Origin. Quarterly Journal of Speech.* 72.351–376.

_____ 1990. Scientific discovery and rhetorical invention: Darwin's path to the *Origin.* In H. Simons (ed.) *The Rhetorical Turn.* Chicago: University of Chicago Press. 58–90.

_____ 1994. The comic frame and the rhetoric of science, epistemology, and ethics in Darwin's *Origin. Rhetoric Society Quarterly.* 24.27–50.

Ceccarelli, L. 1994. A masterpiece in a new genre: The rhetorical negotiation of two audiences in Schrödinger's "What is Life?" *Technical Communication Quarterly.* 3.7–17.

_____, R. Doyle and J. Selzer (eds.) 1996. *The rhetoric of science.* [Special issue of *Rhetoric Society Quarterly* 26.4.]

Charney, D. 1993. A study in rhetorical reading: How evolutionists read "The Spandrels of San Marcos." In J. Selzer (ed.) *Understanding scientific prose.* Madison: University of Wisconsin Press. 203–231.

Conrad, S. 1996. Investigating academic texts with corpus-based techniques: An example from biology. *Linguistics and Education.* 8.299–326.

Curtis, R. 1994. Narrative form and normative force: Baconian story-telling in popular science. *Social Studies of Science.* 24.419–461.

Dear, P. 1985. Totius in verba: Rhetoric and authority in the early Royal Society. *Isis.* 76.144–161.

Ding, D. 1998. Rationality reborn: Historical roots of the passive voice in scientific discourse. In J. Battalio (ed.) *Essays in the study of scientific discourse: Methods, practice, and pedagogy.* Greenwich, CT: Ablex. 117–134.

Dong, Y. R. 1996. Learning how to use citations for knowledge transformation: Non-native doctoral students' dissertation writing in science. *Research in the Teaching of English.* 30.428–459.

Dubois, B. L. 1980. Genre and structure in biomedical speeches. *Forum Linguisticum.* 5.140–169.

_____ 1987. "Something on the order of around forty to forty-four": Imprecise numerical expressions in biomedical slide talks. *Language in Society.* 16.527–541.

_____ 1997. *The biomedical discussion section in context.* Greenwich, CT: Ablex.

Espinoza, A. M. 1997. Contrastive analysis of the Spanish and English passive voice in scientific prose. *English for Specific Purposes.* 16.229–243.

Fahnestock, J. 1986. Accommodating science: The rhetorical life of scientific facts. *Written Communication.* 3.275–296.

_____ 1996. Series reasoning in scientific argument: *Incrementum* and *gradatio* and the case of Darwin. *Rhetoric Society Quarterly.* 26.13–40.

https://doi.org/10.1017/S026719059919010X Published online by Cambridge University Press

Farnsworth, R. and A. Crismore. 1991. On the reefs: The verbal and visual rhetoric of Darwin's other big theory. *Rhetoric Society Quarterly*. 21.11–25.

Flowerdew, J. 1992. Definitions in science lectures. *Applied Linguistics*. 13.202–221.

Geertz, C. 1983. *Local knowledge: Further essays in interpretive anthropology*. New York: Basic Books.

Gilbert, G. N. and M. Mulkay. 1984. *Opening Pandora's box: A sociological analysis of scientific discourse*. Cambridge: Cambridge University Press.

Golinski, J. V. 1990. Language, discourse, and science. In R. C. Olby, G. N. Cantor, J. R. R. Christie and M. J. S. Hodge (eds.) *Companion to the history of science*. London: Routledge. 110–123.

Gosden, H. 1992. Discourse functions of marked theme in scientific research articles. *English for Specific Purposes*. 11.207–224.

_____ 1993. Discourse functions of subject in scientific research articles. *Applied Linguistics*. 14.56–75.

_____ 1995. Success in research article writing and revision: A social constructionist perspective. *English for Specific Purposes*. 14.37–57.

_____ 1996. Verbal reports of Japanese novices' research writing practices in English. *Journal of Second Language Writing*. 5.109–128.

Grabe, W. and R. B. Kaplan. 1997. On the writing of science and the science of writing: Hedging in science text and elsewhere. In R. Markkanen and H. Schröder (eds.) *Hedging and discourse: Approaches to the analysis of a pragmatic phenomenon in academic texts*. Berlin: De Gruyter. 151–167.

Gragson, G. and J. Selzer. 1990. Fictionalizing the readers of scholarly articles in biology. *Written Communication*. 7.25–58.

Graves, H. B. 1995. Rhetoric and reality in the process of scientific inquiry. *Rhetoric Review*. 14.106–125.

Gross, A. 1990. *The rhetoric of science*. Cambridge, MA: Harvard University Press.

_____ 1993. Experiment as text: The limits of literary analysis. *Rhetoric Review*. 11.290–300.

_____ (ed.) 1994. *The rhetoric of science*. [Special issue of *Technical Communication Quarterly* 3.1.]

_____ and W. M. Keith (eds.) 1997. *Rhetorical hermeneutics: Invention and interpretation in the age of science*. Albany, NY: State University of New York Press.

Gross, P. R. and N. Leavitt. 1994. *Higher superstition: The academic left and its quarrels with science*. Baltimore, MD: Johns Hopkins University Press.

Gunnarsson, B-L. 1995. Studies of language for specific purposes: A biased view of a rich reality. *International Journal of Applied Linguistics*. 5.111–134.

_____, P. Linell, and B. Nordberg (eds.) 1997. *The construction of professional discourse*. London: Longman.

Halliday, M. A. K. 1998. Things and relations: Regrammaticalizing experience as technical knowledge. In J. R. Martin and R. Veel (ed.) *Reading science*. London: Routledge. 185–235.

https://doi.org/10.1017/S026719059919010X Published online by Cambridge University Press

Halliday, M. A. K. and J. R. Martin. 1993. *Writing science: Literacy and discursive power.* Pittsburgh: University of Pittsburgh Press.

Haraway, D. 1997. *Modest_witness@second_millenium.femaleMan ©_meets_oncomouse™: Feminism and technoscience.* New York: Routledge.

Harmon, J. E. 1992a. An analysis of fifty citation superstars from the scientific literature. *Journal of Technical Writing and Communication.* 22.17–37.

_____ 1992b. Current contents of theoretical scientific papers. *Journal of Technical Writing and Communication.* 22.357–375.

Harré, R. 1990. Some narrative conventions of scientific discourse. In C. Nash (ed.) *Narrative in culture: The use of storytelling in the sciences, philosophy, and literature.* London: Routledge. 81–101.

Harris, R. A. 1990. Assent, dissent, and rhetoric of science. *Rhetoric Society Quarterly.* 20.13–37.

_____ 1991. Rhetoric of science. *College English.* 53.282–307.

_____ (ed.) 1997. *Landmark essays on the rhetoric of science.* Davis, CA: Hermagoras Press.

Harvey, A. 1992. Science reports and indexicality. *English for Specific Purposes.* 11.115–128.

Harwood, J. T. 1994. Science writing and writing science: Boyle and rhetorical theory. In M. Hunter (ed.) *Robert Boyle reconsidered.* Cambridge: Cambridge University Press. 37–56.

Holmes, F. L. 1991. Argument and narrative in scientific writing. In P. Dear (ed.) *The literary structure of scientific argument.* Philadelphia: University of Pennsylvania Press. 164–181.

Horsella, M. and G. Sindermann. 1992. Aspects of scientific discourse: Argumentation. *English for Specific Purposes.* 11.129–139.

Hunston, S. 1993. Evaluation and ideology in scientific writing. In M. Ghaddessy (ed.) *Register analysis: Theory and practice.* London: Pinter. 57–73.

Hyland, K. 1994. Hedging in academic writing and EAP textbooks. *English for Specific Purposes.* 13.239–256.

_____ 1996a. Talking to the Academy: Forms of hedging in science research articles. *Written Communication.* 13.251–281.

_____ 1996b. Writing without conviction? Hedging in scientific research articles. *Applied Linguistics.* 17.433–454.

_____ 1998. *Hedging in scientific research articles.* Amsterdam: John Benjamins.

Jensen, J. V. 1991. *Thomas Henry Huxley: Communicating for science.* Newark, DE: University of Delaware Press.

Johns, A. 1991. History, science, and the history of the book: The making of natural philosophy in Early Modern England. *Publishing History.* 30.5–30.

_____ To appear. Miscellaneous methods: Authors, societies and journals in Early Modern England. *British Journal for the History of Science.*

https://doi.org/10.1017/S026719059919010X Published online by Cambridge University Press

Johnson-Sheehan, R. D. 1995. Scientific communication and metaphors: An analysis of Einstein's 1905 special relativity paper. *Journal of Technical Writing and Communication*. 25.71–83.

_____ 1997. The emergence of a root metaphor in modern physics: Max Planck's 'quantum' metaphor. *Journal of Technical Writing and Communication*. 27.177–190.

Journet, D. 1991. Ecological theories as cultural narratives: F. E. Clements's and H. A. Gleason's "stories" of community succession. *Written Communication*. 8.446–472.

_____ 1993. Biological explanation, political ideology, and "blurred genres": A Bakhtinian reading of the science essays of J. B. S. Haldane. *Technical Communication Quarterly*. 2.185–204.

Kaplan, R. B. and W. Grabe. 1991. The fiction in science writing. In H. Schröder (ed.) *Subject-oriented texts: Language for Special Purposes and text theory*. Berlin: de Gruyter. 199–217.

Knorr-Cetina, K. D. 1981. *The manufacture of knowledge: An essay on the constructivist and contextual nature of science*. Oxford: Pergamon.

Latour, B. 1987. *Science in action*. Cambridge, MA: Harvard University Press.

_____ and S. Woolgar. 1979/1986. *Laboratory life: The construction of scientific facts*. Princeton, NJ: Princeton University Press.

Locke, D. 1992. *Science as writing*. New Haven, CT: Yale University Press.

Lott, H. M. and M. Barrett-O'Leary. 1996. Implications of professional writing experiences of academic veterinary scientists for technical writing pedagogy. *Technical Communication Quarterly*. 5.169–181.

Lynch, M. 1985. *Art and artifact in laboratory science: A study of shop work and shop talk in a research laboratory*. London: Routledge.

Machamer, P. 1991. The person-centered rhetoric of seventeenth-century science. In M. Pera and W. R. Shea (eds.) *Persuading science: The art of scientific rhetoric*. Canton, MA: Science History Publications. 143–156.

Markel, M. 1993. Induction, social constructionism, and the form of the scientific paper. *Journal of Technical Writing and Communication*. 23.7–22.

Martin, J. R. and R. Veel (eds.) 1998. *Reading science*. London: Routledge.

Master, P. 1991. Active verbs with inanimate subjects in scientific prose. *English for Specific Purposes*. 10.15–33.

Medawar, P. B. 1964. Is the scientific paper fraudulent? *Saturday Review*, August 1: 42–43.

Miller, C. R. 1992. *Kairos* in the rhetoric of science. In S. P. Witte, N. Nakadate and R. D. Cherry (eds.) *A rhetoric of doing: Essays on written discourse in honor of James L. Kinneavy*. Carbondale: Southern Illinois Press. 310–327.

Montgomery, S. L. 1996. *The scientific voice*. New York: Guilford Press.

Myers, G. 1989. The pragmatics of politeness in scientific articles. *Applied Linguistics*. 10.1–35.

_____ 1990. *Writing biology: Texts in the social construction of science*. Madison, WI: University of Wisconsin Press.

https://doi.org/10.1017/S026719059919010X Published online by Cambridge University Press

Myers, G. 1991a. Lexical cohesion and specialized knowledge in science and popular science texts. *Discourse Processes*. 14.1–26.

_____ 1991b. Stories and styles in two molecular biology review articles. In C. Bazerman and J. Paradis (eds.) *Textual dynamics of the professions: Historical and contemporary studies of writing in professional communities*. Madison: University of Wisconsin Press. 45–75.

_____ 1992a. 'In this paper we report...': Speech acts and scientific facts. *Journal of Pragmatics*. 16.295–313.

_____ 1992b. Textbooks and the sociology of scientific knowledge. *English for Specific Purposes*. 11.3–17.

_____ 1993. Making enemies: How Gould and Lewontin criticize. In J. Selzer (ed.) *Understanding scientific prose*. Madison: University of Wisconsin Press. 256–275.

_____ 1996. Out of the laboratory and down by the bay: Writing in science and technology studies. *Written Communication*. 13.5–43.

Ochs, E., P. Gonzales and S. Jacoby. 1996. "When I come down, I'm in the domain state": Grammar and graphic representation in the interpretive activity of physicists. In E. Ochs, E. A. Schegloff and S. A. Thompson (eds.) *Interaction and grammar*. Cambridge: Cambridge Univesity Press. 328–369.

Paul, D. and D. Charney. 1995. Introducing chaos into science and engineering: Effects of rhetorical strategies on scientific readers. *Written Communication*. 12.396–438.

Pera, M. 1994. *The discourses of science*. Chicago: University of Chicago Press.

_____ and W. R. Shea (eds.) 1991. *Persuading science: The art of scientific rhetoric*. Canton, MA: Science History Publications.

Prelli, L. J. 1989. *A rhetoric of science: Inventing scientific discourse*. Columbia, SC: University of South Carolina Press.

Rauch, Y. M. 1997. The rhetoric of the probable in scientific commentaries: The debate over the species status of the Red Wolf. *Technical Communication Quarterly*. 6.91–104.

Reeves, C. 1992. Owning a virus: The rhetoric of scientific discovery accounts. *Rhetoric Review*. 10.321–336.

Robinson, P. 1980. *ESP (English for Specific Purposes)*. Oxford: Pergamon.

Rodman, L. 1981. The passive in technical and scientific writing. *Journal of Advanced Composition*. 2.165–172.

_____ 1991. Anticipatory *it* in scientific discourse. *Journal of Technical Writing and Communication*. 21.17–27.

_____ 1994. The active voice in scientific articles: Frequency and discourse functions. *Journal of Technical Writing and Communication*. 24.309–331.

Rymer, J. 1988. Scientific composing processes: How eminent scientists write. In D. A. Jolliffe (ed.) *Advances in writing research*. Volume 2. Norwood, NJ: Ablex. 211–250.

Salager, F. 1984. Compound nominal phrases in scientific-technical literature: Proportion and rationale. In A. K. Pugh and J. M. Ulijn (eds.) *Reading for professional purposes*. London: Heinemann. 136–145.

https://doi.org/10.1017/S026719059919010X Published online by Cambridge University Press

Schröder, H. 1991. Linguistic and text-theoretical research on Language for Specific Purposes. In H. Schröder (ed.) *Subject-oriented texts: Language for Special Purposes and text theory.* Berlin: de Gruyter. 1–48.

Selinker, L., E. Tarone and V. Hanzeli (eds.) 1981. *English for academic and technical purposes: Studies in honor of Louis Trimble.* Rowley, MA: Newbury House.

Selzer, J. (ed.) 1993. *Understanding scientific prose.* Madison: University of Wisconsin Press.

Shapin, S. 1984. Pump and circumstance: Robert Boyle's literary technology. *Social Studies of Science.* 14.481–520.

_____ 1994. *A social history of truth: Civility and science in seventeenth-century England.* Chicago: University of Chicago Press.

Simons, H. W. (ed.) 1990. *The rhetorical turn: Invention and persuasion in the conduct of inquiry.* Chicago: University of Chicago Press.

Sinding, C. 1996. Literary genres and the construction of knowledge in biology: Semantic shifts and scientific change. *Social Studies of Science.* 26.43–70.

Sionis, C. 1995. Communication strategies in the writing of scientific research articles by non-native users of English. *English for Specific Purposes.* 14.99–113.

Swales, J. M. 1971. *Writing scientific English.* London: Nelson.

_____ 1981. *Aspects of article introductions.* Birmingham, UK: The University of Aston, Language Studies Unit.

_____ 1988. Language and scientific communication: The case of the reprint request. *Scientometrics.* 13.93–101.

_____ 1990. *Genre analysis: English in academic and research settings.* Cambridge: Cambridge University Press.

_____ 1998. *Other floors, other voices: A textography of a small university building.* Mahwah, NJ: L. Erlbaum.

_____, U. K. Ahmad, Y-Y. Chang, D. Chavez, D. F. Dressen and R. Seymour. 1998. Consider this: The role of imperatives in scholarly writing. *Applied Linguistics.* 19.97–121.

_____ and H. Najjar. 1987. The writing of research article introductions. *Written Communication.* 4.175–192.

Tarone, E., S. Dwyer, S. Gillette and V. Icke. 1981. On the use of the passive in two astrophysics journal papers. *ESP Journal.* 1.123–140.

_____ 1998. On the use of the passive and active voice in astrophysics journal papers: With extensions to other languages and other fields. *English for Specific Purposes.* 17.113–132.

Taylor, C. A. 1994. Science as cultural practice: A rhetorical perspective. *Technical Communication Quarterly.* 3.67–81.

_____ 1996. *Defining science: A rhetoric of demarcation.* Madison: University of Wisconsin Press.

Taylor, G. and T. Chen. 1991. Linguistic, cultural, and subcultural issues in contrastive discourse analysis: Anglo-American and Chinese scientific texts. *Applied Linguistics.* 12.319–336.

https://doi.org/10.1017/S026719059919010X Published online by Cambridge University Press

Thompson, D. K. 1993. Arguing for experimental "facts" in science. *Written Communication.* 10.106–128.

Trimble, L. 1985. *English for science and technology: A discourse approach.* Cambridge: Cambridge University Press.

Valle, E. 1993. The development of English scientific rhetoric in the *Philosophical Transactions of the Royal Society*, 1711–1870. *Finlance: A Finnish Journal of Applied Linguistics.* 12.94–124.

_____ 1997. A scientific community and its texts: A historical discourse study. In B.-L. Gunnarsson, P. Linell and B. Nordberg (eds.) *The construction of professional discourse.* London: Longman. 76–98.

_____ In press. *A collective intelligence: The life sciences in the Royal Society as a scientific discourse community, 1665–1965.* Turku, Finland: University of Turku.

Vande Kopple, W. J. 1994. Some characteristics and functions of grammatical subjects in scientific discourse. *Written Communication.* 11.534–564.

_____ 1998. Relative clauses in spectroscopic articles in the *Physical Review,* beginnings and 1980. *Written Communication.* 15.170–202.

van Naerssen, M. and R. B. Kaplan. 1987. Language and science. In R. B. Kaplan, *et al.* (eds.) *Annual Review of Applied Linguistics*, 7. New York: Cambridge University Press. 86–104.

Walters, F. D. 1993. Scientific method and prose style in the early Royal Society. *Journal of Technical Writing and Communication.* 23.239–258.

Walvoord, B. and L. P. McCarthy. 1990. *Thinking and writing in college: A naturalistic study of students in four disciplines.* Urbana, IL: National Council of Teachers of English.

Westfall, R. S. 1991. Galileo and Newton: Different rhetorical strategies. In M. Pera and W. R. Shea (eds.) *Persuading science: The art of scientific rhetoric.* Canton, MA: Science History Publications. 107–124.

Widdowson, H. 1979. *Explorations in applied linguistics.* Oxford: Oxford University Press.

Wilkinson, A. M. 1992. Jargon and the passive voice: Prescriptions and proscriptions for scientific writing. *Journal of Technical Writing and Communication.* 22.319–325.

https://doi.org/10.1017/S026719059919010X Published online by Cambridge University Press