SUGGESTED READING

English for Science and Technology

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Introduction

The wide range of purposes and contexts in which English is used has made English for specific purposes (ESP) an eclectic discipline. Typically trained as writing or language teachers, ESP teachers work outside of their own disciplines, and must become ethnographers, exploring unfamiliar language varieties, disciplinary cultures and modes, and drawing on scholarship from a wide range of fields to do so. These include sociocultural studies, literacy studies, second language (L2) writing studies, rhetoric, and systemic functional linguistics.

Perhaps because of the rapid expansion of English for science and technology (EST) in the last 50 years, science and technology were an early focus for ESP researchers (e.g. Barber 1988; Bazerman 1984, 1988; Braine 1989; Halliday 1993a; Herbert 1965; Swales 1971, 1988). The initial interest of EST teachers and researchers was on linguistic forms (see Johns, this volume), with later emphasis on skills, a more recent focus has been on disciplinary socialization, and most recently a critical perspective, which considers how literacy practices express societal or disciplinary power differences. In tracing this expansion, Hyland (2006) notes that each expanded focus comprehends rather than replaces prior ones. I represent this expanding focus in Figure 8.1 and use it to organize this chapter, starting with the widest focus, disciplinary culture, and values.

The expanding focus of ESP

What does English for science and technology encompass? Halliday (1993a) comments that a text is recognized as scientific English because of the combined effect of clusters of features and, importantly, the relations of these features throughout

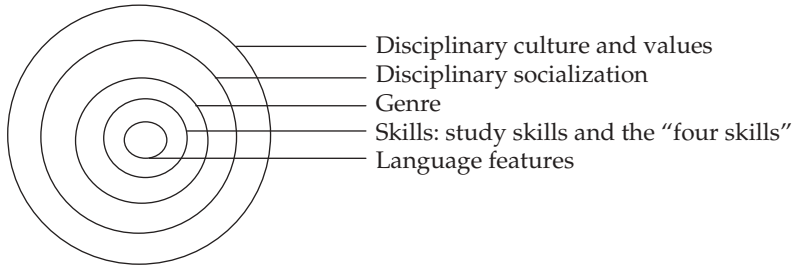

Figure 8.1 The expanding focus of ESP.

a text. Yet characteristic forms and vocabulary of science or technology should not be considered as separate from the genres in which they occur, because linguistic differences are part of what constitutes genre. Similarly the genres of science and technology partially constitute the various disciplines, and cannot be separated from them. Being a member of a discourse community involves using its characteristic language and genres, and also sharing its values (which are reflected in its language and genres), and taking on a role recognized by other members of the discourse community (Paltridge 2012).

This expanded perspective of ESP has replaced a notion of skills transferable between disciplines with the conception of specific literacies acquired in the context of the discipline. This creates a difficulty for EST teachers, who must provide access for their students into a discourse community of which they are usually not members. Spack (1988) noted this difficulty early on, suggesting that disciplinary discourse is too diverse and complex for ESP teachers to provide this access. Indeed, Mackiewicz (2004) outlines how humanities-trained writing tutors may give inappropriate advice to engineering students, for example. I outline below how EST practitioners have variously used employers, disciplinary teachers or students as resources to provide this insight.

To mitigate the status of EST teacher as disciplinary outsider, Smith Taylor (2007) suggests training discipline insiders in writing instruction to circumvent EST teachers' lack of insider knowledge. Stoller et al. (2005) stress the importance not only of working with discipline specialists in designing EST interventions, but of working towards a shared understanding with discipline specialists of what is valuable to them in writing, (e.g. content accuracy).

Swales and Lindeman (2002), teaching the literature review to graduate students, suggest that ESP instructors facilitate students' own investigation of disciplinary discourse. Pritchard and Nasr (2004), considering the teaching of reading to engineering students with greater disciplinary knowledge than their ESP reading teachers, suggest that students become informants to the teacher and classmates.

Collaboration with disciplinary experts is highly recommended if EST teachers are not knowledgeable about students' disciplines (Horn, Stoller, and Robinson

2008). Discipline and EST teachers can work together to identify the key features of genres. However, although collaborative approaches have been a key element in ESP methodology (Hyland 2007), collaboration is not always straightforward. Braine (2001) found reluctance among science and engineering professors, themselves L2 English speakers, to show him writing assignments they set for students. He speculated that they were ashamed of possible grammatical errors, and could see no value in a process approach to writing, having been educated through the grammar-translation method.

In addition to relying on employers, disciplinary teachers or students to ameliorate their outsider status, EST teachers also have available studies of the discourse features of science and technology texts, as well as studies of disciplinary cultures. I begin by reviewing studies of disciplinary cultures.

Culture and Values

To become a member of a science discourse community, a student needs to participate in and come to regard as natural, research science values: that science is quantitative, repeatable, and ideally free from bias. Engineering values by contrast are concerned with the design process and problem-solving within set specifications; associated discourse includes argument that links scientific phenomena to specific contexts (Archer 2008).

However, from a critical discourse perspective, disciplinary discourse is not equally accessible to everyone and the task of ESP teachers includes assisting students in unpacking their disciplines' ideological assumptions, rather than merely accepting and coming to share these. A critical perspective recognizes that science and technology are not context-free (Johnston, Lee, and McGregor 1996; Pennycook, 1997). Archer (2008), working in post-apartheid South Africa with students from underdeveloped rural communities, found a discontinuity between student expressions of suffering in rural communities, and the impersonal professional engineers' writing. Her work indicates the need to make professional conventions available to students, while ensuring that these are continuous with, not in opposition to, students' own values. Archer notes the value to developing countries of engineers who are knowledgeable about rural underdevelopment. To facilitate access to disciplinary discourse, EST teachers need awareness of such societal inequalities.

A discipline's culture may vary too between countries. Artemeva (1998) found that the different values in a North American and a Russian engineering company resulted in different views of rhetorical purpose, audience, organization, all expressed at the levels of sentence and paragraph organization, thematic structure and even content of periodic progress reports. The North American engineers saw an engineer's role as finding concrete solutions to technical problems, while the Russian engineers saw themselves as scientists. They were thus unwilling to frame this genre in ways expected by the report's North American audience.

Social constructionist studies of the talk, writing, and actions of scientists in research laboratories have been an important information source about disciplinary values. Latour and Woolgar (1979) studied how research findings become facts: generally we view facts as pre-existing, awaiting scientists' discovery. They suggest instead that facts are socially constructed (through intuition, data interpretation, collegial discussion, publication, etc.). They note that a statement gains factual status when recognized as true beyond a particular place and time, or its producers; it becomes part of the body of knowledge drawn upon by the community (Latour and Woolgar 1979).

Insight into discourse communities' values has come too from examination of the research article (RA), including Bazerman's (1988) study of its historical development. Discourse communities are driven by this published outcome of research, because publication represents community acceptance of research claims (Myers 1989). Linguistic and rhetorical features of RAs reflect this purpose. For example, the impersonal language of science RAs is a convention for expressing objectivity and the need to represent findings as separated from time and person. It reflects the desire to broaden applicability of a finding (not tied to the individual researcher) and also to make it appear that nature speaks for itself. Rhetorically, too, the RA presents the research process as more deliberate than it is. Researchers appear to follow a carefully planned path, rather than trying a number of possibilities; false starts and mistakes are not represented in the RA and opportunistic findings are represented rhetorically as part of a coherent research plan (see Flowerdew, this volume; Knorr-Cettina 1981).

Insight into the values of science and technology discourse communities is valuable to EST teachers from another perspective too, in that it helps them to assist students to access these communities. In the next section, I review an important trend in ESP, the focus on learners' socialization into a discourse for the purposes of becoming members of a target discourse community.

Integration into the EST Discourse Community

A disciplinary socialization perspective views students as not merely learning the registers and genres important in their disciplines, but as being enculturated into those disciplines by learning disciplinary values and behavior. This perspective draws on sociocultural theory, viewing discourse practices as learnt through interaction with those who have already mastered them (Duff 2010; Lemke 1990). A language socialization perspective may, however, represent the process of acquiring new literacy practices too simply. Lea and Street (1998) argue that acquiring disciplinary literacy requires a student to take on a new disciplinary identity, one with which they may not be comfortable, and which they may therefore resist.

These perspectives have led EST practitioners/researchers to use ethnographic methods in investigating the target discourse community. Vickers (2007: 624), for example, conceptualized a US computer engineering department as a "speech community containing communicative norms;" she viewed individuals as being

competent members of this discourse community when they had an understanding of the range of activities that members participate in. Focussing on a single speech event, the team meeting, she describes the socialization of a NNS student into the discourse of a student design team. She traces how participation by the student, initially a peripheral member of the group, was scaffolded by core members who provided opportunities for design experiences. The student gained the confidence to suggest design solutions, initiate topics in discussions, and provide explanations. Considering engineering student writing from a similar perspective, Nelson (2000) aimed to socialize students into professional engineering culture by building peer review into engineering writing instruction.

Attention has been paid too to professional engineers' team meetings. Angouri (2010) compares recordings of engineers' meetings with their representation in ESP textbooks. Her findings include different turn-taking mechanisms, much overlapping talk, back-channelling, interactants extending or completing each others' utterances, and a lower degree of explicitness in the real data. By contrast, in the textbooks, speakers have non-overlapping turns in which speakers nominate the next speaker rather than speakers judging the appropriate place to take a turn. Angouri (2010) suggests how EST teachers can supplement textbook materials with real data to teach meeting interaction.

Also working in a language socialization paradigm, Chinn and Hilgers (2000) studied instructors in undergraduate science and engineering content courses. They characterized them as variously playing the role of corrector (where the goal was content mastery), journal editor (students peer-reviewed each other's work) and collaborator (collaborative assignments involved research and had multiple readers). Students of the editor- and collaborator-instructors learnt about genre in addition to content, while the collaborator-assignments gave students a sense of working within science or engineering, where collaboration and repeated review of writing are the norm.

Artemeva, Logie, and St Martin (1999), to assist students' integration into the engineering discourse community, based communication assignments on each student's chosen engineering area. This made the context seem more genuine for students, improving perceptions that the course served their needs. Their course, which included several engineering genres, focussed on audience and purpose, encouraging a sense of dialogue with instructor and peers. Similarly, Parkinson (2000) aimed to assist socialization into a discourse community by situating EST coursework in the content of undergraduate science students' subject areas. Students collected experimental data and wrote lab reports on this data, thus simulating students' disciplinary discursive contexts.

Research into EST Genres

To mitigate teachers' outsider status and gain insight into the genres and culture of these communities, researchers have worked on identifying key EST genres. Swales (2004) has noted that genres in any discipline or discourse community

come in related sets, such as the RA and the lab report, the feasibility study and progress report, and the engineering presentation and design report. Much progress has been made also in analyzing the rhetorical and linguistic features of genres and identifying how they reflect the values and culture of the discourse community. The task is complicated by the fact that the key genres of these discourse communities are not identical with the genres demanded of students. Having identified work-related genres and/or pedagogical student genres, the EST teacher must consider how best to teach them in order to provide access to the discourse community. In the next section I review work on a range of science and engineering genres, starting with the RA.

Rhetorical features of the research article

Investigation of high stakes genres such as the RA have been valuable to EST teachers of graduate or professionals, who must read or write RAs. This investigation has also been valuable in revealing register features, and providing insight into the value system of particular science and technology disciplines and their discourse communities

In his study of the development of the RA, Bazerman (1988) indicates how the genre developed to convince readers who had not observed experiments. Newton, for example, represented himself in his writing as an ideal experimental scientist who isolates phenomena in a planned and orderly way. Newton's persuasive use of language has been influential, and Halliday (1993c) explores its continuing grammatical influence. Bazerman (1988) notes that literature survey length and number of references to the literature depends on how focussed the discipline is and the degree of consensus within it. As a discipline develops it becomes increasingly embedded in theory and knowledge rather than methods or instruments.

As a discipline, ESP regards students as benefitting from explicit instruction in genre structure. Much ESP work on RA structure has followed Swales' well-known CARS (create a research space) model (1981, 1984, 1990) on the moves in RA introductions. Considerable attention has been paid to the different sections, including Abstracts (Samraj 2005), Introductions (Swales 1981, 2004), Methods (Lim 2006; Wood 1982), Results (Brett 1994) and Discussions (Dudley-Evans 1994; Holmes 1997; Kanoksilapatham 2005; Parkinson 2011; Peacock 2002; Swales 1990).

Anthony (1999) studied software Engineering RA introductions, and found deviations from Swales' CARS model. Anthony suggests that research is needed in a wide range of fields so that these disciplinary variations can be available for ESP teachers unfamiliar with a particular discipline.

In reading pedagogy too, focus on genre has been of value. Stoller (2010) suggests ways for EST teachers to guide reading of chemistry texts, including consideration of purpose, audience, language, organization, and content. Students are sensitized by first considering linguistic and nonlinguistic features of nondisciplinary genres, then considering texts in the field written for an expert and non-expert audience, and finally focussing on the target genre.

Theses and dissertation

Theses and dissertations represent a genre similar in form to the RA. Paltridge (2002) found a number of alternative macro-structures and that advice in published handbooks did not match practice, indicating the value of specific instruction for graduate students. Koutsantoni (2006) compared rhetorical strategies used by engineering RA and thesis writers. She suggests the tendency of the student writers to hedge more, avoid personal attribution, distance themselves from their claims, and acknowledge limitations reflects different reader-writer power relationships in the two genres. She suggests a need for prospective engineers to be sensitized to expected community rhetorical strategies.

Studies of science textbooks

Science textbooks have been the subject of some study (Myers 1992, Schleppegrell 2004, Unsworth 1997, Young and Nguyen 2002). Textbooks are the main reading of science (Jackson, Meyer, and Parkinson 2006; Myers 1992) and engineering undergraduates (Parodi 2009), although Leventhal and Mynatt (1987) found that senior software engineering students read RAs. Swales (1995) notes that textbooks employ little hedging or human agency, and use abstract nominalizations as subjects of processes. In comparison with RA knowledge, textbook knowledge is not provisional (and thus has few citations), having been accepted by the science research community (Myers 1989). These differences mean that textbooks cannot easily be used as models for graduate students, who need to write RAs, or for undergraduate students, who need to write laboratory reports, a genre similar to RAs (Hyland 1998b).

Myers' (1992) comparison of these two genres found a number of register differences. Personal subjects such as *We* in RAs refer to researchers; in textbooks they refer to reader and writer. RAs are written in past tense for methods and in the present for well-accepted facts in the discipline. Textbooks are written largely in the present tense because textbooks limit information to published research that is already accepted by the research community, and are thus presented as all fact (Myers 1992). In RAs, almost all claims are hedged, while in textbooks there are few hedges (Hyland 2004; Parkinson and Adendorff 2005). RAs achieve cohesion through noun phrase repetition, while textbooks do so using logical connectors and a range of metadiscoursal markers (Hyland 2004). The main types of images associated with RAs are graphs and equations while textbooks use photographs and naturalistic drawings and diagrams (Pozzer-Ardenghiam and Roth 2010).

Pedagogical genres

A controversial issue in writing pedagogy has been whether genre should be explicitly taught. In the area of rhetorical genre studies some writing specialists (e.g. Freedman 1993), have avoided explicit instruction, because of the dynamic

nature of genres and incidental student learning of genre features through immersion in the disciplinary culture, while others have focussed explicit teaching on context and situation rather than form (Giltrow and Stein 2009). ESP writing instruction has however favored explicit instruction on form, viewing it as of particular value to non-native speakers, who may find access to disciplinary cultures less easy than do native speakers.

Samraj (2004) notes that identically labeled texts may have distinct differences. EST teachers can therefore not rely on their own understanding of a genre, which may not coincide with that of the students' discipline. My own experience indicates that, compared with humanities essays, biology and geology essays are descriptive and do not expect writers to take a stance on an issue. Samraj (2004) examined the features of graduate research reports in two environmental science fields: conservation biology and wildlife behavior. She found that the first usually had a problem-solution structure and focussed on the environmental phenomenon, not the research. By contrast, wildlife behavior focussed on the research and tried to identify a gap in the field.

Artemeva and Fox (2010) used genre-competence assessment to see how well students identify and characterize rhetorical and textual features. They found that this ability is necessary but not sufficient for developing competence in writing engineering genres. Flowerdew (2000, 2003, 2008) considered good "apprentice" models, using high-performing student writing as models to teach the genre from the perspective of Hoey's (1983) situation-problem-response-evaluation pattern.

Laboratory reports

Braine's (1989) study of writing assignments in science and engineering courses found that most assignments were either lab or design reports (other writing included summary/reactions, case studies and library research papers). The lab report socializes students into core disciplinary values in experimental science including conventions for expressing objectivity, a value for quantitative methods, the need to show continuity of one's own findings with the literature, and a preference for mathematical models.

The lab report "encodes a scientific way of knowing in its structure" as Carter, Ferzli, and Wiebe (2007: 295) point out; the biology students in their study reported that the lab report encouraged them to act as scientists trying to solve a problem and it enabled them to view themselves as connected to the science community. Interestingly, they viewed their lab reports as more authoritative than textbooks and lecture notes, because they had used the register and ways of knowing of science.

The Introduction-Method-Results-Discussion organization of lab reports is similar to the experimental RA. The two genres also have similarities in purpose in that they report experimental results, although the RA must report new findings, while the lab report displays laboratory skills and understanding of accepted knowledge (Parkinson 2011). The lab report writer writes for a person grading the report, while the RA writer addresses peers.

Schleppegrell (2002) compared the lab reports of ESL Chemical Engineering writers to a well-written first language (L1) student's lab report. She found that the ESL students' difficulties were not merely ESL errors. Even if all errors were corrected, their lab reports would have a more restricted lexico-grammatical range than the L1 students'. For example to express assumptions, L1 writers used a range of grammar including *assume* as a verb, (passive, active, finite, and nonfinite), as an adjective, and as a noun as well as synonyms of *assume*. L2 writers by contrast depended on the imperative, or merely listed assumptions, because they lacked resources for expressing assumptions.

Smith Taylor (2007) notes that for many engineering students their main writing instruction is the grading of their reports by teaching assistants (TAs). For this reason she suggests training TAs in report grading, a further example of the collaborative approach taken by ESP. Interestingly, TAs focussed on content rather than surface form-related issues; they requested specificity, and probed validity. Use of a rubric led to about twice the proportion of coaching comments rather than authoritative comments.

Design reports

The design report is identified by Marshall (1991) as one of three important written engineering genres. (The other two he identified as important are the work experience report and the instruction manual). Design, usually taught through problem-based learning (PBL), is a key outcome for engineering education. PBL enculturates students into the activities of engineering by using group work, as practicing engineers do, to solve design problems. Students make and test the products of their designs. They report on this process in the design report as well as interim progress reports. Unlike a lab report, design reports consider the feasibility and cost of designs as well as match to specifications, not merely scientific/technical elements.

Part of the same genre set as the design report is the design presentation. The work of Dannels (2003, 2009) illustrates how ESP teachers have investigated disciplinary communities' values and activities. In teaching the design presentation, Dannels (2003) found that although this genre was designed to simulate a workplace environment, professors had academic expectations. Students responded to these contradictory demands by addressing an academic rather than an industry audience and enacting an academic identity, but structured their presentations to show the influence of both academic and industry contexts. Dannels (2009) found that highly graded presentations were more likely to provide justifications for assumptions, evaluate their solutions and provide a personalized motivation. Lower-graded presentations used detached language and an impersonalized motivation. Dannels concludes that the higher-graded presenters were more skilled at negotiating a relationship with both the imagined professional audience and the real academic audience.

Olsen and Huckin (1990) studied another oral genre, the academic lecture in engineering. They found that students ignored the rhetorical problem-solution

structure of the lecture. They understood the details, but ignored the main points and how they fitted together. They explain this failure as stemming from reliance on board notes, a focus on absorbing facts, and ignoring introductory remarks, prosodic markers, and rhetorical cues emphasizing main points. They suggest that the problem-solution-based nature of science and engineering is not stressed enough, either within the disciplines or within EST.

A Malaysian survey of professional engineers (Kassim and Ali 2010) suggested that ESP stress other oral genres including teleconferencing, and networking for contacts and advice. They suggest ESP courses for engineers should take into account workplace scenarios.

Language Features of EST

The grammatical and lexical features of language we use for specific purposes are by definition specialized and not a routine part of a native speaker's repertoire (Tudor 1997). Indeed corpus studies have shown how specialized the lexico-grammar and discourse strategies of disciplinary genres are (Paltridge 2009). Thus, ESP has tended to emphasize communication in the specialized target context rather than language teaching (Hyland 2007). Attention to language has been embedded in the teaching of key genres and language varieties learners will need to use in their disciplines.

Halliday's (1993b) influential analysis of the distinctive organization of written scientific text has shown how meaning in science tends to be expressed nominally rather than clausally, with meaning "buried" within the clause rather than explicitly signaled between clauses by use of conjunctions:

Clausal packaging of meaning:

Ozone	is destroyed	because	chlorine	reacts	with ozone
noun	verb	conj	noun	verb	prepositional group

Nominal packaging of meaning:

Reaction with chlorine	causes	ozone destruction
nominal group	verb	nominal group

Between these two examples, the actions *react* and *destroy* (most naturally or "congruently" expressed as verbs) become nominalized into the nouns *reaction* and *destruction*, a less expected, "less spoken" way of expressing this meaning. Similarly, the conjunction *because*, which signals the causal relation between two clauses is re-expressed as a verb, *causes*, and buried in a single clause, a less expected, "more written" way of expressing this meaning. Halliday (1993b) has labeled these more written uses of language "grammatical metaphor," because these meanings are metaphorical with respect to the grammar used to express them.

As Unsworth (1997) notes, the less congruent expression of written science makes this meaning less accessible. Mohan and Beckett (2003) studied the scaffolding of the acquisition of this nominalized writing in teacher talk. They found that the teachers of undergraduate science students recast student talk in more "literate," more nominalized and abstract ways. An example from their study is the following teacher recast:

S: To stop the brain's aging, *we can use our bodies and heads*.
T: So we can prevent our brain from getting weak *by being mentally and physically active*?

The student expresses meaning congruently, using a verb to talk about an action (use), and nouns (bodies, heads) to talk about objects. In the teacher's recast, the objects are construed as adverbs (mentally, physically) and the action as an adjective (active).

Packaging of meaning into nominalizations functions in science and engineering discourse to allow complex information to be compressed into a word, and it also allows a high level of abstraction e.g. *curvature of material surfaces* (Pueyo and Val 1996). Another important function of nominalization is allowing a process/action expressed in one clause to become, in the next clause, the theme about which a point can be made; this allows progress of the argument. An example from Halliday (1993b: 81) is:

Theme	Rheme
The atomic nucleus	*absorbs* energy in discrete units
Each *absorption*	absorbs energy in discrete units

Comparing the thematic structure of biology RA Method and Discussion sections, Martinez (2003) found that Method sections had simple literal experiential themes, referring to entities in the world; Discussions had more abstract and more multiple themes (i.e. a textual theme, linking the clause to other parts of the message, or an interpersonal theme, signaling writer attitude, in addition to an experiential element). An example of a multiple theme from her data is:

Therefore	it is possible that	classical MAP kinase isoforms	play a role in . . .
Textual theme	interpersonal theme	experiential theme	

She notes these sections' differing rhetorical goals: Method sections aim to describe methods in chronological order, while Discussions use abstract argument to convince readers. Martinez suggests raising awareness of this amongst L2 writers of RAs.

Vocabulary

Vocabulary as well as grammar differs from discipline to discipline. Ward (2009) estimated that his Thai engineering students knew only half of the 2000 most frequent English words as described in the General Service List (West 1953) and only 30 percent of academic words, yet had to read their textbooks in English. He identified 299 word types giving good coverage across five engineering subjects. These words are all from the General Service List plus the Academic Word List (Coxhead 2000) but are all distinctly engineering words (e.g. *system, equation, flow*). Mudraya (2006) distinguishes such sub-technical words, which have both an engineering and non-engineering meaning, from technical words, which have no exact synonym, resist semantic change, and have a narrow range of use, (e.g. *urethane*). She uses collocations to assist students to acquire both meanings. Ward (2007) used concordancing to study divergence in meaning in common sub-technical engineering words. His pedagogical suggestions include raising awareness of collocations, and teaching students to read collocates as chunks, not as single words.

Cortes (2004) and Hyland (2008) found lexical bundles (e.g. this result suggests) to be discipline-specific. Cortes (2004) found that RA writers use far more of these fixed expressions than do inexperienced writers (e.g. students at all levels, both native and non-native speakers). When students did use them, their use was not typical of use in the research articles, being more restricted and more repetitive in the bundles used. Cortes (2004) suggests that students might avoid the lexical bundles for fear of using them wrongly. A pedagogical implication of research in this area is to assist students in "noticing" the frequent use of the expressions.

Engagement, personal language, and citation practices

Language in science and technology is generally viewed as very impersonal. Students are encouraged by discipline specialists and ESP textbooks and teachers to avoid personal language in order to appear objective. Corpus studies have, however, shown that RAs do use personal pronouns, and that writers express stance and engagement in a number of ways.

Hyland (2001) studied personal pronouns in published RAs. On average in physics, biology, and electrical and mechanical engineering, there were 17.6 self mentions per RA including 11.9 personal pronouns. He notes that use of personal pronouns is a way of projecting a scholarly identity. It is important for students to be sensitized to their own disciplinary norms as norms vary between disciplines as Hyland found: for example on average there were 38.1 self mentions per RA in the humanities and social sciences. Kuo's (1999) study of engineering and applied physics journals suggests that personal pronouns show how writers view their own role in the research and their relationship with readers: *we* can refer to the writers themselves or to writer and readers or to the discipline as a whole.

What does this mean for personal language in undergraduate writing for EST students? Like all writers, students need to be sensitive to their audience, their

professors, who expect a high level of impersonality. Luzon (2009) found different uses of *we* in undergraduate student engineering reports compared to the use of *we* in RAs. While noting the different purposes and audiences of these two genres, Luzon suggests students should analyze professional engineering reports for patterning of the pronoun. Harwood (2005), however, found the greater use of *I* in method sections of Computer Science MA projects than in RAs to be justified by the different audience and purpose of the student writers. He found that the student writing used *I* to highlight resourcefulness, justify procedures, and construct themselves as tenacious. He suggests corpus methods to draw students' attention to how the various requirements of different genres.

Hyland (1999) found that science RAs use fewer citations than humanities RAs, are less likely to quote their sources' names, or use them as an integral part of the sentence, employ fewer reporting verbs and do not represent their sources as taking a stance. He explains this in terms of the norms and culture of each discipline.

Koutsantoni (2004) considered how writers express attitude and evaluation in engineering RAs, looking specifically at attitude markers (e.g. *significantly*), certainty markers (e.g. *clearly*) and common knowledge markers (e.g. *it is widely accepted*). She suggests ESP materials should familiarize students with the preferred ways of limiting claims and of predisposing readers towards particular interpretations. Hyland (1998a) found fewer interpersonal markers in the science disciplines he studied than in the other disciplines. Hyland and Tse (2005) studied evaluative that-clauses (*We believe that . . .*) in RAs in a range of disciplines including biology, computer science, and electronic engineering. To evaluate their own findings, authors use this construction to mark the main argument, summarize purpose and express stance on the reliability of findings. Hyland and Tse suggest use of concordancing for exploration of these functions.

Modals and other hedges in academic writing function to soften what writers say and may even deliberately introduce an element of vagueness. They function variously to provide an accurate account of results (*approximately, about*), to signal the provisional nature of findings until accepted by the research community (*may be interpreted as*), protect the writer from claims of exaggeration and avoid offending other researchers (*we believe this is . . .*) (Hyland 1996; Myers 1989).

Visual Elements and Multimodal Interpretation

Graphs and diagrams are an important part of science and technology discourse. Myers (2003) notes that diagrams are not an easily accessible language, but rather conventional depictions, which require disciplinary knowledge to understand; thus science and engineering students must learn to "read" images of molecules, flowcharts, graphs, micrographs, and so on. The social practices of engineering and science disciplines depend heavily on these visual forms, particularly graphs. Good control of a genre involves an understanding of how different modes – visual, written and oral – interact. Different modes offer different constraints and

possibilities for making meaning. Archer (2006) used the poster as a tool to form links between the visual and the written, and between engineering culture new to her rural students and the culture students bring with them to university.

Mathematical discourse is a particular example of multimodal language. O'Halloran (2000) calls mathematics discourse multisemiotic in that it relies on language, maths symbolism, and visual elements. She shows that to participate in maths discourse requires shifting between these codes. Mathematical symbolism allows a precise, economical, complete statement of a particular relationship, which cannot be achieved in language alone. Molle and Prior (2008) found that writing in technology and mathematics-based sciences is likely to contain linguistically notated graphics and mathematical notation both on graphs and in the text. This makes collaboration with disciplinary specialists even more important for EST teachers, as understanding of equations, text, and visual elements and the meaning they make together is necessary for full understanding of texts in these disciplines.

Indications for Further Research Directions

Although much is known about the RA, much work on this genre is still necessary, particularly on sections other than the Introduction. Another area where research is needed is of variation between RAs in different disciplines. Corpus studies have emphasized the RA, comparing discourse in different disciplinary areas, and making comparisons with textbooks or dissertations and writing of graduate students, but seldom considering the writing of undergraduate students such as lab reports and design reports. Corpus studies of the language of professional design reports would also be valuable in guiding teachers of engineering writing. Another under-researched genre is the conference poster, an important genre for science and engineering graduate students. Some attention has been paid to oral science and engineering genres, but more work is needed. This includes meetings, formal presentations, conference presentations and everyday interaction in the laboratory or workplace. Mathematics discourse has also received little attention. More work is needed on how language, graphical interpretation, and mathematical expressions work together to make meaning. Finally, possibly because of its focus on classroom teaching, emphasis has been on practice; more attention could be paid to the construction of a theoretical framework for why we should teach in certain ways and how students acquire genre and register features.

Conclusion

This chapter has indicated the need for EST teachers to take account not only of lexis, grammar, and genres of science and engineering, but also to consider the disciplinary contexts into which students are being socialized, including the culture and values of these disciplines. The chapter has discussed how the typical

position of EST teachers as disciplinary outsiders has led to the need to investigate these disciplines, their values, their genres, and the discourse features of their genres. Such investigations have used a number of approaches, most notably ethnographic studies of specific contexts, and discourse analysis of the genres and register features of these target disciplines. Written genres, especially the research article, have been the major focus of research to date. Further investigation of other written genres and of oral genres of science and technology, as well as further work on mathematical discourse would be of value to EST.

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