Functional Grammar and the Rhetoric of Scientific Discourse  
in Teaching English for Science and Technology

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1. Introduction

Students of English as a foreign language (EFL) in courses of English for Science and Technology (EST) need to acquire the linguistic conventions of their specific fields of study (Kuroda, 2003) in order to fully comprehend the content of research reading materials and for academic writing. They need to develop critical awareness of language in science and technology for these purposes. In order to develop and advance their scientific literacy and disciplinary knowledge, students of EST need to see “how the linguistic features of disciplinary texts construe particular kinds of meanings” (Schleppegrell, Achugar & Orteiza, 2004, p. 70).

Kimball (1996) has noted generally the differences between Japanese and English language rhetorical conventions and the difficulties for Japanese college students that result from their “unfamiliarity with the dominant function of rhetorical norms that drive communication in English-language [discourse]” (p. 55). He has found “Trimble’s [1985] idea of isolating rhetorical functions an excellent point of departure for introducing and reviewing the basic, generative elements of scientific written discourse in English” (p. 61).

During a recent period of four years, I taught a one-semester elective course in scientific English for third-year students in the department of Earth Science at a university in Japan. The students were generally at lower to mid-intermediate levels of English language proficiency. I fashioned the instructional focus on the rhetorical functions of scientific discourse, such as cause and effect, hypothesizing, definition, description, and classification (see Trimble, 1985) for the purpose of developing students’ skills for reading research materials specific to their field of study. Course materials included articles from the “Science and Technology” section of the weekly magazine The Economist which digest original research articles from science journals. These magazine articles were used along with the judiciously selected original research articles themselves which were current, relevant, and interesting for the students. An example of this pairing of articles is the one given below from The Economist, titled “The Early Earth” (1998), and the original research article from which the content was drawn, “Low-latitude glaciation and rapid changes in the Earth's obliquity explained by obliquity-oblateness feedback” (Williams, Kasting & Frakes, 1998), which appeared in Nature.
The rationale for employing these materials is discussed in detail in Porcaro (2000, 2001). The articles from *The Economist* served well as effective instructional instruments to orient students to the forms and patterns of written scientific discourse in English and to provide practical application of reading strategies for such materials. The students would have been overwhelmed, frustrated, and discouraged by the challenge of comprehending articles from science journals used alone. They are written at a level of English well beyond their level of language proficiency. The students did not know a considerable amount of the scientific vocabulary in the texts, may not have learned yet some of the scientific concepts the research dealt with, and may not have understood the presentation of advanced mathematical data. Importantly, *The Economist* articles generally parallel the schematic structure of the original articles from the science journals, yet they are considerably shorter, lighter in terms of scientific vocabulary, and do not include mathematical formulations. After working with *The Economist* articles, the students in my class would go on to work with at least parts of the original research articles in the science journals. To that extent, this aspect of the instruction would conform to Hudson's (1991) content comprehension approach using authentic reading materials that are unmodified in any way. In short, students applied content comprehension strategies that focus on the rhetorical features of English scientific discourse, working from both structure to meaning and meaning to structure in a “purposeful interaction with the text” (Hudson, p. 79).

2. Functional grammar

At the same time, discourse analysis that employs the functional linguistic framework developed by Halliday (1994) can help students to acquire the critical language awareness and strategies needed for understanding the ways meaning is constructed in disciplinary texts. Such analysis can show key linguistic features that characterize scientific discourse. Functional grammar operates at the level of the whole text and emphasizes how language functions to construct meaning through choices made from the linguistic resources of the language system.

The systemic functional model of language “treats language as a network of systems through which each clause construes three different kinds of meaning: experiential meanings (what is happening), interpersonal meanings (what roles participants are playing), and textual meanings (how the information is organized)” (Schleppegrell et al., 2004, p. 76).

“By analyzing the texts in terms of the content constructed through particular linguistic choices, students can develop an awareness of how the language operates as a resource for making meaning, and learn the ways of making meaning that are most prevalent in particular content areas. This awareness helps them develop strategies for accessing content in the texts they read and producing it in discipline-specific ways in the texts they write.” (Schleppegrell & Achugar, 2003, p. 21)
Following, then, is a full analysis of an instructional text, “The Early Earth” from the “Science and Technology” section of The Economist that was used in the EST course for university students of Earth Science that was described above. (Although the “obliquity” hypothesis presented in this article [drawn from Williams, et al., 1998] has not been rejected completely nor disproved, many scientists think the “snowball” Earth hypothesis [Hoffman & Schrag, 2002] is more plausible than the “obliquity” hypothesis. Nevertheless, the analysis of the article presented in this paper exemplifies the value of the application of functional grammar to such texts for instruction in the rhetoric of scientific discourse in English.)

3.1 Text analysis: “The Early Earth”

The genre (a staged, goal-oriented, purposeful activity) of the text is that of explanation. It reports a hypothesis that explains the occurrence of a natural phenomenon and enables the readers to understand how the world literally once operated. Sub-genres of sequential and causal explanation may be identified.

Whenever we use language there is a context. The situational context of any particular language text can be characterized by three features, as summarized by Collerson (1994): the field of human activity which is involved, the tenor of the relationship between the people involved, and the mode of language use. “The meanings explicit in the text come directly from the context; they include the purposes of the text, who it’s addressed to and who it’s from” (p. 4). The field of the given text is earth science, specifically geology and geophysics. Technical and abstract language is an integral part of the text. As for tenor, the text is written by a science reporter for lay readers assumed to be highly literate, as it is a digest of a paper previously published in a science journal. The writing style is formal and impersonal. With regard to mode, as a written scientific report, the text can be characterized as planned, crafted language.

The schematic structure is outlined below in the margin of the text. In this way, through these stages, the text effectively achieves its purpose.

Background information. The pre-Cambrian earth was not a comfortable place. From around 820m to 550m years ago, if the record of the rocks is to be believed, the planet was in the grip of an ice age far fiercer than the one that has afflicted it on and off for the past 2m years. According to the tale the rocks appear to tell, glaciers in those far-off days reached right down to the tropics.

Identification and description of the phenomenon. Many researchers have had difficulty believing those rocks. If the tropics were frozen, that would presumably mean that the rest of the earth was, too. And an earth frozen solid for 270m years would not have been the best preparation for the sudden outburst of animal life that happened as the glaciers receded.
Now however, Darren Williams of Pennsylvania State University, and his colleagues, suggest that when the great pre-Cambrian ice age began, the earth was leaning over in a way that made the tropics colder than the poles. They also think that it was the build-up of the ice itself that caused the planet to tip upright into the current, familiar arrangement, with ice at the poles and tropics that are, so to speak, tropical.

At the moment, the earth spins on an axis that is inclined at 66 ½ degrees to the plane of its orbit around the sun. Dr Williams’s hypothesis is that in the late pre-Cambrian this angle was shallower - at most 36 degrees, and possibly less. That would have meant that, as the earth went around its orbit, first one pole and then the other would be face-on to the sun, melting any ice that had accumulated. The equator, by contrast, would have received the sun’s rays only at a shallow angle, as the poles do today, which would have sharply reduced the amount of solar heat arriving there. Therefore, if other conditions favoured an ice age, the ice would have tended to accumulate at the equator, rather than the tropics.

While it is not inherently unreasonable that the earth once lay on its side, something must have happened subsequently to make it sit upright. According to Dr Williams’s calculations, that something might simply have been the quantity of equatorial ice.

Because the earth spins, it is not a perfect sphere. Centrifugal force causes it to bulge at the equator. This bulge means that the gravity of the sun and the moon has more to pull on it at the equator than at the poles. Add tropical ice and the equatorial bulge would grow, increasing the disparity.

That could have been enough to tip the balance. Over time, the stronger gravitational force on the equator would tend to pull that part of the earth towards the sun. As a result, the equator would slowly approach the earth’s orbital plane, the equatorial ice would melt, the differential pulling would diminish - and the earth would eventually stabilize at something like its current inclination. The planet would then be left balmy and ready to brim with new animal life.

3.2 Transitivity analysis

Within a functional approach to English grammar, structural focus is on the clause wherein
most of the meaning is organized. The clause is the structure that carries a message. As Collerson (1994, p. 12) makes clear, “It allows us to bring several specific meanings together and show how they are related. It also allows us to show what part the message plays in interaction... and how each message fits into the text and the context.” There are three main kinds of components of experience in the clause: participants, processes, and circumstances. Participants refer to the things in our experience; processes indicate what’s going on, or the state of affairs; and circumstances describe features of the context in which the processes take place. “We build up our picture of the world by putting these resources together in the structure of the clause. They function as components of the clause... The crucial thing is the way the components are related to each other, through the process. This is called the transitivity relationship” (Collerson, p. 19). Thus, as Schleppegrell & Achugar (2003, p. 23) concisely state: “The key to understanding what a text is about is in the types of processes that each clause presents.”

This text reports a hypothesis to explain why and how a phenomenon took place, namely, in the pre-Cambrian period the earth was frozen at the tropics but not at the poles because of the shallow angle of its orbital axis and it subsequently tipped upright to its present angle precisely because of the accumulation of ice at the equator, causing the familiar arrangement of today of ice at the poles and warm tropics. The text includes a preponderance of non-reversible relational processes (marked in the text above by italics, as are two instances of existential processes) and material processes (marked by underline), realized often by verbal groups, to describe the physical world and the geophysical process put forth in the hypothesis. As the text is concerned with a particular event within a particular geological time period, the past tense is primarily used. At the same time there are clauses using the timeless present tense to describe physical phenomena in a general context. (“Because the earth spins, it is not a perfect sphere. Centrifugal force causes it to bulge at the equator. This bulge means that the gravity of the sun and moon has more to pull on it at the equator than at the poles.”) (The final paragraph of the text continues stylistically in the present tense but refers to the past event.)

The main participants in the processes, then, are particular things (‘The pre-Cambrian earth’, ‘the rocks’, ‘the planet’, ‘the tropics’, ‘the equator’, ‘the poles’, ‘the ice’, ‘the sun’, ‘the equatorial bulge’). There are a number of abstract and technical terms that are participants (‘axis’, ‘plane’, ‘orbit’, ‘angle’, ‘centrifugal force’, ‘gravity’). Throughout the text participants are realized by the grammatical structure of (sometimes long) nominal groups which, including technical terms, compress a lot of information into a short space (‘an ice age far fiercer than the one that has afflicted it on and off for the past 2m years’, ‘an earth frozen solid for 270m years’, ‘the best preparation for the sudden outburst of animal life’, ‘the great pre-Cambrian ice age’, ‘the amount of solar heat arriving there’, ‘the stronger gravitational force on the equator’).

Circumstances also are important in the construction of reality in this text. Examples are: Time: ‘From around 820m to 550m years ago’, ‘for the past 2m years’, ‘for 270m years’, ‘At the
moment'; 'in the late pre-Cambrian'; Place: 'at the poles and tropics', 'around the sun', 'around its orbit', 'at the equator', 'toward the sun'; Manner: 'in a way that made the tropics colder than the poles', 'into the current, familiar arrangement', 'at a shallow angle', 'by contrast', 'on its side'; Cause: 'as the glaciers receded'; Angle: 'According to the tale the rocks appear to tell'; 'According to Dr Williams’s calculations'.

Although nominalization is a common feature of explanations, it is used to a limited extent in this text. Examples are: ‘the sudden outburst of animal life’, ‘the build-up of the ice itself’, ‘The equatorial bulge’, ‘the stronger gravitational force’, ‘the differential pulling’, ‘its current inclination’.

Given that a hypothesis is a tentative explanation for why something happens, this text employs modality in the expression of a number of statements (‘that would presumably mean...’; ‘Darren Williams..., and his colleagues, suggest...’; ‘They also think...’, ‘something must have happened...’; ‘that something might simply have been...’; ‘That could have been enough...’).

There are several cohesive devices employed in the text to help tie it together. In the first paragraph, the anaphoric reference pronoun ‘it’ refers back to ‘the planet’ and in the latter half of the text there are five instances in which ‘it’ and ‘its’ refer back to ‘the earth’. ‘His’ refers back to Dr Williams and ‘they’ to Dr Williams and his colleagues. The demonstrative ‘this angle’ connects back to the angle of inclination of the earth on its axis, and ‘That would have meant...’ to the supposition of the angle being shallower in the late pre-Cambrian. In the first paragraph, ‘one’ is substituted for ‘ice age’ and in the second paragraph there is an ellipsis of frozen in ‘the rest of the earth was, too.’ Conjunctive relations of the causal type are present in three instances of conditional relations (‘if the record of the rocks is to be believed,...’, ‘If the tropics were frozen,...’, ‘if other conditions favoured an ice age,...’). Other causal conjunctions in the text are ‘Therefore’, ‘Because’, and ‘As a result’. Temporal conjunctions include ‘subsequently’ and ‘then’. Lexical cohesion primarily involves repetition. Earth and the synonym planet appear in the text 14 times, ice 10 times, tropics/tropical 7 times, poles 5 times, equator/equatorial 9 times, sun/solar 6 times. These words alone comprise approximately 10% of the entire text.

4. Commentary

The text, ‘The Early Earth’, is an explanation that focuses on a geophysical process that occurred hundreds of millions of years in the past. A statement of a hypothesis that has been formulated is reported in the article. The linguistic resources of action verbs in material processes especially are used to explain how the phenomenon happened. There is a logical sequence in the explanation of the process involving multiple cause and effect relationships in which often the effect of one occurrence becomes the cause of a second event, and the effect of the second becomes the cause of a third. It is the job of science to connect situations and events and thereby discover the how’s and why’s of our world. The language of scientific discourse
constructs scientific understanding. It is important, then, that science students understand the structures of the major genres of science, such as description, explanation, and information reports.

The text was chosen for this study because it was one of a set of articles I used in a course entitled “Scientific English” for third year students in the department of Earth Science at a Japanese university. The purpose of the course was to introduce common rhetorical functions of written scientific discourse, including classification, comparison, cause and effect, hypothesizing, definition, description, exemplification, reporting, and prediction. In the course, each function was taught and illustrated before examination of texts in which they appear.

Just as Kimball (1996) noted the difficulties with English rhetorical conventions faced by Japanese students, the students in my course indeed had difficulty finding the statements of the hypothesis and following the sequences of cause and effect in the text. Their greatest difficulty was with the inductive and deductive reasoning implied in the second paragraph. Identifying the schematic structures and language features of the common genres of scientific discourse provided access to the meaning constructed in the texts. With instructional devices such as scaffolding, explicit explanations, and the use of authentic texts, teachers can develop and advance the scientific literacy of EFL students. The systemic functional model of language from the work of Halliday and others can provide a solid and effective underpinning for this task.

References


