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Teaching English for Science and Technology: An Approach for Reading with Engineering English

More and more teachers in recent years are teaching courses in English for Specific Purposes (ESP), which is defined as "the branch of English language education which focuses on training in specific domains of English to accomplish specific academic or workplace tasks" (Orr 2005, 9). Unfortunately, many instructors are delegated to teach ESP without the opportunity for extensive preparation, and to make matters worse, ESP courses often stand alone without a curriculum-wide program of ESP or a resource-rich university center with an English language faculty specialized in this field. As a result, the opportunity for orientation, training, support, and collaboration related to this branch of teaching is quite limited or entirely unavailable for many ESP teachers.

In the future, the relevance of ESP instruction will undoubtedly be recognized and demand more support for teachers and institutions. This article is a response to the growing need for ESP, and it illustrates an approach I use in Japan to teach a course in one of the many sub-branches of ESP, known as English for Science and Technology (EST). It is a stand-alone, one-semester course in Engineering English for two groups: (1) second-year students in the department of electrical and electronic engineering, and (2) third-year students in the department of mechanical engineering. Each 90-minute class meets once a week 15 times a semester and targets the reading skills of 50 engineering students with low-intermediate or intermediate level English proficiency. The approach is based on the selection of authentic readings that are relevant, interesting, and at the right level for students, in conjunction with activities and materials that highlight specific rhetorical and discourse features in order to facilitate comprehension of the specialized texts. Activities and supporting materials serve as a scaffold that builds on students' existing language and content knowledge

to enable them to comprehend increasingly more complex research in science and engineering journals.

This article will discuss the rationale, aims, procedures, and content-specific materials used in the course. Hopefully, this will provide guidelines and ideas that will help other ESP practitioners who do not have deep specialist knowledge in the target subject or who have limited expertise in the field of ESP.

Needs analysis and ESP

Experts in the field of ESP stress the importance of conducting a rigorous needs analysis before designing a course, producing a syllabus, and starting instruction in ESP (Hutchinson and Waters 1987). A needs analysis includes determining to what extent, in what ways, and for what purposes students will use English in their university program and later in their jobs, along with "the significant characteristics of the language in these situations," such as vocabulary, grammar, rhetorical structures, and discourse devices for both oral communication and written texts (Orr 1998). These needs are customarily garnered from university faculty, current students, graduates who are employed, company personnel, and research in the discourse of the specific discipline (Orr 2010).

However, in most circumstances ESP teachers have limited time and resources for such thorough needs analysis. Guest (2009) supports a more informal needs analysis and suggests that, for the competent, professional English language teacher, assessing the needs of students for ESP should be derived from common sense and experience acquired in the classroom and gradually refined and then incorporated in the course design and instructional plan.

For my course, I first consulted with Japanese professors in the departments of electrical and mechanical engineering for advice on the English language needs of my students. They informed me that students especially need to use English for reading research in their senior year and later when they enter the master's degree program. They indicated that potential employers of these students are interested in their English ability, and that about 20 percent of students go abroad for business meetings and need English for that purpose. At the same time, the professors told me that most students in their early years at the university are not very aware of this need for English language proficiency.

In a search for Engineering English textbooks I found a few that are done rather well; however, I determined that none of them would adequately meet the needs of my students in terms of content specific to their fields, language level, approach, and appeal, nor the course design that I was coming to formulate. Indeed, as Smoak (2003, 27) correctly observes, "We must acknowledge the fact that much of the language that our students need will not be found in any course books or pre-packaged materials; therefore, we must be willing and able to prepare our own."

A rhetorical focus on Engineering English

A primary instructional aim of my course is the ability to identify and utilize the rhetoric of Engineering English. In the course introduction, I describe this to my students as the special way in which information is selected, organized, and presented in writing for communication and understanding among scientists and engineers. These basic rhetorical and discourse elements are especially critical for students of ESP, as the elements permit the students to read and understand the content of texts specific to all the various disciplines. In addition, the manner in which grammar, vocabulary, and specialized terminology connect with specific rhetorical elements is also underscored throughout the lessons.

Students in science and technology, as well as other academic areas, advance their scientific literacy when they develop a critical awareness of the special linguistic conventions that govern their specific fields of study. They profit from seeing "how the linguistic features of disciplinary texts construe particular kinds of meaning" (Schleppegrell, Achugar, and Oteiza 2004, 70). An awareness of discourse and rhetorical features allows them to "develop strategies for accessing content in the texts they read" and produce acceptable content "in discipline-specific ways in the texts they write" (Schleppegrell and Achugar 2003, 21).

Kimball (1996, 55) notes the differences between Japanese and English rhetorical conventions and the problems students confront when they are unfamiliar "with the dominant function of rhetorical norms" that drive English language

discourse, especially in the field of science. I suspect that students with other native language backgrounds experience a similar challenge.

The focus on discourse and rhetoric in ESP is compatible with Hudson's (1991, 78) approach to EST reading tasks, which "places instructional emphasis on the process of comprehending the content of texts." That process requires recognition and understanding of the rhetorical features of discourse in science and technology. Hudson (79) emphasizes the primacy of "the learner's purposeful interaction with the text." Therefore, my approach entails comprehension of the text content through interactive learning tasks and responses to comprehension questions, among other exercises. One of the implications of this approach is that instructional objectives are made clear through the reading assignment: "that is, the instruction directed to grammar, vocabulary, and rhetorical structures arises from the need to process the text and carry out the comprehension task" (Hudson, 85).

ESP and reading for content

I consult regularly with an engineering professor in either the electrical or mechanical engineering department on the relevance of reading topics before deciding whether to include them in the coursework. The average length of a reading is about 700 words and, importantly, the schematic structure of an article generally parallels that of an article written for a research journal. The topics are highly interesting, important, and up-to-date. In fact, they include cutting-edge research that does not yet appear in students' engineering coursework. The articles clearly motivate the students, who are very willing to engage with the readings and complete the assigned tasks. At the same time I, as a layman to the field of engineering, can follow the flow of the content and on the surface, at least, also understand the readings.

The aim of the Engineering English course is to develop students' reading skills for comprehension of science, technology, and engineering materials published in the most important journals. However, academic journal articles are too difficult for my students, specifically in terms of content, much of which they have not yet learned, and the English itself. Therefore, I use authentic readings—very carefully selected for content—from a number of alternate sources that are manageable yet challenging for the students and serve as a scaffold for later work during their senior year and graduate studies, when they will have to regularly process the higher-level technical content of those journals.

I make it explicit to my students from the beginning that they are the ones learning science and engineering and that I have little background in those specialist fields, and that my expertise is in teaching English as a foreign language. In fact, the students' knowledge of the particular content of the Engineering English articles they read is typically little better than mine, although they certainly have the background knowledge to understand the subjects much more deeply than I can after they have thoroughly read the materials. My goal is to help them, as we work together, advance their knowledge and proficiency in English as it relates to reading comprehension in the fields of science and engineering.

Bell (2002) astutely addresses the question of how much knowledge of the students' field of study the ESP teacher needs to have. He notes that the relationship between the teacher and students in the ESP classroom is more equal than in ordinary English language learning settings. While teachers are considered language experts, students have related expertise in their own fields. Therefore, "the teacher must be willing to learn from the student and the issue is not so much one of how much the teacher knows about the student's subject area, but a matter of knowing what the right questions are to ask" (Bell 2002).

Bell (2002) goes on to propose the idea of three Cs as a way for ESP teachers to successfully engage with students:

- *Curiosity*. ESP teachers should be interested in the subject area and actively seek to learn more about it.
- *Collaboration*. ESP teachers should consult with subject matter specialists.
- *Confidence*. ESP teachers' confidence will grow as they understand their role, learn more about the subject matter, and work with specialists in the field.

Considerable preparation is needed before students in an Engineering English course are ready to approach and manage their work with authentic technical texts. Students must first demonstrate a firm understanding of the purpose and efficacy of the assigned work

in relation to its benefit for them. Then the instructor must ensure that students have clearly grasped the rhetorical and discourse elements they will encounter so they can comprehend the content of the texts.

Teaching Engineering English

Lessons 1 and 2

The first class meeting of the semester naturally includes an introduction and overview of the course along with the usual organizational matters and class policies. Students then are asked to complete a questionnaire entirely in English about their engineering studies. Questionnaire items include the following:

- Explain briefly what electrical (or mechanical) engineering is.
- What are some of the things that electrical (or mechanical) engineers do?
- What are your particular interests in this field of engineering?
- After graduation, what do you expect to do in the field of engineering?
- In what ways is English important to you in your field of engineering?

The questionnaire also asks students about the extent of their use of English—in reading, writing, speaking, and listening—thus far in their university studies, and for a self-assessment of their English language proficiency.

Students' responses to this questionnaire allow the teacher to acquire information about student needs as well as an initial assessment of their level of written English proficiency. The task also serves to establish for the students that English will be the medium of instruction for lectures, activities, and assignments. In the context of universities in Japan, at least, and probably in other countries as well, it cannot be assumed that students fully realize this prior to the first class meeting.

In the first class, students are given a 500-word handout to read for homework; it includes ten multiple-choice questions, each with four options, that students will answer while listening to a 45-minute presentation on Engineering, English, and Employment during the second class. The pre-listening reading task orients students to the structure and content of the lecture. The handout and comprehension questions have a strategic purpose at this early stage to convince students of the relevance and value of the course. In addition, their answers to the listening comprehension questions provide an estimate of the overall listening proficiency level of the class and a gauge of the students' ability to follow the instructor's speaking style.

The content of the lecture is drawn from the written transcript of a forum that was sponsored by the *Japan Times* (2009) with experts in the field of engineering and ESP. Teachers in other circumstances or in other countries could derive content for such a lecture from personal knowledge and research or from interviewing university professors and company personnel who belong to the desired discipline.

The purpose of this lecture is both informational and motivational. As the associate dean of the engineering faculty stated to me, many students are not aware of the necessity of English language proficiency; nor are they always aware of the rapidly changing circumstances for engineering companies in the global economy and in a world of global communications that will require the use of English.

In other contexts, teachers might choose to have the students discuss the questionnaire items and the theme of the lecture in pairs or small groups followed by some reports to the whole class. However, such an approach requires not only a certain level of English oral proficiency among the students but also a familiarity and willingness to engage in that kind of student-centered activity.

Lessons 3 through 5

The instructional approach of the next three weeks is based on scaffolding to make sure that the new language, material, and concepts students encounter are not totally unfamiliar. For example, I clearly introduce and explain the concept of rhetorical and discourse features of English as employed in written discourse for science and technology. At the same time, the class works with a seven-page handout related to several rhetorical elements at the sentence level that I present in a straightforward manner.

Technical rhetorical conventions are the "basic, generative elements of scientific written discourse in English" (Kimball 1996, 61) and include the rhetorical elements described by Trimble (1985): classification, comparison, cause and effect, exemplification, definition, description, hypothesizing, reasoning (deductive, inductive), the statement of research problems, prediction, and reporting. The pre-

sentation in Day Two is followed by structured practice with each rhetorical element, one by one at the sentence level, with content specific to science and technology. Students must complete exercises to demonstrate they can identify, understand, and analyze the use of these elements. An excellent source of material for such exercises is Zimmerman (1989).

Students collaborate with a partner as I monitor and facilitate their work, which is completed by each student for homework. After two weeks, the class is given a short article with science content along with a worksheet. Now students must identify some of the rhetorical elements they have learned in the reading and write them down at the appropriate place on the worksheet. After this work is completed for homework I review it with the class the following week.

Lessons 6 through 15: The core lessons

The essence of the Engineering English course lies in the content-specific readings related to engineering and the assigned work for those readings. The next ten lessons, then, constitute the core of the course. The ordinary material in the few textbooks available for this branch of ESP is designed for a generic market and thus falls short of immediate relevance, suitability, and appeal for the specific students in the class; therefore, the materials utilized for the course are taken from more appropriate sources for engineering readings. Following are some of the resources I use to select and adapt engineering texts:

1. *The Economist Technology Quarterly*: www.economist.com/technology-quarterly
2. *The Economist*: www.economist.com (see the "Science & technology" section)
3. *engine*: www.engine-magazin.de/xist4c/web/engine_id_43_.htm (English for Engineers quarterly published in Germany. Only the table of contents of each issue is available on the website. Articles are available with a subscription, which is quite reasonable.)
4. *Spectrum*: http://spectrum.ieee.org/magazine (monthly journal of the Institute of Electrical and Electronics Engineers [IEEE])
5. *Mechanical Engineering*: http://memagazine.asme.org/home.cfm# (online publication of the American Society of Mechanical Engineers [ASME])

Readings from these sources during the course relate to the following topics, among others: thermodynamics, engineering ceramics, battery technology, graphene electronics, photovoltaic cells, osmotic power, thermoelectric devices, silicon carbide, carbon composite materials, electroactive polymers, flywheels, and surface engineering.

Each week a simple and systematic worksheet exercise connected to a new reading enables students to concentrate on reading the texts while deriving essential meaning from them. A topic is introduced one week in advance, and students receive an article to read for homework. For each new reading, an associated worksheet is handed out the following week, and students work on it for the full class period. The worksheet items lead students to recognize and understand several important rhetorical elements of scientific discourse and allow them to "unpack" the article; they are able to see how it is structured, and the steps and ideas are cohesively integrated. Thus, they come to understand the content and are able to construct meaning from the text. (See the Appendix for a sample worksheet on battery technology.)

Some worksheet items involve other tasks, such as writing short summaries or synthesizing content from the text, or identifying referents within the text. Also, one reading in the semester course is given as a cloze exercise, in which about 20 important concept words are deleted from a text of about 500 words. Students read the text and fill in the blanks with the most appropriate words. This exercise focuses their attention on simple reading strategies; while considering words to fill in the spaces, students draw on the surrounding text and use their general knowledge of engineering to complete the task.

I emphasize that the coursework should emulate the collaborative nature of conducting actual science and engineering projects. Therefore, students are encouraged to do the worksheets in collaboration with a partner. At the same time, I caution that collaboration does not mean merely copying. During the lesson, the teacher should actively but unobtrusively circulate around the classroom and facilitate students' work when necessary and encourage them with recognition of good work that is in process. Students need to complete most of the worksheets for homework.

As is the case in many countries of the world, most Japanese students at middle and high school are taught English with a reliance on the

L1 through grammar-translation; they are therefore accustomed to reading in English word for word rather than for meaning. In this process, whatever meaning they get from an assigned text is derived from a Japanese translation of the text and not from the English itself. Thus, for many students, the Engineering English reading process presents a great challenge; however, it is an essential challenge because the course probably will be the only opportunity for them to develop the reading comprehension skills that they will need at a later time.

Assessing the ESP course

Evaluation is an essential component of the ESP course design. In order to better determine their capacity and progress, students are directed to do some of the worksheets alone, rather than in collaboration with a partner and without my direct oversight. Weekly formative assessment of the completed worksheets establishes each student's capabilities and allows the teacher to make appropriate adjustments for the class by editing the reading materials and revising the worksheets where necessary.

The task of examining about 100 worksheets most weeks of the semester course certainly is time-consuming. However, as have most experienced teachers, I have developed efficient ways of going through the worksheets to minimize the task; for example, I leaf rapidly through all the sheets and scan for the answer to just one question at a time.

After work on four readings is completed, usually twice during the course, an overhead projector, PowerPoint, or interactive whiteboard is used to review the text and worksheet items for each reading with the class. This technique enables me to indicate specifically from the text, for all members of the class to see clearly, the source for a particular comprehension or rhetorical issue. This review also reinforces for students the overall structure and integration of the text.

At the end of the term I give an exam with one new reading or more that is administered the same way students have completed assignments during the semester. The exam verifies the extent of each student's capability to successfully complete the coursework and contributes to the assignment of a fair grade.

Further instructional considerations

The readings for students can be presented more effectively with graphic illustrations. This is the case for about 40 percent of the articles for my course. For example, for a reading on carbon composite materials for automobile bodies, I use an illustration from the research and development work with these materials at Volvo. Graphics often provide brilliant illustrations, such as for a piece on electroactive polymers that can be found in *The Economist Technology Quarterly* (www.economist.com/technology-quarterly). In some cases I search Google Images to find something appropriate to accompany the article.

About ten years ago when I taught a similarly designed course for third-year students in the department of Earth Science, I was able to develop lessons around a 25-minute video produced by BBC TV for the Open University in the United Kingdom on the subject of volcanoes; I used the video narrative script to integrate the reading technique described in this article with listening comprehension (Porcaro 2001). Although I have not come across any videos suitable for Engineering English, certainly this example points to another potential avenue of ESP lessons.

After students in this English for Earth Science course completed work on readings of the same nature as those for Engineering English, in a few cases I gave the class the original research journal article from which the piece they read had been digested in the "Science & technology" section of *The Economist*. However, given the students' level of English proficiency and current state of knowledge in their field of study, we went little beyond the abstract and an overview of the structure of the article. Although some of the Engineering English readings also are digested articles—for example, the one on photovoltaic cells is drawn from the *Journal of Applied Physics*—work with research journals should be reserved for students at graduate level or with much higher English proficiency. Yet again, this points to a very worthwhile approach for ESP lessons in the appropriate circumstances.

Conclusion

The role of English in the fields of science, engineering, information technology, and business is ever increasing. Consequently, so too are the demands on ESP practitioners to serve the needs of students and professionals in these fields to conduct their studies, research, and business in English on an international scale.

More and more instructors will find themselves called upon to teach ESP, and others will do so on their own initiative. Certainly, then, the rising competence of practitioners in this field is an important professional goal. This article has addressed the practical points of course design and implementation, and the immediate instructional needs of ESP teachers, especially those new to the field. I hope that the discussion of my development of an Engineering English course that focuses on reading comprehension skills will serve to stimulate and guide other teachers into this important and exciting area of English language education which affords so much reward for both them and their students.

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Appendix Sample Worksheet for the English Engineering Course

Teaching English for Science and Technology: An Approach for Reading with Engineering English • **James W. Porcaro**

Name _____ Student Number _____

Einstein and car batteries
[from *The Economist* (Science & technology), January 13, 2011]

Rhetorical elements:
hypothesizing, definition, description, comparison, cause and effect

1. State the **hypothesis** of Dr. Pekka Pyykko and his colleagues.
_____
_____

2. State the **scientific problem** addressed by Dr. Pyykko, generally mentioned in paragraph 3 and expressed in detail in paragraph 5.
_____
_____

3. State the given **physical description** of a lead-acid battery.
_____
_____

4. State the given **definitions** of "electropositive" and "electronegative."
_____
_____

5. State the given **process description** of the operation of a lead-acid battery.
_____
_____

6. State the given six points of **comparison** of tin and lead.
_____
_____

7. At the start of paragraph 9, "That" **causes** "the **effect** of making metallic lead less electropositive than classical theory indicates it should be." What does "that" refer to?
_____
_____

8. State the **cause and effect** process (in paragraph 9) related to the electronegativity of lead dioxide.
_____
_____