T. Orr, "English language education for science and engineering students," in *English for Professional and Academic Purposes*, M. F. Ruiz-Garrido, J. C. Palmer-Silveira, and I. Fortanet-Gomez, Eds., Amsterdam: Rodopi, 2010, pp. 213-231.

NOTE: This is a **revised version**, which corrects publisher mistakes that were printed in the original book.

English Language Education for Science and Engineering Students

Thomas Orr, PhD

This chapter provides an introduction to English for Science and Engineering (ESE), not only for those who may be interested in developing an ESE program, but also for those who may be interested in pursuing ESE as a career. It contains explanations of ESE work, descriptions of successful practice, attributes of an ideal practitioner, and a detailed profile of one representative program.

1 Introduction

Science and engineering are global disciplines, with English being the language of preference for top international conferences and scholarly publications, as well as for communication among international employees in the workplace and on international project teams. Competence in the English of scientific and technical work is essential for success, not only for native speakers, but also for nonnative speakers, who comprise the vast majority of professionals in scientific and engineering fields. Schools of science and engineering know this fact and continually search for better ways to improve the English skills of their students, but specialists in English for Specific Purposes (ESP) who possess the appropriate knowledge, skills, and interests to contribute significantly to this work, unfortunately, are in very short supply.

The intent of this chapter is to help alleviate this problem by offering some helpful perspectives and guidelines to university students and mid-career professionals who might be persuaded to pursue a career in English language education for Science and Engineering (ESE).[1] As a university administrator who recruits and hires professionals in ESE; who lectures frequently to science and engineering faculty about ESE; and who routinely seeks competent science/engineering English experts for research projects, conference keynotes, publication review committees, and consultation opportunities, I am continually troubled by the enormous gap between human supply in ESE and world demand. If this chapter can help to increase both interest and competence in the work of English language instruction for science and engineering, this will

[1] Historically, English for Science and Engineering has been called EST (English for Science and Technology) in the ESP literature; however, in this chapter *engineering* will be used instead of *technology* since, currently, the greatest plea for effective academic and professional English instruction in these disciplinary domains comes from the engineering community which prefers to be labeled as *engineering* rather than labeled as *technology*.

advance the field of ESP and the science and engineering disciplines in equally positive ways.

Before we begin, however, it would be best for me to note that English language instruction for native speakers (NS) and nonnative speakers (NNS) will not be strongly differentiated in this chapter, since both groups are frequently expected to possess similar levels of competence in English but merely bring different domains of experience and training with them to the university when they matriculate. Some of the instruction proposed on the following pages will be better suited for novices in the professional English discourse of science and engineering, and other instruction will be better suited for the more proficient. But expertise in English communication does not divide cleanly between native and nonnative speakers in technical fields, which often attract students surprisingly weak in all forms of social and professional interaction, even when communicating in their native language. Consequently, no particular distinction will be made between learners beyond those with different kinds of learning needs. As ESP continues to evolve, it seems probable that the field will eventually expand its sphere of interest to include addressing the specific English learning needs of both native and nonnative speakers at whatever levels of English require professional assistance.

2 Ideal Interests and Abilities for Successful Instruction

Language education has been around for a very long time, producing not only generation after generation of successful (and not so successful) language users but also a very large archive of knowledge about what ought to be done to enable language acquisition to occur. In the context of ESE, professional literature in ESP (e.g., Dudley-Evans, 1998), ESL (e.g., Tsui, 2003), general higher education (e.g., Biggs and Tang, 2007, Sawyer, 2006; Bain, 2004; Fink, 2003) and higher education for science and engineering (e.g., Kalman, 2008; Baillie and Moore, 2004; Reis, 1997) can be used to build a profile of what might be called the ideal educator for the ESE profession. Naturally, no one is born with all of these characteristics. But having a clear view of what the ideal might look like provides a much better professional target for educators who are thinking of developing some professional expertise in this field. In fact, scholarly research on expertise and expert performance (Ericsson et al., 2006) supports this assertion with multiple examples from the cognitive sciences which show that people who become experts have much clearer mental images of what expertise in their professional domain actually entails than long time novices, who perhaps wish to become experts but typically posses no more than vague notions of how genuine professionals actually think and act.

3 Profile of an Ideal Educator in ESE

General Professional Interests
- Interest in knowledge, learning, and personal improvement
- Interest in people and in helping them with their own personal improvement

Specific Professional Interests
- Interest in human language and communication
- Interest in math, science, engineering, and other relevant fields
- Interest in the learning sciences (cognitive science, educational psychology, sociology, education, instructional design, etc.)

General Professional Abilities
- Ability to identify essential knowledge, learn it, and apply it
- Ability to identify problems, understand their causes, and generate successful solutions
- Ability to communicate, build positive relationships, and work well with others

Specific Professional Abilities
- Ability to understand the culture, activities, and English of science and engineering
- Ability to identify the English and supporting attitudes and behavior that make work successful in science and engineering
- Ability to determine where students are lacking in these areas
- Ability to select or design appropriate instructional content and supporting instructional methods
- Ability to deliver the instruction effectively and achieve good results
- Ability to assess learner progress and respond with helpful feedback
- Ability to evaluate instruction and continually make improvements
- Ability to work productively with administrators, educators, and others involved in the work

One thing that this profile cannot do is specify the amounts of interest, knowledge, or ability that are needed to assure there will be successful results from one's efforts. However, it may be reasonable to assume that the more one has the better one will perform, although success in some educational contexts may require no significant amount of interest or ability at all. Necessary amounts of professional expertise in different areas depend heavily on local circumstances.

4 Descriptions of English Language Need

One of the most noticeable elements of professional practice in ESP is needs analysis, a set of carefully designed procedures for determining what specifically needs to be learned in what specific way. In regard to the English language learning needs of university students majoring in science or engineering, it should be noted that curriculum designers, materials developers, and instructors can benefit from the considerable amount of knowledge that scholars, practitioners and authorities have already identified as essential learning needs based upon their own professional perspectives. Naturally, different learners in different contexts aiming at different skill sets will require different instructional content and learning activities, but incorporating the recommendations of those who support science and engineering professionally will help create far richer, more effective instruction than can be obtained from personal observations or the ESP literature alone.

What do authorities identify as essential language-related learning needs for students in science or engineering? Here are a few representative examples.

According to ABET, Inc. (2008, p. 2), the world's largest accreditation board for quality assurance in applied science, computing, engineering, and technology education, engineering programs must demonstrate that their students attain the following outcomes by graduation if their programs expect to qualify for accreditation.

A. An ability to apply knowledge of mathematics, science, and engineering
B. An ability to design and conduct experiments, as well as to analyze and interpret data
C. An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
D. An ability to function on multidisciplinary teams
E. An ability to identify, formulate, and solve engineering problems
F. An understanding of professional and ethical responsibility
G. An ability to communicate effectively
H. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
I. A recognition of the need for, and an ability to engage in life-long learning
J. A knowledge of contemporary issues
K. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Although all of these activities require skill in special modes of language, item D requires students to be able to communicate both technical and nontechnical information to other people on a project team who may not be familiar with some of the vocabulary or concepts being discussed. Therefore, ESE in some contexts might need to train students to be sensitive to the linguistic and disciplinary knowledge of different audiences, as well as equip students with the English language skills that are needed to speak or write at a variety of different levels of complexity in order to convey their messages successfully. This would include the ability to comprehend English messages expressed in different accents and levels of language proficiency as well as the ability to respond appropriately. Scientists and engineers nearly always work in teams, and it is increasingly common these days, thanks to the Internet, for team membership to not only be multidisciplinary but equally international both in terms of nationality and work location.

Item G, the ability to communicate effectively, extends the need for competence in English to include all aspects of spoken and written communication that are required to connect professionally with others for all of the academic and professional purposes that characterize a student's field. Since faculty and administrators must demonstrate to ABET what communicative tasks require student proficiency, along with evidence that students have actually attained it, it is best for ESE specialists and engineering/science faculty to work together to create language training programs that can satisfy the accreditation demands of ABET or any other accreditation board or government ministry that the university may have to answer to. English proficiency standards that may satisfy specialists in ELT may not be sufficient to satisfy the expectations of science and engineering departments, where English needs differ from the language skills normally measured by popular assessment tools, such as the International English Language Testing System (IELTS) or the Test of English for International Communication (TOEIC).

In addition to accreditation boards and government agencies that may specify particular English requirements for schools of science and engineering, practitioners also have opinions about what students need to learn in school, based upon their own experience with university learning and its usefulness (or not) in preparing them to succeed in the workplace. A frequently cited survey (Middendorf, 1980) of 4,057 working engineers, for example, generated a list of 38 skill areas recommended for development—eight of which specifically involve communication, and all of which rank in the top ten of all the skills on the list.

1. Management
2. Technical writing
3. Probability and statistics
4. Public speaking
5. Creative thinking
6. Working with individuals
7. Working in groups
8. Speed reading
9. Talking with people
10. Business practices (e.g., marketing)
11. Computer use
12. Etc.

Additionally, university administrators, such as science and engineering school deans, also have ideas about language-related requirements for their students in science or engineering. Out of ten recommendations for engineering school reform proposed by James Plummer, Dean of Engineering at Stanford (LaPedus, 2008), three of them (recommendations 4, 7, and 8) deal specifically with competence in English.

4. Engineering schools must teach students how to work well as a member of a diverse team (i.e., diverse in expertise, culture, and language).

7. Engineering schools must provide global knowledge and experience (e.g., Stanford offers summer internships in companies worldwide).

8. Engineering schools must teach better communication skills.

Parallel to the requirements of ABET, Plummer recommends better training for English communication among professionals of diverse language, cultural and professional backgrounds, that not only includes all of the standard spoken and written discourse for academic and professional purposes, but also includes sufficient knowledge and experience using English at work in different global contexts which would logically require skill in cross-cultural communication.

Calls for better English language use in science and engineering—along with specifics about what kind of language that includes as well as some rather excellent training materials to facilitate its mastery—can also be found at the websites of professional societies in science and engineering, and in their professional newsletters, magazines, and journals.

The American Society for Mechanical Engineering (ASME), for example, has a website with 48 modules of professional training, including several in the

English of profession practice, such as Conducting Effective Meetings, Effective Technical Presentations, and Negotiation in addition to the writing of technical, cost, and grant proposals. One module on general communication skills includes instruction in listening, speaking, and writing, prefaced with a wonderful story (and photograph) of a real English listening comprehension problem. It seems that the command from a supervisor "Don, turn if off" was misunderstood as "Don't turn it off," resulting in a high-pressure soapsuds machine, used to wash airplanes, being left on all night, thereby filling a hanger full of aircraft with soap bubbles (See www.professionalpractice.asme.org/communications/commskills/index.htm).

Additional resources of information about English language use in fields of science and engineering, which can be used both for increasing one's knowledge of ESE as well as for making informed decisions about what content and training might be appropriate for a specific population of science and engineering students, are the websites and publications of two of the most internationally respected organizations for research and education in scientific and technical communication: the IEEE Professional Communication Society (www.ewh.ieee.org/soc/pcs) and the Society for Technical Communication (www.stc.org).

Other organizations within the sphere of science and engineering also contain valuable insights, research, training recommendations, and training modules/materials that can help educators and other decision-makers develop appropriate English language training for a variety of different language learners with a range of different learning needs. Here are a few of the many that exist.

- American Society for Engineering Education (www.asee.org)
- Council of Science Editors (www.councilscienceeditors.org)
- International Federation of Engineering Education Societies (www.ifees.net)
- National Science Teachers Association (www.nsta.org)
- Association for the Education of Teachers in Science (www.aets.unr.edu)
- National Association of Biology Teachers (www.nabt.org)
- American Association of Physics Teachers (www.aapt.org)
- National Association for Research in Science Teaching (www.narst.org)
- American Association for the Advancement of Science (www.aaas.org)
- American Chemical Society (www.acs.org)
- National Academy of Sciences (www.nas.edu)
- ACM Special Interest Group on Design of Comm. (www.sigdoc.org)
- Association of Teachers of Technical Writing (www.attw.org)
- International Organization for Standardization (www.iso.org)
- National Association of Science Writers (www.nasw.org)
- Institute of Scientific and Technical Communicators (www.istc.org.uk)

5 Programs and Instruction

Depending on university need, funding, and educational politics, English language education for university students majoring in science or engineering may consist of separate English language courses, English instruction embedded within science and engineering content courses, online independent study modules, special workshops or seminars, or off-campus training retreats. Those who provide the training may be applied linguists specializing in English education for science and engineering; specialists with degrees in technical communication; knowledgeable scientists or engineers on the science and engineering faculty; scientists or engineers currently working in or retired from industry; specialists in linguistics, literature, or composition from an engineering schools' neighboring English Department on the same campus; or language teachers recruited from local English conversation schools. To generate better educational success, however, it is best to employ specialists who match the profile presented earlier in this chapter. All of the potential language trainers mentioned above possess useful knowledge and perspectives that enable them to contribute something of value to the design and delivery of ESE. But if language training needs are significant and success from the program is crucial, then more substantial investment in talented professionals with long term commitments to ESE as their life profession will usually generate more satisfactory results.

6 Example: Center for Language Research (CLR)

One of the programs for English language education for science and engineering that illustrates ESE most characteristically is the one I direct in Japan, which in many ways exemplifies the kind of full-fledged ESE program that most universities would benefit from establishing if they simply knew more about this option and had the resources to make it a reality. It also clarifies for ESP professionals who may be interested in shifting their focus to ESE what kind of activities this line of work typically involves.

General Description: The Center for Language Research (CLR) is a language research and training center within the School of Computer Science and Engineering at the University of Aizu in Japan, a public bilingual university of 1,200 students, offering studies in computer science, computer engineering, information systems, information technologies and project management. The Center for Language Research (CLR) works in parallel with the Center for Cultural Research and Studies (CCRS) to provide language support (via the CLR) and general studies support (via the CCRS) to broaden student learning in complementary subject areas as well as to enable students to succeed in a

bilingual campus environment, where the vast majority of students, faculty, and staff are nonnative speakers of English.

CLR Mission: The mission of the Center for Language Research is to contribute to the development of professionals in computer science, computer engineering, and related fields through the research and teaching of successful language use in academic and workplace contexts.

CLR Faculty: The CLR is staffed with eleven tenured and tenure-track professors at Assistant Professor, Associate Professor, and full Professor levels, with one of the full Professors serving as Director. All eleven faculty members hold PhD degrees issued by reputable international universities, and are actively engaged in teaching and research, as well as university, public, and professional service.

CLR Faculty Expertise: CLR faculty members possess varying levels of expertise in the following areas, which they employ in both their teaching and research to support ESE in undergraduate and graduate school classes, as well as in workshops, seminars and consultation for science, engineering, and business professionals in the workplace.

- English for specific purposes (academic and professional purposes)
- Teaching English as a foreign language (TEFL)
- Teacher training and professional development
- Second language acquisition
- Applied and theoretical linguistics
- Pronunciation / Articulatory and acoustic phonetics
- Educational technology / Instructional design
- Cognitive science / Semantics / Expertise and expert performance
- Language testing and assessment
- Corpus linguistics / Vocabulary acquisition
- Sociocultural theory
- Composition and rhetoric
- Research methods / Statistics
- Usability design and testing
- Technical communication / Information design
- Writing for publication / Oral presentation
- Business documents, communication, and negotiation
- Asian languages and culture

The rationale for recruiting PhDs and offering them tenure-track positions with employment up to age 65 is that ESE is not something that anyone can pick up easily and obtain good results from through part-time or short-term efforts.

Practitioners need an attractive, stimulating environment for long term research, experimentation, and professional development in ESE before they are able to posses the right balance of knowledge, skills, and perspectives that are required to produce significant results. They also need to have research interests (and capacities) in areas that complement ESE and then target their research toward meeting the genuine academic and professional learning needs of their students and clients. Hiring practices during the early years of CLR history proved all too clearly that faculty with high interest but low capacity in ESE, as well as faculty with high capacity but low interest in ESE, both failed to be good fits for ESE work and thus were not able to take students very far in their development of technical discourse and documentation.

CLR Research: In the Center for Language Research, there are currently two research laboratories: the Phonetics Laboratory and the eLearning and Usability Laboratory.

The **Phonetics Lab** (http://clrlab1.u-aizu.ac.jp/) researches speech production and pronunciation, with some research projects focusing on articulatory phonetics and others on acoustic phonetics. For studies on articulatory phonetics, the laboratory uses an ultrasound machine to display real-time images of the tongue moving during speech, and it also uses a Vicon motion capture system for tracking the lips, jaw, eyebrows, and other parts that typically move during speech. For studies on acoustic phonetics, the laboratory mainly uses open-source acoustic analysis software, such as Praat. Many of the research projects, however, involve an analysis of both articulation and acoustics.

The **eLearning and Usability Lab** (http://droyjapan.googlepages.com/home) studies elearning and courseware management systems, such as Moodle, to determine their appropriateness in different contexts and their usability in terms of user experience. Usability research related to graphics and information design is also conducted.

Other faculty members conduct research in their offices, in their classrooms, or wherever else is appropriate in order to generate reliable information that can guide them in their decision-making about the suitability of course content, teaching methods, or supporting technologies. In fact, every classroom is considered a site for experimentation in the CLR. Classrooms and English courses are not only for English language education but equally for the testing of new ideas and technologies to discover if they really work. Needs analysis is central to ESE (as well as every other branch of ESP), and thus it is essential for ESE specialists to continually research target academic and workplace environments; the language, thinking, and behavior that are required for success

in these environments; and assess the teaching and technologies employed in ESE training to see if they are actually meeting the target educational goals. CLR findings generated from formal and informal research efforts are applied to improve CLR instruction and frequently published in international journals, conference proceedings, or scholarly books in order to support other professionals who are also working in ESE. It is additionally the aim of the Center to publish information that can support working scientists, engineers, and business professionals, who use English in science and engineering and would like to improve their professional performance. A few illustrative titles of CLR publications in ESE demonstrate the kind of research that an ESE center may need to conduct in order to provide it with the specific information it needs to develop the most suitable educational program.

- Survey of Workplace English Needs among Computer Science Graduates
- Using Concept Maps for Information Conceptualization and Schematization in Technical Reading Courses
- IEEE Best Papers in Science and Engineering
- Structured Authoring of Technical Documents through Systematic Collaboration in Using Open-Source Technologies
- The Language and Rhetoric of Bibliographic Citation in the Field of Computing
- Writing for Publication: An Undergraduate Course for Students in Computing
- Twenty Problems Frequently Found in English Research Papers Authored by Japanese Researchers
- Models of Professional Writing Practices within the Field of Computer Science
- Using Praat and Moodle for Teaching Segmental and Suprasegmental Pronunciation

CLR Curriculum: Undergraduates at the University of Aizu take eight required courses, along with two or more electives which change annually to adjust to current needs and interests. Courses are designed to train students in the English language and complementary professional thinking and lifestyle that will enable them to succeed in their studies at a bilingual university, as well as succeed in part-time jobs, internships, and after-graduation employment where English will also be used if the students are genuinely proficient enough to manage the technical and business English responsibilities that companies reserve for their best employees with the greatest professional potential.

The required courses in listening and reading focus on developing English reception skills. Required courses in speaking and writing focus on developing

English production skills. The electives focus on specialized knowledge and applications, requiring the use of both English reception and production skills. And the capstone course, *Thesis Writing and Presentation*, parallels senior research in the research labs, which must culminate in a senior thesis written in English and PowerPoint slide presentation delivered in English before a panel of judges and an audience of faculty and students. The thesis must be formatted in LaTeX and follow a University of Aizu template similar to that used for journal articles published by the Computer Society of the IEEE (Institute of Electrical and Electronics Engineers, Inc.), the world's largest professional organization for scientists, engineers, managers, technical communicators, and educators who work in fields related to electrical products and services, or the education and business fields that support them.

In the graduate school, which is taught almost entirely in English, language instruction blends to a much greater degree with content instruction than it does at the undergraduate level, and thus some language-focused courses are taught by ESE faculty in the CLR and others are taught by faculty or experts from the corporate world who specialize in English-medium computer science, engineering, or project/corporate management. Lists of current graduate and undegraduate courses can be found in the Appendix.

At present, CLR faculty are embedding more of their ESE instruction in realistic contexts and professional development activities, since over 15 years of experience has revealed that students who learn the English and culture of science and engineering from the very first day of freshman English class achieve higher proficiency in all of their English skills by graduation than those who spend considerable time on general English instruction and review in the early months of class before advancing on to instruction that more typically characterizes the scientific/technical community. In addition, students who learn the English of science and engineering, along with how to use that language in the context of a mature, professional lifestyle, achieve the greatest success in English and obtain some of the most attractive, high-status, high-salaried jobs after graduation. Experience has shown us that students who are treated as EFL students and given EFL-like games, pairwork activities, and grammar drills tend to think and act as EFL students. On the other hand, students who are treated as budding adult scientists or engineers and given lectures, projects, and assignments that typically interest adults actually begin to think, act, and speak as mature professionals even while they are still undergraduates. Consequently, the CLR continues to improve its training by experimenting with more mature, innovative content that can transform ordinary Japanese high school graduates into mature English-proficient professionals within the short span of four years – an immensely difficult but delightfully challenging task.

Additional Modes of Training

Beyond classroom-based English language training provided in the courses listed above, the Center also experiments with additional ESE learning opportunities in other environments that seem to generate good educational results.

Extra-Curricular Projects: One of the unique features of the University of Aizu is that any professor can create a credit-earning extra-curricular project to introduce students from all grade levels to some aspect of professional research and development or current professional topics and issues. CLR faculty sometimes use this option to offer students the opportunity to read and discuss mature topics of interest (e.g., the thoughts and writings of great scholars) or the opportunity to join professors in specific research projects resulting in an international publication and conference presentation (e.g., projects related to language acquisition, technology, or professional ESE discourse).

University Clubs: All universities in Japan allow students and/or faculty to create university clubs for academic, social, or athletic purposes. CLR faculty members have taken advantage of this culture by creating clubs that allow students to develop their English language skills in rich social environments. Some clubs have focused on playing English-based computer games and competing in game competitions, some have focused on playing sports with strong international student/faculty blends which require heavy use of English, and others have focused on more academic pursuits such as intelligent/philosophical discussions in English or English test preparation support for students who aim at taking the TOEIC or other standardized English tests that may be required for admission to a company or foreign graduate school.

Special Seminars: Another successful mode for ESE training has been special English-only seminars that focus on specific topics or issues. One recent seminar, for example, brought together twelve highly proficient English speaking undergraduates from the University of Aizu, the University of Tokyo, and Waseda University for an English-only weekend titled *Seminar on International Negotiation and Group Decision-Making for Engineering Students* at a pension (bed and breakfast) in a nearby mountain resort district. Students heard lectures on negotiation and group decision-making in the context of engineering projects, and then worked in groups to create their own PowerPoint presentations on different aspects of the topic for feedback and discussion from the other project teams. Taking students off campus and out of the city to enjoy

more concentrated time with others to study and discuss significant topics that are highly relevant to one's students' professional development works very well to keep motivation high and English developing rapidly in areas that match their specific academic and professional needs.

Others: Other modes of training that provide students with ESE in rich educational contexts include internships at international/English-medium companies; short and long term study abroad programs at partner schools of science and engineering; volunteer work to meet the needs of international students or residents in the prefecture; international online projects with students in other countries; or participation in local, national, or international conferences that are run in English.

Samples of ESE Content

Instructional content in ESE is no different from that in other domains of ESP in terms of selection and development. Like that in other areas, ESE is designed to meet a set of specific learner needs that have been identified through ongoing inquiry. Courses in the CLR include instruction in the following content, which CLR research has identified as relevant to University of Aizu student needs.

***Spoken English Tasks*:** Make appointments; Ask questions; Participate in discussions; Share ideas, advice, perspectives; Evaluate, critique, correct, caution; Negotiate decisions/agreements; Present research and engage in Q&A; Guide, teach, assist; Communicate with clients; Communicate on project teams; Communicate via technology (e.g., Skype); etc.

***Written English Texts*:** Webpages; PowerPoint slides; Proposals and position papers; Descriptions and definitions; Specifications and documentation; Reports (feasibility, progress, final); Instructions, procedures, directions; Business letters and email; Résumés, CVs, cover letters; User reviews (books, software, etc.); Articles for publication (research, etc.); Applications (membership, grant, etc.)

***Professional Vocabulary*:** Abort, access, adapt, adjust, align, allocate, analyze, annotate, append, apply, approve, archive, assemble, assign, attach, augment, automate, etc.

Professional Collocations: Write a report, write an email (message), write software, write a (computer) program, write (source) code, write (computer, requirements, design, technical, user) documentation, write an algorithm, write a review, write a (research) paper, write script, write applications, write applets, write plug-ins (or plugins), write queries, etc.

Specific Language Required for Individual Courses (e.g., the Writing for Publication course): Sentence, paragraph, text, list, grammatical parallelism, table, figure, citation, title, abstract, IMRD, references, style manual, acknowledgments, appendix, periodical, newsletter, trade magazine, journal, article, user review, tutorial, title page, cover letter, submission, copyright, etc.

Grammar Instruction: Generic and discipline-specific sentence patterns (e.g., sentence grammar of definitions), grammatical parallelism, subject-verb agreement, plural/singular distinctions, count/noncount distinctions, nominalization, lessons on common errors in student writing (e.g., *Almost univercity job in science and engineering need doctorate*. → *Most university jobs in science and engineering require doctorates*.)

Professional Development Components: Time management; Study skill development; Information acquisition and management; Relationship building and professional networking; Wise decision-making in regards to part-time job selection, free time activities, reading material, and friendships; Career selection, planning, and development; etc.

Samples of ESE Learning Activities

Create a Company: For this project, students created private consultancies and engaged in real consultation, which not only gave them a wealth of experience in multiple aspects of English and management, but it also expanded their résumés with some impressive accomplishments as undergraduates. Project activities included creating a company name and logo, a company mission statement, a company webpage and stationery, and various emails, proposals, progress reports and final reports in the context of real consultation via English with real clients.

Create a Learning Log: For this project, students kept a daily record of the things they learned in their university classes, learned from their daily reading, learned through personal experience, or learned through conversation with others. Everything was recorded in English, with specific words given by the professor that were required for use in the report each day to encourage students to use different grammatical constructions and phrase their thoughts in different ways. Here is a (corrected) example.

> **FURTHERMORE**: Today, I made progress in learning Java, a programming language commonly used for cellphone applications. Furthermore, I made progress in understanding my professor's Russian-accented English. Progress in these two things made me very happy because I want to become a good programmer, and I want to be more international.

In class, students exchanged learning logs, read them, underlined confusing content or poor English in red ink, and then advised each other on how to communicate their messages more clearly and attractively. The professor, of course, provided helpful feedback and instruction as well.

Plans for Further Program Improvement

Although this program has made significant progress since its humble beginnings in 1993 when it was established along with the University of Aizu, there are many more improvements that need to be made to make the Center even more successful in its English education for students and working professionals in science and engineering. Short term goals for further improvement include better coordination between individual English courses, better coordination with university content courses, additional studies of professional English use in newly evolving workplace contexts, greater innovation in instructional methods and technologies, and better use of assessment tools and techniques to generate the kind of data needed to make quality educational and administrative decisions. Long term goals include the eventual addition of a major or minor in ESE for students who want to focus exclusively on the production and management of corporate knowledge and communication in global work environments rather than pursue computer science or engineering as their primary career path. Of course, further professional development for all of us in the CLR toward the goal of becoming more like the ideal ESE educator profiled earlier in this chapter is naturally the key to improvement in every project we attempt, for teaching or research rooted in anything but mature professional interests, motives and methodologies tends to generate mere appearances of success rather than actual results that can benefit everyone.

7 Conclusion

English education in support of students and professionals in science and engineering is a serious endeavor saddled with high expectations for successful results. To date, many language specialists have shied away from ESE because they lack sufficient understanding of the work or enough interest in science and engineering to sustain the long term commitment that is required to develop expertise. But ESE does not need to be difficult. The central aim of science is to understand the world around us, and the central aim of engineering is to improve the quality of life in that world through technology. Science is based on curiosity and systematic inquiry, and engineering is based on curiosity and creative problem-solving. No one is born a scientist or engineer, but rather people grow

into these roles through meaningful exposure to useful input and experience. Language specialists need not shy away from ESE because they assume that they need to know more about effective language use in science and engineering than all of the scientists and engineers they will ever meet. No, language specialists who select ESE as their profession simply need to share the same curiosity for knowing about the world and the same drive for finding effective solutions to problems they encounter. In fact, ESE is most successful when practitioners simply bring out the scientist and engineer within themselves and work in unison with their science/engineering peers to discover how English can be understood and employed to its greatest advantage for all scientific and engineering endeavors.

References

ABET (2008) *Criteria for Accrediting Engineering Programs*, Baltimore, MD: Engineering Accreditation Commission.

Baillie, C., & Moore, I. (ed) (2004) *Effective Learning and Teaching in Engineering*, New York: RoutledgeFalmer.

Bain, K. (2004) *What the best college teachers do*, Cambridge, MA: Harvard University Press.

Biggs, J., & Tang, C. (2007) *Teaching for Quality Learning at University* (Society for Research Into Higher Education), 3rd ed. Birkshire, England: Open University Press.

Dudley-Evans, T., & St. John, M. J. (1998) *Developments in English for specific purposes: A multidisciplinary approach*, Cambridge, UK: Cambridge University Press.

Fink, L. D. (2003) *Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses* (Jossey Bass Higher and Adult Education Series), San Francisco, CA: Jossey Bass/Wiley.

Ericsson, K. A., Charness, N., Feltovich, P. J., & Hoffman, R. R. (eds) (2006) *The Cambridge handbook of expertise and expert performance*, New York: Cambridge University Press.

Kalman, C., S. (2008) *Successful Science and Engineering Teaching: Theoretical and Learning Perspectives* (Innovation and Change in Professional Education), Springer.

LaPedus, M. (2008, December 16) 'Change' needed in engineering education. *EETimes*, Retrieved December 20, 2008 from http://www.eetimes.com/showArticle.jhtml?articleID=212500800.

Middendorf, W. H. (1980) Academic programs and industrial needs. *Engineering Education*, 71 (8), 835-837.

Reis, R. M. (1997) Tomorrow's Professor: Preparing for Careers in Science and Engineering, Piscataway, NJ: IEEE Press.

Sawyer, R. K. (ed) (2006) *The Cambridge handbook of the Learning Sciences*, New York: Cambridge University Press.
Tsui, A. B. M. (2003) *Understanding expertise in teaching: Case studies of ESL teachers*, Cambridge, UK: Cambridge University Press.

Thomas Orr, PhD, is a professor at the University of Aizu and director of the university's Center for Language Research, where he studies the professional English discourse of science and engineering with the aim of developing effective educational programs and materials for university students and working professionals. He has taught English for roughly 30 years in the United States and Japan; held administrative positions in IEEE, PERC, TESOL, and JACET; and had his work published by IEEE, Wiley-Interscience, Halldin, Rodopi, Blackwell, Wiley-Blackwell, TESOL, and others.

Appendix

Current Courses in the CLR English Program (2009-10 Academic Year)

First Year (First Semester) – Required English
RE1 Listening & Reading 1 (40-50 students per section)
RE2 Speaking & Writing 1 (25-35 students per section)

First Year (Second Semester) – Required English
RE3 Listening & Reading 2 (40-50 students per section)
RE4 Speaking & Writing 2 (25-35 students per section)

Second Year (First Semester) – Required English
RE5 Listening & Reading 3 (40-50 students per section)
RE6 Speaking & Writing 3 (25-35 students per section)

Second Year (Second Semester) – Required English
RE7 Listening & Reading 4 (40-50 students per section)

Third Year (First and Second Semester) – Elective English (Students choose at least two.)

Advanced English Acquisition Courses
EE1 Discourse Analysis for Computer Science
EE2 Pronunciation: Comparing English and Japanese Sound Systems
EE3 Vocabulary Development
EE4 Preparation for the TOEIC

EE5 Language, Space, and Time
EE6 Introduction to Second Language Acquisition
EE7 Introduction to Syntax

Advanced Professional English Applications Courses
EE8 Reporting Statistical Research in English
EE9 Resume Design and Development
EE10 Writing for Professional Publication
EE11 Document Design and Usability Testing
EE12 Strategic Interaction for Professional Communication
EE13 Advanced Technical Communication
EE14 Innovators in Science and Computing

Advanced English and Technology Courses
EE15 History of Language-Related Technologies
EE16 Pronunciation: Acoustic Analysis Using Software
EE17 Design and Research of Games for Language Learning
EE18 Corpus Linguistics
EE19 Language Use on the Internet
EE20 Cyberethics for Information Technology

Fourth Year (First Semester) – no English classes.
Students are busy searching for jobs or graduate schools.

Fourth Year (Second Semester) – Required English
RE8 Thesis Writing and Presentation (15-25 students per section)

Graduate School Courses – Requirements vary according to field of study
G1 Language Analysis
G2 Computer-Assisted Language Learning
G3 International Negotiation
G4 Documentation for Technical Procedures
G5 Technical Writing in Software Engineering
G6 The Design of Computer-Based Instruction
G7 Human Aspects of Software Engineering
G8 Fundamentals and Practices of Project Management

Note: These course lists are upgraded each year to meet new needs and interests as well as to incorporate new findings from CLR faculty research.