NASA/DOD Aerospace Knowledge Diffusion Research Project

Paper Sixty One

The Technical Communications Practices of ESL Aerospace Engineering Students in the United States: Results of a National Survey

Paper presented at Embry-Riddle Aeronautical University's Aviation Safety Symposium: Aviation Communication – A Multi-Cultural Forum held April 9-11, 1997, at the Davis Learning Center on the Prescott, Arizona Campus of Embry-Riddle Aeronautical University

John R. Webb
Concurrent Communications
Knoxville, Tennessee

Thomas E. Pinelli
NASA Langley Research Center
Hampton, Virginia

Rebecca O. Barclay
Knowledge Management Associates
Portsmouth, Virginia

John M. Kennedy
Indiana University
Bloomington, Indiana

National Aeronautics and Space Administration

Department of Defense

INDIANA UNIVERSITY

The Technical Communications Practices of ESL Aerospace Engineering Students in the United States: Results of a National Survey

John R. Webb
Concurrent Communications

Thomas E. Pinelli
NASA Langley Research Center

Rebecca O. Barclay
Knowledge Management Associates

and
John M. Kennedy
Indiana University

ABSTRACT

When engineering students graduate and enter the world of work, they make the transition from an academic to a professional community of knowledge. The importance of oral and written communication to the professional success and advancement of engineers is well documented. For example, studies such as those conducted by Mailloux (1989) indicate that communicating data, information, and knowledge takes up as much as 80% of an engineer's time. However, these same studies also indicate that many engineering graduates cannot (a) write technical reports that effectively inform and influence decisionmaking, (b) present their ideas persuasively, and (c) communicate with their peers. If these statements are true, how is learning to communicate effectively in their professional knowledge community different for engineering students educated in the United States but who come from other cultures—cultures in which English is not the primary language of communication? Answering this question requires adequate and generalizable data about these students' communications abilities, skills, and competencies. To contribute to the answer, we undertook a national (mail) survey of 1,727 student members of the American Institute of Aeronautics and Astronautics (AIAA). The focus of our analysis and this paper is a comparison of the responses of 297 student members for whom English is a second language with the responses of 1,430 native English speaking students to queries regarding career choice, bilingualism and language fluency, communication skills, collaborative writing, computer use, and the use of electronic (computer) networks.

INTRODUCTION

Because the effective communication of information is fundamental to engineering, questions arise as to what communications skills should be taught to engineering students and when, how much communications instruction is really necessary, and how effective that instruction is. What is missing from any discussion of communications skills instruction for engineering students is

(a) a clear explanation from the professional engineering community about what constitutes "acceptable and desirable communications norms" within that community; (2) adequate and generalizable data from engineering students about the communications skills instruction they receive; (3) adequate and generalizable data from entry-level engineers about the adequacy and usefulness of the instruction they received as students; and (4) a mechanism, probably focused within academia, that solicits feedback from the workplace and a system that utilizes the feedback for answering the questions of what and how much should be taught and when, and for determining the effectiveness of instruction.

Paradis, Dobrin and Miller (1985) note that "college training does not prepare engineering graduates to communicate successfully in the work environment." Their observation is hardly new; engineering professionals have voiced this concern for decades. If college training does not prepare engineers to communicate successfully, can we assume the existence of a disconnect between academic perceptions of workplace communication and the realities of workplace communication? By extension, does the existence of a disconnect place engineering students who come from wholly different cultures—cultures in which English is not the primary (spoken and written) language of communication and for whom English is a second (or third) language—at risk in terms of professional success in their chosen field? Scholars speculate about this possibility in the literature, however, our review of the literature (i.e., composition, rhetoric, and English as a Second Language) produced little in terms of qualitative and quantitative data that might support the existence of a disconnect. To contribute to the answer, we present the selected results of a national (mail) survey of 1,727 student members of the American Institute of Aeronautics and Astronautics (AIAA). The focus of our analysis and this paper is a comparison of the responses of 297 student members for whom English is a second language (ESL) with the responses of 1,430 students who are native English speakers (NES) to queries regarding career choice, bilingualism and language fluency, communication skills, collaborative writing, computer use, and the use of electronic (computer) networks. This research was undertaken as a Phase 3 activity of the *NASA/DoD Aerospace Knowledge Diffusion Research Project* (Pinelli, Kennedy, and Barclay, 1991).

BACKGROUND

In the November 1990 issue of the journal, *Civil Engineering*, Basheim Khafagi, an ESL engineering student, reported that for the decade 1980 to 1990, only three to five percent of all engineers employed by U.S. industry were foreign (borne) engineers. Using 1985 statistics, he notes that (a) one out of three doctorate engineers employed in industry is of foreign origin, (b) the proportion is rising, and (c) more than 50% of the foreign students with visas intended to stay in the U.S. In fact, over 50,000 foreign students were enrolled at accredited engineering universities in 1989. In 1987, foreign students received 55% of the doctorates awarded in engineering. About 50% of the doctorates in science and engineering are awarded to "nonnative speakers of English" (Belcher 1991, citing DePalma 1990). Foley (1994, p. 124) quotes a recent survey by the Engineering Manpower Commission that in 1992 14% of all bachelor of science degrees in civil engineering awarded in the United States went to minorities (a distinction of

ethnic origin, not gender). If the number of foreign students studying engineering and science in the U.S. continues to increase and if those students earning degrees in engineering and science intend to stay (i.e., work) in the United States, then the issue of a disconnect between academic preparation and workplace requirements takes on added importance.

METHODOLOGY AND RESEARCH DESIGN

Self-administered (self-reported) questionnaires were sent to a sample of 4,300 aerospace engineering students who were members of the American Institute of Aeronautics and Astronautics (AIAA). The survey instrument was (a) prepared using input from a group composed of engineering faculty and technical communicators, (b) pretested using a small group of engineering students, (c) modified and finalized, and (d) mailed in spring 1993. Altogether, 1,727 surveys were returned by the completion date of September 1, 1993. After reducing the sample size for incorrect addresses and other mailing problems, the response rate for the survey was 42%. This rate is very acceptable for a student survey with one mailing. Responses to the questions "What is your native language?" and "What is your native country?" were used to establish two groups of respondents—ESL students numbering 297 and NES students numbering 1,430. No statistical tests were used to estimate if observed differences between the responses of the ESL and NES students were statistically significant.

Demographics

The final sample included 948 undergraduate students (57.3%) and 707 graduate students (42.7%). The majority of respondents are male. About 82% of the undergraduates and 87% of the graduate students were male. Most respondents report that they are studying to become engineers. Most AIAA student members are U.S. citizens; about 92% of the undergraduate students and about 81% of the graduate students indicated they were U.S. citizens. English is the first (native) language for most of the student participants. About 87% of the undergraduate students reported that English is their first (native) language and about 77% of the graduate students indicated that English is their first (native) language. The U.S. was the native country of most survey participants. About 84% of the undergraduates and about 73% of the graduate students indicated that the U.S. was their native country.

Aerospace Engineering as a Career Choice

Most ESL and NES students made their decision to study engineering prior to beginning college. Nearly 54% of the ESL students made their decisions to pursue a career in engineering while in high school, and about 10% made their decisions while in elementary school. About 61% of the NES student reported that they made their decisions in high school and about 14% while in elementary school. A higher percentage of the ESL students (32.4%) than NES students (20.3%) made their decisions to pursue a career as an engineer either when they started or after they had started college.

Students were asked to rate the importance of six factors that may have influenced their choice of careers. Three of the factors deal with the influence of people (i.e., parents, other family members, and teachers) in helping students to make their career choices; one factor focused on the influence of information about the career. The remaining two factors related to the career itself and include such elements as financial security. For both the ESL and NES students, the most important factors were those related to the job itself. About 68% of the ESL and about 84% of the NES students rated "engineering is a career with rewarding activities" as very important followed by the perception that a "career in engineering will lead to financial security" (ESL = 25.4% and NES = 27.9%). The availability of information on career opportunities also appears to have had an important influence on the career decision. About 38% of the ESL students and about 24% of the NES students indicated that this factor was very important. Importance ratings of the influence of other people—parents, teachers, and other family members—were lower than the importance rating of the job-related factors. It is interesting, however, that about 25% of the ESL students rated "my parents encouraged your area of study" as very important compared to about 14% of the NES students.

Students were asked to rate their current level of satisfaction with their career choice. About 28% of ESL students and 29% of the NES students reported that they are happier about their career decisions now compared to when the decisions were first made. About 46% of ESL students and about 44% of NES students surveyed reported that they feel about the same now as when they first made their career decision. The percentages of ESL and NES students reporting they were less happy with their career choice were about equal (ESL = 26.4% and NES = 26.9%). Students were asked to identify the type of organization in which they hope to work after graduation. About 30% of the ESL students compared to about 12% of the NES students aspire to work in academia. About 25.3% and 51.2% of the ESL students compared to 43.6% and 23% of the NES students plan to work in either a national or multi-national industrial organization.

Finally, students were asked to rate the importance of 15 goals to a successful career. The list included aspirations that are classified as either engineering, science, or management goals. Both ESL and NES students gave high ratings to the *engineering-related goals and aspirations*. The ordering of the mean importance ratings for these factors, from highest to lowest, is similar for both ESL and NES student members. The opportunity to explore new ideas about technology or systems ranked highest with ($\bar{X}$ = 6.4) for ESL students and ($\bar{X}$ = 6.3) for NES students. The opportunity to work on projects that require learning new technical knowledge ranked second with ($\bar{X}$ = 6.1) for ESL students and ($\bar{X}$ = 5.9) for NES students. Having the opportunity to work on complex technical problems ranked third ($\bar{X}$ = 5.9) for ESL students and ($\bar{X}$ = 5.8) for NES students. *Science-related goals and aspirations* were rated second highest by ESL students and were ranked least important by NES students. Establishing a reputation outside your organization as an authority in your field was ranked highest by ESL students ($\bar{X}$ = 5.7). Being evaluated on the basis of your technical contributions ranked highest for NES students ($\bar{X}$ = 5.4). Being evaluated on the basis of your technical contributions was ranked second highest by ESL students ($\bar{X}$ = 5.6). Establishing a reputation outside your organization as an authority in your field was ranked second highest by NES students ($\bar{X}$ = 5.3). ESL students rated

presenting papers at professional society meetings and publishing articles in technical journals ($\bar{X}$ = 5.5 and $\bar{X}$ = 5.4) considerably higher than did the NES students ($\bar{X}$ = 4.9 and $\bar{X}$ = 4.7). Receiving patents for your ideas were rated least important by both groups. *Leadership or management goals and aspirations* were rated least important by ESL students but were ranked second highest by NES students. Planning projects and making decisions affecting the organization and planning and coordinating the work of others ($\bar{X}$ = 5.4 and ($\bar{X}$ = 5.2) were ranked highest by ESL students. Planning projects and making decisions affecting the organization and becoming the technical leader of a group of less experienced professionals ($\bar{X}$ = 5.3 and $\bar{X}$ = 5.3) were ranked highest by NES students. Advancing to a policy-making position in management was ranked least important ($\bar{X}$ = 4.8 and $\bar{X}$ = 4.6) by both ESL and NES students.

Bilingualism and Language Fluency

About 83% of the total sample indicated that English was their first (native) language and about 80% of the sample indicated that the United States was their native country. About 88% indicated that they were a citizen of the country where they were attending college. Almost 87% of the ESL students reported that they read English fluently and about 77% reported that they spoke English fluently. The (first) native languages of the ESL students were compiled according to the absolute number of ESL students and as a percentage of the total ESL sample: 62 Chinese speakers (21%), 38 Spanish speakers (13%), 17 Korean speakers (6%), 14 German speakers (5%), 11 Vietnamese speakers (4%), 10 French speakers (3%), 10 Greek speakers (3%), 9 Japanese speakers (3%), 8 Hindi speakers (2.5%), and 8 Portuguese speakers (2.5%). About 16% (47 ESL students) did not report their native language.

Survey respondents were asked to report their fluency (i.e., reading and speaking) in five languages—French, German, Japanese, Russian, and Spanish. These languages were selected because they are the native languages of countries with a sizable aerospace industry and/or government aerospace programs. French was read or spoken, at least to some extent, by more students in both groups than were any of the other languages, followed by German, then Spanish. The ESL respondents reported higher fluency, both speaking and reading, in French than did the NES students, somewhat more in German, and slightly more in Japanese and Russian. Neither the ESL nor the NES students reported that they read or spoke Russian fluently.

Survey respondents were asked to determine, in terms of their career goals and aspirations, "how important will it be for you to be bilingual?" About 90% of the ESL students reported that bilingualism was at least somewhat important compared to about 84% of the NES students. A higher percentage of the ESL students (69.8%) rated being bilingual very important to their career goals and aspirations than did the NES students (35.5%). About 8% of the ESL students compared to about 26% of the NES students reported that being bilingual was not very important in terms of their career goals and aspirations.

PRESENTATION OF THE DATA

The literature on engineering education establishes the importance of effective communications skills to professional success (Black, 1994; Morrow, 1994; Evans, et. al., 1993; Katz, 1993; Garry, 1986; Devon, 1985). AIAA student members were asked to assess the importance of selected communications skills to professional success, to indicate if they had received instruction in these skills, and to rate the helpfulness (usefulness) of that instruction.

Importance of Communications Skills to Professional Success

Students were asked to rate the importance of six communications skills to professional career success (Table 1). Both ESL and NES students assigned the highest importance ratings to the ability to use computer, communication, and information technology (89.5% for ESL students and 91.3% for NES). ESL students rated having a knowledge and understanding of engineering/science information resources and materials second highest (86.1%). NES students rated effective communication of technical information orally second highest (84.3%). Neither group of students rated being able to search electronic (bibliographic) databases very highly (54.9% for ESL students and 50.7% for NES students).

Table 1. Importance of Selected Communications Skills to the Professional Success of U.S. Aerospace Engineering Students

	ESL[a]		NES[b]	
Competencies	%[c]	(n)	%[c]	(n)
Effectively Communicate Technical Information In Writing	83.1	(245)	83.9	(1190)
Effectively Communicate Technical Information In Writing	81.7	(241)	84.3	(1191)
Have A Knowledge And Understanding Of Engineering/Science Information Resources And Materials	86.1	(253)	79.1	(1116)
Ability To Search Electronic (Bibliographic) Data Bases	54.9	(161)	50.7	(705)
Ability To Use A Library That Contains Engineering/Science Information Resources And Materials	69.6	(206)	62.6	(884)
Effectively Use Computer, Communication And Information Technology	89.5	(265)	91.3	(1295)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker
[c]Students used a 7-point scale to rate the importance of each competency, where 7 indicates the highest rating. Percentages include combined "6" and "7" responses.

Receipt and Helpfulness of Communication Skills Instruction

Table 2 shows the percentage of students who reported having received communications skills instruction in seven areas. About 78% of the ESL students and about 84% of the NES students had received instruction in the use of computer, communication, and information technology. Approximately 64% of the ESL students and about 74% of the NES students have had technical writing instruction. About 48% of the ESL students and 65% of the NES students had received instruction in speech/oral communication. Slightly more than half of the ESL and slightly more than 60% of the NES students had received instruction in (1) using engineering/ science information resources and materials and (2) using a library that contains engineering/ science information resources and materials. About 44% of the ESL students and 51% of the NES students had received instruction in searching electronic (bibliographic) data bases.

Table 2. Communications Skills Instruction Received by U.S. Aerospace Engineering Students

	ESL[a]		NES[b]	
Instruction	%	(n)	%	(n)
Technical Writing Information	64.2	(190)	73.8	(1048)
Speech/Oral Communication	48.1	(142)	65.1	(925)
Using A Library That Contains Engineering/Science Information Resources And Materials	54.4	(161)	61.1	(868)
Using Engineering/Science Information Resources And Materials	51.4	(152)	66.3	(936)
Searching Electronic (Bibliographic) Data Bases	43.9	(130)	51.4	(730)
Using Computer, Communication, And Information Technology	77.7	(230)	83.9	(1189)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker

Students receiving communications skills instruction were asked to rate the helpfulness (usefulness) of that instruction (Table 3). Overall, students reported that the instruction they received was not very helpful. Comparing the two groups, the "helpfulness" ratings reported by the ESL students were slightly higher than the ratings reported by the NES students. Respondents in the two groups assigned the highest ratings (78.1% for ESL students and 66.6% for NES students) to instruction in using computer, communication, and information technology. Helpfulness ratings assigned by the ESL students for the five remaining skills ranged from a high of 60.4% (technical writing/communication) to a low of 54.5% (using a library containing engineering/science information resources and materials). Helpfulness ratings assigned by the NES students for the five remaining skills ranged from a high of 52.9% (technical writing/communi-

cation) to a low of 36.4% (using a library containing engineering/science information resources and materials).

Table 3. Helpfulness of Communications Skills Instruction Received by U.S. Aerospace Engineering Students

Instruction	ESL[a]		NES[b]	
	%[c]	(n)	%[c]	(n)
Technical Writing Information	60.4	(119)	52.4	(545)
Speech/Oral Communication	59.2	(93)	52.9	(490)
Using A Library That Contains Engineering/Science Information Resources And Materials	54.8	(91)	36.4	(315)
Using Engineering/Science Information Resources And Materials	55.1	(93)	43.1	(397)
Searching Electronic (Bibliographic) Data Bases	54.5	(79)	38.7	(289)
Using Computer, Communication, And Information Technology	78.1	(181)	66.6	(781)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker
[c]Students used a 7-point scale to rate the helpfulness of each competency where 7 indicates the highest rating. Percentages include combined "6" and "7" responses.

Impediments to Preparing Written Technical Communications

We asked students to report the extent to which a lack of knowledge/skill about certain communications principles impedes their ability to write (Table 4). Overall, students did not report serious problems with their writing skills, at least to the point that any deficiencies might impede the technical writing process. (Mean scores clustering around 3.9 for the ESL students and around 3.3 for NES students with a score of "7" being highest impedance.) The highest and lowest "impedance" scores reported by ESL students were assigned to "assessing the needs of the reader" and for "notetaking and quoting." The highest and lowest "impedance" scores reported by NES students were assigned to "assessing the needs of the reader" and were tied for "notetaking and quoting" and "writing grammatically correct sentences." In terms of their ability to prepare written technical communication, both ESL and NES students appear to have the greatest difficulty with assessing the needs of the reader, preparing/presenting information in an organized manner, and defining the purpose of the communication.

Table 4. Factors Impeding the Ability of U.S. Aerospace Engineering Students to Produce Written Technical Communication

Instruction	ESL[a]		NES[b]	
	Mean[c]	(n)	Mean[c]	(n)
Defining The Purpose Of The Communication	4.0	(258)	3.6	(1284)
Assessing The Needs Of The Reader	4.2	(261)	3.9	(1311)
Preparing/Presenting Information In An Organized Manner	4.1	(270)	3.5	(1312)
Developing Paragraphs (Introductions, Transitions, Conclusions)	4.0	(273)	3.2	(1314)
Writing Grammatically Correct Sentences	3.9	(275)	3.0	(1316)
Notetaking And Quoting	3.5	(262)	3.0	(1286)
Editing And Revising	3.9	(257)	3.2	(1284)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker
[c]Students used a 7-point scale to rate the helpfulness of each competency where 7 indicates the highest rating.

Collaborative Writing

Most of the students reported having experience in collaborative writing (Table 5). About 77% of the ESL students and about 82% of the NES students report that they have produced written technical communication as part of a group. On average, ESL students report that they collaborate on about 36% of their written technical communication. A slightly lower percentage, on average about 34%, of NES students report that their written technical communication is collaborative. Table 5 also reports the percentage of students' written technical communication that is required to be collaborative. A greater percentage of both ESL and NES students' written technical communication is required to be collaborative. On average, ESL students report that they are required to collaborate on about 49% of their written technical communication compared to about 45% of written technical communication prepared by NES students.

We also asked students who write collaboratively to compare the productivity of group writing to the productivity of writing alone (Table 6). A high percentage of students (52% of the ESL students; 42.2% the NES students) reported that group writing is more productive than writing alone. About 21% of the ESL students and about 29% of NES students reported that group writing is less productive. About 27% of ESL students and about 29% of NES students reported that group writing was as productive as writing alone.

Table 5. Production of Written Technical Communication by U.S. Aerospace Engineering Students

Factor	ESL[a]		NES[b]	
	%	(n)	%	(n)
Percentage Of Written Technical Communication Involving Collaborative Writing				
0%	22.8	(58)	18.3	(234)
1 - 25%	24.0	(61)	34.5	(442)
26 - 50%	28.0	(71)	23.6	(302)
51 - 75%	9.1	(23)	11.2	(144)
76 - 99%	11.0	(28)	9.8	(125)
100%	5.1	(13)	2.7	(35)
Percentage Of Written Technical Communication Required To Be Collaborative				
0%	4.0	(7)	7.3	(70)
1 - 25%	22.7	(40)	29.6	(284)
26 - 50%	40.9	(72)	33.5	(321)
51 - 75%	12.5	(22)	8.7	(83)
76 - 99%	7.4	(13)	9.6	(92)
100%	12.5	(22)	11.3	(108)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker

Table 6. Productivity of Collaborative Writing of U.S. Aerospace Engineering Students

How Productive	ESL[a]		NES[b]	
	%[c]	(n)	%[c]	(n)
Less Productive Than Writing Alone	21.0	(42)	29.2	(309)
About As Productive As Writing Alone	27.0	(54)	28.5	(302)
More Productive Than Writing Alone	52.0	(104)	42.2	(447)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker
[c]Percentages exclude students who report that they never collaborate on academic writing projects.

The use of computers to prepare written technical communications and the use of computer (electronic) networks were investigated. Specifically, students were asked about their use of electronic networks, their use of electronic networks for specific purposes, and their use of electronic networks to exchange messages and files.

Computer Ownership and the Use of Computers to Prepare Written Technical Communications

About 62% of the ESL students and almost 69% of the NES students owned a personal computer (Table 7). Almost all of the students in both groups used a computer to prepare written technical communication. About 75% of the ESL students and about 84% of the NES students reported "always" using a computer to prepare written technical communication.

Table 7. Computer Ownership and Use by U.S. Aerospace Engineering Students in Preparing Written Technical Communication

	ESL[a]		NES[b]	
Factor	%	(n)	%	(n)
Do You Own A Personal Computer?				
Yes	62.2	(184)	68.8	(980)
No	37.8	(113)	31.2	(450)
Do You Use A Computer To Prepare Written Technical Communication?				
No	2.4	(7)	1.2	(17)
Yes	97.6	(290)	98.8	(1413)
Sometimes	4.8	(14)	3.9	(55)
Frequently	17.9	(52)	11.1	(155)
Always	74.8	(217)	83.8	(1174)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker

Use of Electronic (Computer) Networks

Most students also use electronic networks. Table 8 shows that about 85% of the ESL students and about 81% of NES students reported that they use electronic (computer) networks. About 73% of the ESL students and about 72% of the NES students reported that they personally use them. About 12% of ESL students and about 9% of the NES students use electronic (computer) networks through intermediaries. About 15% of the ESL students and about 9% of the NES students reported that they did not use computer (electronic) networks. Of these, 3.4% of the ESL students gave "no access" as their reason for nonuse; 7.5% reported that they may use networks in the future. Further, 5.4% of the NES students gave "no access" as their reason for nonuse; 10.1% reported that they may use networks in the future.

Table 8. Use of Electronic (Computer) Networks
by U.S. Aerospace Engineering Students

Factor	ESL[a]		NES[b]	
	%	(n)	%	(n)
Do You Use Electronic (Computer) Networks?				
Yes	84.7	(249)	80.6	(1143)
Yes, I Use Them Personally	73.1	(215)	71.5	(1014)
Yes, I Use Them But Through An Intermediary	11.6	(34)	9.1	(129)
No	15.3	(45)	19.4	(287)
No, I Do Not Use Them	4.4	(13)	3.9	(59)
No, Because I Do Not Have Access To Electronic Networks	3.4	(10)	5.4	(79)
No, But I May Use Them In The Future	7.5	(22)	10.1	(149)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker

Table 9 lists the percentages of ESL and NES students who use electronic (computer) networks for 11 different functions. Nearly all students use networks for exchanging electronic mail (90.1% of ESL students and 90.2% of NES students). Students also make extensive use of networks for searching library catalogs (86.3% of ESL students and 77.9% of NES students) and for transferring files electronically (82.2% of ESL students and 78.9 % of NES students). Other network functions utilized by high percentages of students include (a) using networks for computational analysis and to access to design tools, (b) connecting to geographically distant sites (c) information search and retrieval, and (d) searching electronic (bibliographic) data bases. The functions used least included using computer networks to (a) control equipment such as laboratory instruments or machine/design tools, (b) ordering documents from the library, and (c) preparing technical papers with colleagues at geographically distant sites. Less than 28% of students in both groups reported using computer (electronic) networks for these purposes. Although high percentages of ESL and NES students use electronic (computer) networks for most of the functions described in Table 9, greater percentages of ESL than NES students use networks for nearly all functions.

Students who use electronic (computer) networks to exchange messages or files do so with others at a wide array of locations (Table 10). Over 80% of both ESL and NES students reported that they use electronic networks to exchange messages with members of their academic classes. About equal percentages of ESL and NES students used electronic networks to exchange messages with others outside of their academic classes at the same geographic site (68.8%). However, higher percentages of ESL students (55.8%) than NES students (49.2%) used electronic networks to exchange messages with others outside of their academic classes at different geographic

Table 9. Use of Electronic (Computer) Networks by U.S. Aerospace Engineering Students

Purpose	ESL[a]		NES[b]	
	%[c]	(n)	%[c]	(n)
Connect To Geographically Distant Sites	62.5	(150)	63.8	(724)
Electronic Mail	90.1	(219)	90.2	(1026)
Electronic Bulletin Boards Or Conferences	49.2	(117)	52.6	(595)
Electronic File Transfer	82.2	(198)	78.9	(892)
Log On To Computers For Computational Analysis Or To Use Design Tools	75.9	(183)	71.2	(810)
Control Equipment Such As Laboratory Instruments Or Machine Tools	22.7	(54)	15.3	(172)
Access/Search The Library's Catalog	86.3	(207)	77.4	(881)
Order Documents From The Library	26.5	(63)	18.0	(204)
Search Electronic (Bibliographic) Data Bases	63.4	(151)	51.6	(641)
Information Search And Data Retrieval	69.0	(165)	55.8	(631)
Prepare Scientific And Technical Papers With Colleagues At Geographically Distant Sites	27.2	(65)	12.3	(140)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker
[c]Percentages do not total 100% because students could select more than one response.

Table 10. Use of Electronic Networks by U.S. Aerospace Engineering Students to Exchange Messages or Files

Exchange With --	ESL[a]		NES[b]	
	%[c]	(n)	%[c]	(n)
Members Of Your Academic Classes	80.2	(194)	83.2	(949)
Other People In Your Academic Community At The **SAME** Geographic Site Who Are Not In Your Academic Classes	64.7	(155)	62.4	(708)
Other People In Your Academic Community At A **DIFFERENT** Geographic Site Who Are Not In Your Academic Classes	55.8	(134)	49.2	(556)
People Outside Of Your Academic Community	63.5	(153)	58.4	(660)

[a]ESL = English as a Second Language
[b]NES = Native English Speaker
[c]Percentages do not total 100% because students could select more than one response.

sites. A higher percentage of ESL students (63.5%) than NES students (58.4%) also used networks to contact people outside of their academic community.

FINDINGS

1. Most of the ESL and NES students in this study were male and made their decision to study engineering prior to beginning college. For both the ESL and NES students, the most important factors were those related to the job itself. About 68% of the ESL and about 84% of the NES students rated "engineering is a career with rewarding activities" as very important followed by the perception that a "career in engineering will lead to financial security" (ESL = 25.4% and NES = 27.9%). In terms of career selection, about 25% of the ESL students rated "parents encouraged your area of study" as very important compared to about 14% of the NES students. About 46% of ESL students and about 44% of NES students surveyed reported that they feel about the same now as when they first made their career decision. About 30% of the ESL students compared to about 12% of the NES students aspire to work in academia.

2. Considering their career goals and aspirations, both ESL and NES students gave high ratings to the *engineering-related goals and aspirations.* The opportunity to explore new ideas about technology or systems ranked highest with ($\bar{X}$ = 6.4) for ESL students and ($\bar{X}$ = 6.3) for NES students. The opportunity to work on projects that require learning new technical knowledge ranked second with ($\bar{X}$ = 6.1) for ESL students and ($\bar{X}$ = 5.9) for NES students. *Science-related goals and aspirations* were rated second highest by ESL students and were ranked least important by NES students. *Leadership or management goals and aspirations* were rated least important by ESL students but were ranked second highest by NES students.

3. Almost 87% of the ESL students reported that they read English fluently and about 77% reported that they spoke English fluently. French was read or spoken, at least to some extent, by more students in both groups than were any of the other languages, followed by German, then Spanish. The ESL respondents reported higher fluency, both speaking and reading, in French than did the NES students, somewhat more in German, and slightly more in Japanese and Russian. Neither the ESL nor the NES students reported that they read or spoke Russian fluently. A higher percentage of the ESL students (69.8%) rated being bilingual very important to their career goals and aspirations than did the NES students (35.5%). About 8% of the ESL students compared to about 26% of the NES students reported that being bilingual was not very important in terms of their career goals and aspirations.

4. Both groups of students indicated that a mastery of the six communication skills is important to professional career success. ESL and NES students alike assigned the highest importance ratings to the ability to use computer, communication, and information technology (89.5% for ESL students and 91.3% for NES). ESL students rated having a knowledge and understanding of engi-neering/science information resources and materials second highest (86.1%). NES students rated effect communication of technical information orally second highest (84.3%). Neither group of students rated being able to search electronic (bibliographic) data bases very highly (54.9% for ESL students and 50.7% for NES students).

5. About 78% of the ESL students and about 84% of the NES students had received instruction in the use of computer, communication, and information technology. Approximately 64% of the ESL students and about 74% of the NES students have had technical writing instruction. About 48% of the ESL students and 65% of the NES students had received instruction in speech/oral communication. Slightly more than half of the ESL and slightly more than 60% of the NES students had received instruction in (1) using engineering/science information resources and materials and (2) using a library that contains engineering/ science information resources and materials. About 44% of the ESL students and 51% of the NES students had received instruction in searching electronic (bibliographic) data bases.

6. Overall, students reported that the instruction they received was not very helpful. Comparing the two groups, the "helpfulness" ratings reported by the ESL students were slightly higher than the ratings reported by the NES students. Respondents in the two groups assigned the highest ratings (78.1% for ESL students and 66.6% for NES students) to instruction in using computer, communication, and information technology. Helpfulness ratings assigned by the ESL students for the five remaining skills ranged from a high of 60.4% (technical writing/communication) to a low of 54.5% (using a library containing engineering/science information resources and materials). Helpfulness ratings assigned by the NES students for the five remaining skills ranged from a high of 52.9% (technical writing/communication) to a low of 36.4% (using a library containing engineering/science information resources and materials).

7. Overall, ESL and NES students did not report serious problems with their writing skills, at least to the point that any deficiencies might impede the technical writing process. Considering their ability to prepare written technical communication, both ESL and NES students appear to have the greatest difficulty with assessing the needs of the reader, preparing/presenting information in an organized manner, and defining the purpose of the communication.

8. About 77% of the ESL students and about 82% of the NES students report that they have produced written technical communication as part of a group. A greater percentage of both ESL and NES students' written technical communication is

required to be collaborative. On average, ESL students report that they are required to collaborate on about 49% of their written technical communication compared to about 45% of written technical communication prepared by NES students. A high percentage of students (52% of the ESL students; 42.2% the NES students) reported that group writing is more productive than writing alone.

10. About 62% of the ESL students and almost 69% of the NES students owned a personal computer. Almost all of the students in both groups used a computer to prepare written technical communication. About 75% of the ESL students and about 84% of the NES students reported "always" using a computer to prepare written technical communication.

11. About 85% of the ESL students and about 81% of NES students reported that they use electronic (computer) networks. About 73% of the ESL students and about 72% of the NES students reported that they personally use them. About 12% of ESL students and about 9% of the NES students use electronic (computer) networks through intermediaries. About 15% of the ESL students and about 9% of the NES students reported that they did not use computer (electronic) networks. Of these, 3.4% of the ESL students gave "no access" as their reason for nonuse; 7.5% reported that they may use networks in the future. Further, 5.4% of the NES students gave "no access" as their reason for nonuse; 10.1% reported that they may use networks in the future.

12. Nearly all students use networks for exchanging electronic mail (90.1% of ESL students and 90.2% of NES students). Students also make extensive use of networks for searching library catalogs (86.3% of ESL students and 77.9% of NES students) and for transferring files electronically (82.2% of ESL students and 78.9 % of NES students). Although high percentages of ESL and NES students use electronic (computer) networks for most of the 11 functions, greater percentages of ESL students than NES students use networks for nearly all functions.

CONCLUDING REMARKS

The research, development, and production of large commercial aircraft (LCA) is a high-risk venture compounded by technical and marketplace uncertainty. The Boeing 777 is no exception. The RD&P of the 777 cost the Boeing company more than $5 billion. The unit (per plane) cost approximates $150 million. The economics of LCA production pushes companies like Boeing to form international alliances and linkages to share risks. A notable feature of the Boeing 777 is its substantial international component, including the outsourcing of certain product-related activities and components. About 15–20% of the components are foreign-made. To acquire the requisite components for the 777, Boeing contracted with 241 vendors. Nearly one-third were firms from Australia, Brazil, Canada, France, Ireland, Italy, Korea, Singapore, and Japan. The three largest Japanese manufacturers provides about 21% of the aircraft's frame or 10% of the

overall plane (Golich, 1997). Moreover, about 238 "work together" design teams, included representatives from virtually everyone who will use the plane, including pilots, flight attendants, mechanics, baggage and cargo handlers, and passengers. The teams used 2,200 CATIA workstations networked to a cluster of eight mainframe computers manipulating nearly three terabytes of data from suppliers around the world. Finally, Boeing President and Chief Executive Officer Phil Condit recently stated that international collaboration is becoming the foundation upon which Boeing products are built. Condit provided two examples to support his statement. *First*, the Boeing 737-600/-700/-800 models are a good example of this collaboration; the end of the 737 outboard leading edge flap contains parts from five suppliers around the world. *Second*, about 70% of Boeing jetliners are sold outside of the United States. According to Condit, this percentage is expected to grow. The reality is that international collaboration has become the *modus operandi* for the production and operation of LCA. ESL and NES aerospace engineers are increasingly likely to work together. Ergo, the issue of a disconnect between academic preparation and workplace communication requirements takes on added importance.

The results of our national study can be interpreted to support the claim that the engineering students in this study, those for whom English is a second language, may be at risk (to some degree) in terms of professional success in their chosen field. The ESL students agree that proficiency in the six communication skills is important to professional success. However, as a group, they received less skill instruction than did their NES counterparts. Then, there is the question, "how helpful was the skills instruction they received"? Although their rating scores concerning the helpfulness of the communications skills instruction received were higher than the scores of their NES counterparts, ESL students rated the instruction they received "not very helpful." Finally, the factors impeding the ability of ESL students to produce written technical communication are the same factors that one would expect to be included in the skills instruction they did not receive (or do not take if offered) or in the instruction they did received but was not very helpful.

Earlier in the paper, we stated that a mechanism, probably focused within academia, that solicits feedback from the workplace and a system that utilizes the feedback for answering the questions of what and how much should be taught and when, and for determining the effectiveness of instruction, should be implemented. Although the results of this national study constitute input to such a mechanism, clearly other input is needed. Input similar that collected in this study should be obtained from other groups—namely early career-stage aerospace engineers and journeyman level aerospace engineers. Finally, a variety of research designs and methodologies should be utilized to solicit feedback from the workplace.

REFERENCES

Belcher, D.D. (1991). "Nonnative Writing in a Corporate Setting." *The Technical Writing Teacher*, 28, 104-115.

Black, K.M. (1994). "An Industry View of Engineering Education." *Journal of Engineering Education*, 83:1, 26-28.

DePalma, A. (1990). "Foreigners Flood U.S. Graduate Schools." *New York Times*, 29 November.

Devon, R. (1985). "Industry's Advice for the First Two Years." *Engineering Education*, 76:2, 112-114.

Evans, D.L., G.C. Beakley, P.E. Crouch, and G.T. Yamaguchi. (1993). "Attributes of Engineering Graduates and Their Impact on Curriculum Design." *Journal of Engineering Education*, 82:4, 203-211.

Garry, F.W. (1986). "A Business Look at Engineering Education." *Engineering Education*, 76:4, 203-205.

Golich, V. (1997). "Aviation's Technology Imperative and the Transformation of the Global Political Economy." Chapter 13 in *Technology, Culture, and Competitiveness: Change and the World Political Economy*. M. Talalay; C. Farrands; and R. Tooze, eds. London, UK: Routledge, 180-195.

Katz, S. (1993). "The Entry-Level Engineer: Problems in Transition from Student to Professional." *Journal of Engineering Education*, 82:3, 171-174.

Khafagi, B. (1990). "Influence of International Students on the U.S. Educational System and Professional Practice. *Civil Engineering*, November, 67-69.

Mailloux, E.N. (1989). "Engineering Information Systems." In *The Annual Review of Information Science and Technology*. Vol. 25. M.E. Williams, ed. Elsevier Science Publishers, Amsterdam, 239-266.

Paradis, J; D. Dobrin; and R. Miller. (1985). "Writing at Exxon ITD: Notes on the Writing Environment of an R&D Organization." Chapter 8 in *Writing in Nonacademic Settings*. L. Odell and D. Goswami, eds. New York, NY: Guilford Press.

Pinelli, T.E.; J.M. Kennedy; and R.O. Barclay. (1991). "The NASA/DoD Aerospace Knowledge Research Project." *Government Information Quarterly*, 8:2, 219-233.