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Abstract

In this paper we describe the preliminary analysis of four groups of aerospace engineering and science students -- student members of the American Institute of Aeronautics and Astronautics (AIAA) and students from universities in Japan, Russia, and Great Britain. We compare (1) the demographic characteristics of the students, (2) factors that affected their career decisions, (3) their career goals and aspirations, (4) their training in technical communication, and (5) their training in techniques for finding and using aerospace scientific and technical information (STI).

Many employers in the US aerospace industry think there is a need for increased training of engineering students in technical communication. Engineers in the US and other countries believe that technical communication skills are critical for engineers' professional success. All students in our study agree about the importance of technical communication training for professional success, yet relatively few are happy with the instruction they receive. Overall, we conclude that additional instruction in technical communication and accessing STI would make it easier for students to achieve their career goals.

Introduction

Current changes in the aerospace industry include increased collaboration among aerospace producers in multiple countries. Producers, faced with increasing pressures to produce aircraft for an international market, are creating cross-national alliances which improve the opportunities to sell aircraft in multiple countries. An important consequence of cross-national alliances of producers is a more rapid diffusion of technology among nations, which in turn increases the pressures on firms in individual countries to innovate in order to maintain a competitive edge (Pinelli, et al., 1991a).

These changes in the organization of aircraft production and design innovation are evident in the US aerospace industry. Collaboration with foreign firms often results in the external flow of technological knowledge. These changes have intensified the pressures on US firms to innovate and to incorporate new technologies from the research and development (R&D) process into the production process in order to maintain their leadership role in aerospace. The abilities of engineers and scientists to identify, acquire, use, and communicate scientific and technical information play a central role in the innovation process. US firms rely not only on the competence of their own engineers and scientists in using and communicating STI, but also on the competence of engineers and scientists employed by their foreign partners as well (Pinelli and Kennedy, 1990). Many of the non-US students may someday be employed by firms that will enter into collaborative relationships with US-based firms, so the training of non-US students can impact the success of US firms.

Aerospace engineers and scientists spend more time working with STI and communicating STI to others than on any other activity (Pinelli, et al, 1993b). The importance of STI skills is underscored by surveys of employers of engineers and scientists which indicate that employers place a high priority on engineers' skills in accessing and using STI and in communicating STI to others, both orally and in writing. In fact, these studies find that employers rate the importance of engineers' and scientists' skills in the use and communication of STI as highly as, or higher than, their technical skills. Many engineers and managers in the aerospace industry feel that engineers and scientists trained in the US lack proficiency in these skills when they graduate from college (Black, 1994; Morrow, 1994; Evans, et al., 1993; Katz, 1993; Strother, 1992; Garry, 1986; Devon, 1985; Sylvester, 1980).

Surveys of engineers and scientists in foreign countries conducted as part of Phase 4 of the NASA/DoD Aerospace Knowledge Diffusiòn Research Project indicate that technical communication skills are important in other countries as well. Data collected in Europe and Japan (Pinelli, et al., 1991b) and in Russia (Pinelli, et al., 1993b) indicate that engineers and scientists spend an average of 41% to 50% of an average work week using and communicating STI. Over 90% of engineers and scientists in these countries report that the ability to communicate technical information effectively is an important skill. A majority of the European engineers and scientists surveyed believe that a technical communication course should be required of engineering and science students, and while most Japanese respondents reported that it should not be a requirement, most also stated that it should be offered as an elective.

The Aerospace Knowledge Diffusion Research Project

This paper presents data from a five-year Project whose primary aim is to provide an understanding of the information environment in which US aerospace engineers and scientists work and the factors that influence their use of STI (Pinelli, et al., 1993a, Kennedy, et al., 1994b). From this Project, we hope to understand the impact of federal policies and practices on aerospace knowledge diffusion and to contribute to improvements in the transfer of aerospace research knowledge produced through federally funded research. The Project attempts to understand the users and uses of information at the individual, organizational, national, and international levels in the aerospace industry. The Project focuses on the methods used by aerospace engineers and scientists to gather, evaluate, use, and communicate STI.

The Project has four phases. Phase 1 examines the production and use of aerospace information by US aerospace engineers and scientists. Phase 2 examines how information intermediaries (principally librarians and technical information specialists) in the aerospace industry evaluate and disseminate technical information. Phase 3 looks at aerospace engineering in US academic settings, to include students, faculty, and information specialists. Phase 4 examines the international dimensions of aerospace STI. A variety of surveys of aerospace engineers and students in western Europe and in Asia were conducted in this Phase. This paper reports data collected as Phase 3 and Phase 4 activities.

Methods and Data

Self-administered questionnaires were sent to a sample of 4300 student members provided by the AIAA in spring 1993. Altogether, 1743 AIAA student members returned the questionnaires. The adjusted response rate (42%) is very acceptable for a student survey with only one mailing. Self-administered questionnaires were distributed during spring 1994 to engineering and science students attending aerospace engineering classes at the Moscow Aviation Institute, the University of Tokyo, the Cranfield Institute of Technology, and the University of Southampton. Because the samples from each country are small, we do not assume that they represent the engineering and science student populations in Great Britain, Russia, and Japan. Given these limitations, the discussion of the data should be regarded as exploratory rather than conclusive, and the results should be interpreted cautiously. The Great Britain data contain the combined Cranfield and Southampton responses.

Demographic Information

Table 1 contains demographic information for each sample. Most students in the surveys were male. The proportion of women ranged from 4% in Japan to 16% in the US. All Russian students were undergraduates. About 54% of Japanese students, and 58% of US students were undergraduates. Most British students (79%) were graduate students. In general, students reported their families' incomes were equal to or greater than the incomes of most other families in their countries. Just over 10% of Russian, Japanese, and British students estimated that their families' incomes were lower than the incomes of other families.

Table 1: Selected Demographic Characteristics of the Student Samples

	US (n=1743) %	Russia (n=117) %	Japan (n=77) %	Britain (n=127) %
Gender				
Female	16.0	13.0	4.1	14.6
Male	84.0	87.0	95.9	85.4
Educational Status *				
Undergraduate	58.0	100.0	54.1	14.7
Graduate	42.0	0.0	37.8	78.7
Other	0.0	0.0	8.1	6.6
Income Relative to Other Families in Native Country				
Higher	31.1	15.3	22.7	42.4
About equal	50.4	68.6	62.7	44.8
Lower	16.3	13.3	10.0	11.2
Cannot compare	2.2	2.9	2.7	1.6

* There are differences in the educational systems across countries, so the classifications of graduate and undergraduate students in engineering are not always comparable.

Making the Career Choice

The expectation that the nature of engineering and science work is intrinsically rewarding had the greatest influence on the career choices of US, Japanese, and British students (Table 2). Access to information about career opportunities was the factor most frequently rated as important by Russian students. Overall, relatively few students in all countries said that encouragement by parents, other family members, or teachers was as an important factor. Among only one group of students (US) did more than 25% rate financial security as an important factor.

Table 2: Importance of Selected Factors in Making Career Choice*

	US (n=1743) %	Russia (n=117) %	Japan (n=77) %	Britain (n=127) %
Your parents encouraged area of study	14.4	21.5	3.9	14.6
Other family members encouraged your area of study	7.3	8.8	2.6	9.8
Teachers encouraged your area of study	15.3	13.1	1.3	15.7
A career in your major/area of study will lead to financial security	27.1	16.7	7.8	23.0
A career in your major/area of study will provide a career with many rewarding activities	81.4	12.7	76.6	71.5
Information on the career opportunities available in your major/area of study	24.8	45.0	24.7	18.9
Other important factors	29.1	30.8	7.8	22.0

* Importance was measured using a 7-point scale, where 7 = "very important." Percentages include combined "6" and "7" responses.

Career Expectations

Tables 3 and 4 describe some of the students' expectations about the professional aspects of their work as future engineers and scientists. Table 3 lists some types of professional goals that the students believe will contribute to achieving their career success. Table 4 contains some of the students' expectations concerning the importance of technical communication and information use skills for successful careers.

We asked the students to evaluate three categories of goals that might relate to a successful career: 1) the acquisition and application of technological knowledge; 2) the development of a professional reputation; and 3) organizational management and leadership functions (Table 3). Overall, the goals related to the technological aspects of an engineering career were rated highest. In all samples, more students rated the opportunity to explore new ideas about technology or systems as the most important goal. About four-fifths of US and Japanese students and two-thirds of Russian and British students rated this goal as important to career success.

Table 3: Career Goals of Aerospace Engineering Students

Goals	US (n=1743) %	Russia (n=117) %	Japan (n=77) %	Britain (n=127) %
Technology/Engineering				
Have the opportunity to explore new ideas about technology or systems	84.4	66.1	80.2	65.3
Advance to high-level staff technical positions	49.9	35.4	46.0	52.0
Have the opportunity to work on complex technical problems	66.4	50.0	64.5	44.1
Work on projects that utilize the latest theoretical results in your specialty	57.4	58.5	68.4	46.0
Work on projects that require learning new technical knowledge	69.8	55.3	68.9	57.6
Professional/Science				
Establish a reputation outside your organization as an authority in your field	51.0	59.1	24.6	49.6
Receive patents for your ideas	25.1	57.8	23.0	18.6
Publish articles in technical journals	37.3	31.2	25.7	25.4
Communicate your ideas to others in your profession through papers delivered at professional society meetings	40.9	45.6	47.4	37.3
Be evaluated on the basis of your technical contributions	53.0	38.1	40.3	42.7
Management/leadership				
Become a manager or director in your line of work	41.0	33.9	23.9	60.3
Plan and coordinate the work of others	40.0	25.9	11.0	58.8
Advance to a policy-making position in management	35.0	31.2	19.0	67.4
Plan projects and make decisions affecting the organization	49.4	40.5	33.4	73.2
Be the technical leader of a group of less experienced professionals	47.0	25.5	21.1	50.4

* Importance was measured using a 7-point scale, where 7 = "very important." Percentages include combined "6" and "7" responses.

In the other categories, the patterns of importance ratings show significant variation among the samples. For example, the Russian students appear to be a little more interested in the professional/scientific aspects of engineering than do the other students. The British students appear to be more interested in the management aspects of their careers. It is interesting to note the relatively small percentages of Japanese students interested in either the professional/science or the management aspects of their careers.

We also asked the engineering and science students about their expectations concerning the importance of communication and information skills in achieving career success. A significant number of studies indicate the need to educate US engineering and science students in technical communication and the use of scientific and technical information (Black, 1994; Morrow, 1994; Evans, et. al., 1993; Katz, 1993; Garry, 1986; Devon, 1985). Table 4 shows that most students agree on the importance of these skills, which indicates that the message about the importance of these skills is known to most students.

Table 4: Importance of Selected Information Skills for Career Success*

	US (n=1743) %	Russia (n=117) %	Japan (n=77) %	Britain (n=127) %
Effectively communicate technical information in writing	83.8	48.2	67.2	67.8
Effectively communicate technical information orally	83.7	53.6	67.1	71.7
Have a knowledge and understanding of engineering/science information resources and materials	80.3	71.0	77.9	62.6
Be able to search electronic (bibliographic) data bases	51.4	73.4	47.2	41.9
Know how to use a library that contains engineering/science information resources and materials	63.9	64.8	48.0	49.6
Effectively use computer, communication, and information technology	90.9	85.6	71.0	85.8

* Importance was measured using a 7-point scale, where 7= "very important." Percentages include combined "6" and "7" responses.

US students consistently assigned higher ratings to the technical communication skills than the students in any other country. For example, 84% of US students reported that the ability to effectively communicate technical information in writing is an important skill, compared to about 67% of Japanese and British students and 48% of Russian students. The Russian students rated the ability to search electronic data bases much more important than the other countries. The skill that generally received the highest ratings is the ability to use computer, communication, and information technology.

Training in the Use of STI

We also asked questions about the students' training in using STI and in skills related to library use. US and British students received more training than other students in technical communication skills (Table 5). Over one-half of the British students and about three-fourths of the US students reported receiving instruction in technical writing. About three-fifths of both groups reported receiving training in oral communication. Russian students reported receiving training in using engineering/science resources and in using libraries more than any other skills. Few Japanese students reported receiving training in any areas other than using computers, communication, and information technology. Despite the agreement about the importance of these skills for career success, there are many differences across the countries in the training they received in the skills.

Table 5: Instruction in Information Skills Received by Aerospace Students

Instruction	US (n=1743) %	Russia (n=117) %	Japan (n=77) %	Britain (n=127) %
Technical writing/communication	72.2	41.1	10.5	54.0
Speech/oral communication	62.2	43.8	13.2	60.5
Using a library that contains engineering/science information resources and materials	59.9	53.6	10.5	81.3
Using engineering/science information resources and materials	63.6	59.5	9.3	61.3
Searching electronic (bibliographic) data bases	50.2	17.1	11.7	75.0
Using computer and information technology	82.9	32.4	43.4	75.8

Students who received training in each area were also asked to rate the helpfulness of the training (Table 6). Interestingly, many students did not find the training to be helpful. Only the Russian students' evaluations of their training in using engineering/science resources and the British students' evaluations of their training in computer and information technology were considered helpful by over 60% of those who received it. Overall, the US and Japanese students were the least likely to consider their instruction to be very helpful. The data in Table 6 are consistent with other student groups studied in Phases 3 and 4 of this Project (Pinelli, et al., 1994a, Pinelli, et al., 1994b, Pinelli, et al., 1994c, Kennedy et al, 1994a).

Table 6: Helpfulness of Instruction*

Instruction	US (n=1743) %	Russia (n=117) %	Japan (n=77) %	Britain (n=127) %
Technical writing/communication	39.2	38.3	50.0	40.8
Speech/oral communication	34.5	42.6	36.4	47.5
Using a library that contains engineering/science information resources and materials	24.2	61.5	37.5	40.6
Using engineering/science information resources and materials	29.0	63.6	33.3	36.1
Searching electronic (bibliographic) data bases	22.0	50.0	10.0	43.4
Using computer and information technology	56.9	55.0	40.0	60.8

* Helpfulness was measured using a 7-point scale, where 7 = "very helpful." Percentages include combined "6" and "7" responses. Percentages exclude respondents who did not receive training.

Library Use Skills and Frequency of Use

We next describe the students' training in library use skills and their frequency of library use. Table 7 reports the percentages of students who received some library use instruction. As with technical communication skills, most British students reported receiving training in each area. The students from the other countries received substantially less training than their British counterparts. US students received more training than Russian or Japanese students. Fewer than one-fifth of Japanese students received training in any library use skills.

Table 7: Library Use Training.

Instruction	US (n=1743) %	Russia (n=117) %	Japan (n=77) %	Britain (n=127) %
Library tour	46.1	13.0	8.3	78.9
Library presentation as part of academic orientation	36.6	23.1	17.8	62.1
Library orientation as part of an engineering/science course	22.4	12.8	15.3	56.6
Library skill/use course (bibliographic instruction)	28.0	14.5	2.7	57.0
Library skill/use course in engineering/ science information resources and materials	18.9	15.6	2.7	58.3
Library instruction for end-user searching of electronic (bibliographic) data bases	30.0	10.0	8.2	71.4

Despite the amount of instruction US students received in library use skills, they were much less likely than other students to use the library (Table 8). About two-fifths of the US sample and about three-fourths of British respondents are graduate students, while the majority of Russian and Japanese students are undergraduates. Graduate students typically have greater information needs that cannot be satisfied by textbooks and other classroom materials, so they would be expected to make more frequent use of library resources compared to undergraduate students. Yet the Japanese and Russian undergraduate students in this study apparently use the library more frequently than the US students, 40% of whom are graduate students.

Table 8: Use of a Library This School Term

Number of Visits	US (n=1743)	Russia (n=117)	Japan (n=77)	Britain (n=127)
Mean	3.2	5.0	9.6	20.8
Median	3.0	3.0	6.0	15.0

Table 9 shows the students' use of scientific and technical information products published in various countries. US NASA reports were used by the majority of US, British, and Japanese students. The Japanese and British students used NASA technical reports almost as often as US students. In fact, Japanese and British students used NASA technical reports more often than they used the reports from their national aerospace research organizations. Russian students appear to make little use of foreign technical reports, but access to reports from other countries may be very limited. US students use relatively few reports from other countries.

Table 9: Use of Foreign and Domestically Produced Technical Reports

Country/Organization	US (n=1743)	Russia (n=117)	Japan (n=77)	Britain (n=127)
AGARD Reports	21.4	2.0	16.9	52.6
British ARC and RAE Reports	10.1	4.0	11.7	54.6
Dutch NLR Reports	2.1	2.0	2.6	14.9
ESA Reports	11.1	11.9	11.7	33.3
Indian NAL Reports	1.1	0.0	0.0	4.5
French ONERA Reports	5.6	4.0	6.5	16.5
German DFVLR, DLR, and MBB Reports	6.7	4.0	5.2	22.2
Japanese NAL Reports	2.8	3.0	53.2	7.1
Russian TsAGI Reports	2.4	47.1	1.3	4.4
US NASA Reports	75.4	21.6	64.9	73.3

Summary

Surveys of US, European, Russian, and Japanese aerospace engineers and scientists conducted as part of the Project indicate that identifying, using, and communicating STI occupies a significant portion of the average work week (Pinelli, et al., 1993b). The survey respondents also recommended that students receive instruction in information use skills as part of the academic curriculum. Given the importance of the role of STI in engineering and scientific work, enhancing the skills of future engineers and scientists in these areas is crucial both in maintaining and improving productivity and in fostering technological innovation, which relies on ongoing access to and application of information on the latest technological developments. The increased international cooperation among aerospace firms implies that students trained in many countries are likely to employed anywhere in the world.

The US aerospace industry depends on US universities and colleges to provide a technically-skilled workforce. Some in the aerospace industry feel that new engineers do not receive enough training in technical communication skills, but for the most part, it is likely that undergraduate engineering training in the US is as complete as possible. Engineering education in other countries averages about five years (Dorato and Abdallah, 1993), but in the US we expect that undergraduate degrees can be completed in four years. Given the already full curriculum of engineering schools, it is unlikely that any additional training can be accomplished in four years in the US.

Training in technical communication skills appears to be an important factor in the success of engineers from the employers' perspective, the perspective of currently employed engineers, and from the perspective of engineering students' personal goals and aspirations. In our analysis of Table 3, we showed that most students were interested in a career that allows access to new and developing technologies. Only British students were interested in management. All student groups recognized the importance of having technical communication skills and the need to know how to access a variety of STI resources. Among the students who received training in these areas, relatively few feel that the training was helpful.

The concern of employers for improved technical communication skills combined with the students' recognition of the need for this training indicates the message about technical communication skills has diffused throughout the international aerospace community. Despite recognizing the needs, employers think there is too little training, and the students do not think the training they received was helpful. If there is relatively little opportunity for increased training in the academic curriculum, then the aerospace industry may have to look to itself for improvements. This paper indicates that the problem is not limited to the US, but is international in scope.

The ability of engineers to gather and use STI is important for both the personal successes of the engineers and the competitive success of the aerospace industry. Continued frustration by both employers and students in this area indicates that additional research is needed to find solutions to the problem. Given the international scope of the problem and the increasing international cooperation of aerospace firms, it appears that an international solution might be needed.

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